ANATOMY

DESCRIPTIVE AND SURGICAL

BY

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SEVENTEENTH EDITION

THOROUGHLY REVISED AND RE-EDITED WITH ADDITIONS

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THIS

NEW AMERICAN EDITION OF GRAY'S ANATOMY

IS DEDICATED TO

WILLIAM W. KEEN, M.D., LL.D., HON. F.R.C.S. [Eng. and Edin.]
THE DISTINGUISHED PROFESSOR OF SURGERY IN JEFFERSON
MEDICAL COLLEGE

AS AN EVIDENCE OF

THE ADMIRATION, THE AFFECTION AND THE GRATITUDE OF HIS COLLEAGUE

AND FORMER ASSISTANT

THE EDITOR
EDITORS' PREFACE.

The fact that this new edition has been demanded so soon after the publication of the sixteenth edition is gratifying evidence of the continued popularity and usefulness of “Gray.”

In this edition there have been many alterations, a number of eliminations, and additions of important anatomical facts. One hundred and thirty-three new illustrations have been inserted and thirty-eight old ones have been improved and re-engraved, and it is hoped and believed that the cuts will warrant more than ever the approbation of students and teachers. In the illustrations of the Nerve System special effort has been bestowed on combining the features visible to the naked eye with those seen only under high magnifying powers. By the knowledge of macroscopic and microscopic structures the attentive student is enabled to resolve or reconstruct, in the three dimensions of space, and with his mental eye see the opaque interior resolved into intricate yet well-defined projecting and associating mechanisms. Such study is assisted by new illustrations depicting hidden structures in accordance with this principle. Much that could not be described in detail within the confines of a text-book has been summarized in such way as to be of assistance even to advanced students.

Histology and embryology have been treated by resumés, as heretofore. Free quotations have been made from numerous treatises, monographs, and reports, the invariable intention being to give proper credit to the authors.

A universally accepted international nomenclature of anatomical items is eminently desirable. A transition from the old to the new will of necessity be gradual, because in the minds of many the older names are not only fixed but also cherished. The Latin or international nomenclature is in many respects a distinct advance in accuracy and simplicity. It has gained many advocates, but has not as yet completely displaced older designations to the degree its enthusiastic advocates would wish. In this edition the custom previously adopted is still pursued, and the names, according to the new nomenclature, have been introduced in parentheses, following those still in current use in English-speaking countries.

The section on the Nerve System, which has been largely rewritten by Dr. Spitzka, has been prepared with due regard to the advances recently made in the morphological and embryological aspects of the subject. The more important physiological and pathological data have been presented in their anatomical bearings, in order to demonstrate with greater clearness the mutual relations of the structure and functions of the nerve system.

The Digestive System, the Ductless Glands, and the Female Organs of Generation have also received careful consideration by the editors, and they trust these portions of the book will be found to merit the approval of students and teachers.

The editors wish to thank Mr. William A. Hassett, of Lea & Febiger, for indexing the book, for seeing it through the press, and for the valuable aid he has ungrudgingly given.

JOHN CHALMERS DA COSTA,
EDWARD ANTHONY SPITZKA.

(v)
PUBLISHERS' NOTE TO SEVENTEENTH EDITION.

A new edition of Gray's Anatomy is always an event of importance to the English-speaking world of medicine. For fifty years it has been easily the leading work in all medical literature, broadly considered, and, a fortiori, preëminent in its own field, a position which the many excellent treatises that have appeared from time to time have only rendered more conspicuous. During its first half-century it has given hundreds of thousands of students their foundation in medicine, and has been the one book carried from college for guidance in the basic questions underlying the practice of medicine and surgery. Its value for reference leads to a large absorption of each new edition on the part of practitioners desiring to be posted on the most recent developments and bearings of anatomy. This double demand brings about three important results for its readers: In the first place, rendering possible frequent new editions, whereby Gray may always be consulted for the latest knowledge; secondly, warranting an otherwise impossible expense for revisions and improvements; and thirdly, combining these advantages with a low price. A glance at the intrinsic causes which have led to these conditions may not be amiss.

Henry Gray's genius was twofold. He united a profound understanding of human structure with equal insight into the best methods of imparting knowledge to other minds. Reflecting this unique combination of powers, his Anatomy sprang to the front and has never lost its precedence. It joins a text of inimitable didactic quality with engravings of equal force and clearness. If Gray had discerned nothing else than the great advantage to his readers of having the names of the various parts engraved directly on the body of an illustration, he would have performed a notable service. His work, still unique in this respect, was also the first to employ colors. It is hardly to be wondered at that students and teachers alike find their labors cut in half and the permanence of knowledge doubled by the use of such a book.

The early death of Henry Gray has enlisted in successive revisions of this work the services of many leading anatomists. Passing over the intervening editions, and bearing in mind the close relations between anatomy and surgery, it is scarcely necessary to allude to the advantage of uniting in this new issue the knowledge of so eminent a surgeon as Dr. Da Costa, and of Dr. Spitzka, equally eminent as a specialist in anatomy. Professor Spitzka also possesses the ability

(vii)
of a skilful artist, and his delineations therefore convey his grasp of structure directly to the eye of the reader.

As ample directions are given for dissecting, this single volume will serve every requirement of the student throughout his course. The new nomenclature and that still in common use have been introduced in a manner rendering the work universal in the prime essential of terminology. The Table of Contents is so arranged as to give a complete conspectus of anatomy, a feature of obvious value. The whole book is thoroughly organized in its headings and the sequence of subjects, so that the student receives his knowledge of the parts in their anatomical dependence.

As a teaching instrument the new Gray's Anatomy embodies all that careful thought and unstinted expenditure can combine in book form, and it now enters its second half-century well equipped to excel even its own record.
CONTENTS.

DESCRIPTIVE AND SURGICAL ANATOMY.

OSTEOLOGY—THE SKELETON.

<table>
<thead>
<tr>
<th>The Skeleton</th>
<th>Number of the Bones</th>
<th>Form of Bones</th>
<th>Long Bones</th>
<th>Short Bones</th>
<th>Flat Bones</th>
<th>Irregular Bones</th>
<th>Surfaces of Bones</th>
<th>Structure of Bone</th>
<th>Bloodvessels of Bone</th>
<th>Chemical Composition of Bone</th>
<th>Ossification and Growth of Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>39</td>
<td>41</td>
<td>42</td>
</tr>
</tbody>
</table>

THE VERTEBRAL OR SPINAL COLUMN.

General Characters of a Vertebra.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>53</td>
<td>56</td>
<td>58</td>
<td>58</td>
<td>59</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

THE SKULL.

The Cerebral Cranium.

<table>
<thead>
<tr>
<th>The Occipital Bone</th>
<th>The Parietal Bone</th>
<th>The Frontal Bone</th>
<th>Vertical Portion of the Frontal Bone</th>
<th>Horizontal or Orbital Portion of the Frontal Bone</th>
<th>The Temporal Bone</th>
<th>Squamous Portion of the Temporal Bone</th>
<th>The Mastoid Portion of the Temporal Bone</th>
<th>The Petroso-occipital Bone</th>
<th>The Occipito-temporal Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>76</td>
<td>79</td>
<td>79</td>
<td>81</td>
<td>83</td>
<td>83</td>
<td>85</td>
<td>88</td>
<td>92</td>
</tr>
</tbody>
</table>

Bones of the Face.

| The Nasal Bones | The Superior Maxillary Bones | The Processes of the Superior Maxilla | Malar Process of the Superior Maxilla | Nasal Process of the Superior Maxilla | Alveolar Process of the Superior Maxilla | Palate Process of the Superior Maxilla | Changes Produced in the Upper Jaw by Age | The Lachrymal Bone | The Malar Bone | The Palate Bone | The Horizontal Plate of the Palate Bone | The Vertical or Perpendicular Plate of the Palate Bone | The Inferior Turbinated Bone | The Vertebra
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>104</td>
<td>105</td>
<td>109</td>
<td>109</td>
<td>109</td>
<td>109</td>
<td>110</td>
<td>112</td>
<td>112</td>
<td>113</td>
<td>115</td>
<td>116</td>
<td>117</td>
<td>120</td>
</tr>
</tbody>
</table>

THE SKULL AS A WHOLE.

<table>
<thead>
<tr>
<th>The Vertex of the Skull</th>
<th>The Base of the Skull</th>
</tr>
</thead>
<tbody>
<tr>
<td>129</td>
<td>130</td>
</tr>
</tbody>
</table>
## CONTENTS

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Lateral Region of the Skull</td>
</tr>
<tr>
<td>The Temporal Fossa</td>
</tr>
<tr>
<td>The Mastoid Portion</td>
</tr>
<tr>
<td>The Zygomatic or infratemporal Fossa</td>
</tr>
<tr>
<td>The Sphenoid-maxillary or Pterygo-palatine Fossa</td>
</tr>
<tr>
<td>The Anterior Region of the Skull</td>
</tr>
<tr>
<td>Orbits, Orbital Cavities or Orbital Fossae</td>
</tr>
<tr>
<td>The Nasal Cavity</td>
</tr>
<tr>
<td>Shape of the Skull</td>
</tr>
<tr>
<td>Dimensions of the Skull</td>
</tr>
<tr>
<td>Surface Form of the Skull</td>
</tr>
<tr>
<td>Fixed Points for Measurement of the Skull</td>
</tr>
<tr>
<td>Surgical Anatomy of the Skull</td>
</tr>
<tr>
<td>The Hyoid or Lingual Bone</td>
</tr>
<tr>
<td><strong>THE THORAX.</strong></td>
</tr>
<tr>
<td>The Sternum</td>
</tr>
<tr>
<td>The Ribs</td>
</tr>
<tr>
<td>Common Characters of the Ribs</td>
</tr>
<tr>
<td>Peculiar Ribs</td>
</tr>
<tr>
<td>The Costal Cartilages</td>
</tr>
<tr>
<td>Surface Form of the Chest</td>
</tr>
<tr>
<td>Surgical Anatomy of the Chest</td>
</tr>
<tr>
<td><strong>THE UPPER EXTREMITY.</strong></td>
</tr>
<tr>
<td>The Clavicle</td>
</tr>
<tr>
<td>Surface Form of the Clavicle</td>
</tr>
<tr>
<td>Surgical Anatomy of the Clavicle</td>
</tr>
<tr>
<td>The Scapula</td>
</tr>
<tr>
<td>Surface Form of the Scapula</td>
</tr>
<tr>
<td>Surgical Anatomy of the Scapula</td>
</tr>
<tr>
<td><strong>The Arm.</strong></td>
</tr>
<tr>
<td>The Humerus</td>
</tr>
<tr>
<td>Surface Form of the Humerus</td>
</tr>
<tr>
<td>Surgical Anatomy of the Humerus</td>
</tr>
<tr>
<td><strong>The Forearm.</strong></td>
</tr>
<tr>
<td>The Ulna</td>
</tr>
<tr>
<td>Surface Form of the Ulna</td>
</tr>
<tr>
<td>The Radius</td>
</tr>
<tr>
<td>Surface Form of the Radius</td>
</tr>
<tr>
<td>Surgical Anatomy of the Radius and Ulna</td>
</tr>
<tr>
<td><strong>The Hand.</strong></td>
</tr>
<tr>
<td>The Carpus</td>
</tr>
<tr>
<td>Common Characters of the Carpal Bones</td>
</tr>
<tr>
<td>Bones of the Upper Row</td>
</tr>
<tr>
<td>Scaphoid or Navicular Bone</td>
</tr>
<tr>
<td>Semilunar Bone</td>
</tr>
<tr>
<td>Cuneiform Bone</td>
</tr>
<tr>
<td>Pisiform Bone</td>
</tr>
<tr>
<td>Bones of the Lower Row</td>
</tr>
<tr>
<td>Trapezium</td>
</tr>
<tr>
<td>Trapezoideal</td>
</tr>
<tr>
<td>Os Magnum</td>
</tr>
<tr>
<td>Unciform</td>
</tr>
</tbody>
</table>

## THE ARTICULATIONS OR JOINTS.

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulations of the Trunk.</td>
</tr>
<tr>
<td>Articulations of the Vertebral Column</td>
</tr>
<tr>
<td>Articulations of the Atlas with the Axis</td>
</tr>
<tr>
<td>Articulations of the Spine with the Cranium</td>
</tr>
<tr>
<td>Articulation of the Atlas with the Occipital Bone</td>
</tr>
<tr>
<td>Articulation of the Axis with the Occipital Bone</td>
</tr>
<tr>
<td>Surgical Anatomy of Articulations of the Spine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulations of the Thorax.</td>
</tr>
<tr>
<td>Articulations of the Shoulder Girdle</td>
</tr>
<tr>
<td>The Pelvis</td>
</tr>
<tr>
<td>The False Pelvis</td>
</tr>
<tr>
<td>The True Pelvis</td>
</tr>
<tr>
<td>Position of the Pelvis</td>
</tr>
<tr>
<td>Axes of the Pelvis</td>
</tr>
<tr>
<td>Differences Between the Male and the Female Pelvis</td>
</tr>
<tr>
<td>The Os Inominatum</td>
</tr>
<tr>
<td>The Ilium</td>
</tr>
<tr>
<td>The Ischium</td>
</tr>
<tr>
<td>The Pubis</td>
</tr>
<tr>
<td>The Cotyloid Cavity or Acetabulum</td>
</tr>
<tr>
<td>The Obturator or Thyroid Foramen</td>
</tr>
<tr>
<td>Surface Form of the Pelvis</td>
</tr>
<tr>
<td>Surgical Anatomy of the Pelvis</td>
</tr>
<tr>
<td><strong>The Thigh.</strong></td>
</tr>
<tr>
<td>The Femur or Thigh Bone</td>
</tr>
<tr>
<td>Surface Form of the Femur</td>
</tr>
<tr>
<td>Surgical Anatomy of the Femur</td>
</tr>
<tr>
<td><strong>The Leg.</strong></td>
</tr>
<tr>
<td>The Tibia</td>
</tr>
<tr>
<td>Surface Form of the Patella</td>
</tr>
<tr>
<td>Surgical Anatomy of the Patella</td>
</tr>
<tr>
<td>The Tibia or Shin Bone</td>
</tr>
<tr>
<td>Surface Form of the Tibia</td>
</tr>
<tr>
<td>The Fibula or Calf Bone</td>
</tr>
<tr>
<td>Surface Form of the Fibula</td>
</tr>
<tr>
<td>Surgical Anatomy of Bones of the Leg</td>
</tr>
<tr>
<td><strong>The Foot.</strong></td>
</tr>
<tr>
<td>The Tarsus</td>
</tr>
<tr>
<td>The Calcaneus or Heel Bone</td>
</tr>
<tr>
<td>The Astragalus or Ankle Bone</td>
</tr>
<tr>
<td>The Cuboid</td>
</tr>
<tr>
<td>Scaphoid or Navicular Bone</td>
</tr>
<tr>
<td>Cuneiform or Wedge Bones</td>
</tr>
<tr>
<td>The Metatarsal Bones</td>
</tr>
<tr>
<td>Common Characters of Metatarsal Bones</td>
</tr>
<tr>
<td>Peculiar Characters of Metatarsal Bones</td>
</tr>
<tr>
<td>The Phalanges of the Foot</td>
</tr>
<tr>
<td>Development of the Foot</td>
</tr>
<tr>
<td>Construction of the Foot as a Whole</td>
</tr>
<tr>
<td>Surface Form of the Foot</td>
</tr>
<tr>
<td>Surgical Anatomy of the Foot</td>
</tr>
<tr>
<td>Sesamoid Bones</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE LARGER EXTREMITY.</td>
</tr>
<tr>
<td><strong>The Sacrum.</strong></td>
</tr>
<tr>
<td>The Pelvic Girdle.</td>
</tr>
<tr>
<td>The Sacro-iliac Joints</td>
</tr>
<tr>
<td>Surface Form of the Bones of the Hand</td>
</tr>
<tr>
<td>Surgical Anatomy of the Bones of the Hand</td>
</tr>
<tr>
<td>Development of the Bones of the Hand</td>
</tr>
</tbody>
</table>

## THE LARGER EXTREMITY.

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Pelvis</td>
</tr>
<tr>
<td>The False Pelvis</td>
</tr>
<tr>
<td>The True Pelvis</td>
</tr>
<tr>
<td>Position of the Pelvis</td>
</tr>
<tr>
<td>Axes of the Pelvis</td>
</tr>
<tr>
<td>Differences Between the Male and the Female Pelvis</td>
</tr>
<tr>
<td>The Os Inominatum</td>
</tr>
<tr>
<td>The Ilium</td>
</tr>
<tr>
<td>The Ischium</td>
</tr>
<tr>
<td>The Pubis</td>
</tr>
<tr>
<td>The Cotyloid Cavity or Acetabulum</td>
</tr>
<tr>
<td>The Obturator or Thyroid Foramen</td>
</tr>
<tr>
<td>Surface Form of the Pelvis</td>
</tr>
<tr>
<td>Surgical Anatomy of the Pelvis</td>
</tr>
<tr>
<td><strong>The Thigh.</strong></td>
</tr>
<tr>
<td>The Femur or Thigh Bone</td>
</tr>
<tr>
<td>Surface Form of the Femur</td>
</tr>
<tr>
<td>Surgical Anatomy of the Femur</td>
</tr>
<tr>
<td><strong>The Leg.</strong></td>
</tr>
<tr>
<td>The Tibia</td>
</tr>
<tr>
<td>Surface Form of the Patella</td>
</tr>
<tr>
<td>Surgical Anatomy of the Patella</td>
</tr>
<tr>
<td>The Tibia or Shin Bone</td>
</tr>
<tr>
<td>Surface Form of the Tibia</td>
</tr>
<tr>
<td>The Fibula or Calf Bone</td>
</tr>
<tr>
<td>Surface Form of the Fibula</td>
</tr>
<tr>
<td>Surgical Anatomy of Bones of the Leg</td>
</tr>
<tr>
<td><strong>The Foot.</strong></td>
</tr>
<tr>
<td>The Tarsus</td>
</tr>
<tr>
<td>The Calcaneus or Heel Bone</td>
</tr>
<tr>
<td>The Astragalus or Ankle Bone</td>
</tr>
<tr>
<td>The Cuboid</td>
</tr>
<tr>
<td>Scaphoid or Navicular Bone</td>
</tr>
<tr>
<td>Cuneiform or Wedge Bones</td>
</tr>
<tr>
<td>The Metatarsal Bones</td>
</tr>
<tr>
<td>Common Characters of Metatarsal Bones</td>
</tr>
<tr>
<td>Peculiar Characters of Metatarsal Bones</td>
</tr>
<tr>
<td>The Phalanges of the Foot</td>
</tr>
<tr>
<td>Development of the Foot</td>
</tr>
<tr>
<td>Construction of the Foot as a Whole</td>
</tr>
<tr>
<td>Surface Form of the Foot</td>
</tr>
<tr>
<td>Surgical Anatomy of the Foot</td>
</tr>
<tr>
<td>Sesamoid Bones</td>
</tr>
</tbody>
</table>
CONTENTS

Articulation of the Lower Jaw or the Temporo-mandibular Articulation ........................................ 282
Surface Form ........................................................................................................................................ 284
Surgical Anatomy ............................................................................................................................... 284
Articulations of the Rib Labour with the Vertebrae or the Costo-vertebral Articulations ............. 285
Articulation of the Cartilages of the Ribs with the Sternum, etc., or the Costo-sternal Articulations .................................................. 289
Articulations of the Cartilages of the Ribs with Each Other or the Intervertebral Articulations .... 291
Articulations of the Ribs with their Cartilages or the Costo-vertebral Articulations .................. 292
Articulations of the Sternum ............................................................................................................... 292
Articulations of the Vertebral Column with the Pelvis .................................................................... 292
Articulations of the Pelvis .................................................................................................................. 293
Articulation of the Sacrum and Ilium ..................................................................................................... 294
Ligaments passing between the Sacrum and Ilium ............................................................................. 294
Articulation of the Sacrum and Coccyx ............................................................................................... 296
Articulation of the Ossa Pubis ............................................................................................................. 298

Articulations of the Upper Extremity.
Sterno-clavicular Articulation .............................................................................................................. 299
Surface Form ........................................................................................................................................ 301
Surgical Anatomy ............................................................................................................................... 301
Acromio-clavicular Articulation or Scapulo-clavicular Articulation ............................................... 301
Surface Form ........................................................................................................................................ 303
Surgical Anatomy ............................................................................................................................... 303
Proper Ligaments of the Scapula .......................................................................................................... 303
The Shoulder-joint ............................................................................................................................... 305
Surface Form of the Shoulder-joint ...................................................................................................... 309
Surgical Anatomy of the Shoulder-joint .............................................................................................. 309
The Elbow-joint ..................................................................................................................................... 310
Surface Form of the Elbow-joint ........................................................................................................... 314
Surgical Anatomy of the Elbow-joint ................................................................................................... 314
Radio-ulnar Articulation ...................................................................................................................... 315
Superior or Proximal Radio-ulnar Articulation .................................................................................. 316
Surface Form ........................................................................................................................................ 318
Surgical Anatomy ............................................................................................................................... 316
Middle Radio-ulnar Ligaments ............................................................................................................ 316
Inferior or Distal Radio-ulnar Articulation .......................................................................................... 317
Surface Form ........................................................................................................................................ 319
Radio-carpal or Wrist-joint .................................................................................................................... 319
Surface Form of Wrist-joint .................................................................................................................. 320
Surgical Anatomy of Wrist-joint .......................................................................................................... 320
Articulations of the Carpus .................................................................................................................. 321
Articulations of the First Row of Carpal Bones ............................................................................... 321
Articulations of the Second Row of Carpal Bones .......................................................................... 321
Articulations of the Two Rows of Carpal Bones ............................................................................... 322

THE MUSCLES AND FASCIE.

General Description of Muscles ......................................................................................................... 363
General Description of Tendons .......................................................................................................... 366
General Description of Aponeuroses .................................................................................................... 366
General Description of Fascie ............................................................................................................... 366

MUSCLES AND FASCIE OF THE CRANIUM AND FACE.

Subdivision into Groups ....................................................................................................................... 368
The Cranial Region ............................................................................................................................... 368
Dissection ............................................................................................................................................ 368
Superficial Fascia .................................................................................................................................. 368
Ligaments ............................................................................................................................................ 369
The Occipito-frontalis ......................................................................................................................... 369
Surgical Anatomy ............................................................................................................................... 371
Carpo-metacarpal Articulations ........................................................................................................ 323
Articulation of the Metacarpal Bone of the Thumb with the Trapeziun ........................................... 323
Articulations of the Metacarpal Bones of the Four Inner Fingers with the Carpus ......................... 324
Articulations of the Metacarpal Bones with Each Other ................................................................. 326
Metacarpo-phalangeal Articulations .................................................................................................. 326
Surface Form of Metacarpo-phalangeal Articulations .................................................................... 327
Articulations of the Phalanges ............................................................................................................ 327

ARTICULATIONS OF THE LOWER EXTREMITY.
The Hip-joint ............................................................................................................................................... 327
Surface Form of the Hip-joint .............................................................................................................. 335
Surgical Anatomy of the Hip-joint ........................................................................................................ 335
The Knee-joint ....................................................................................................................................... 345
Surface Form of the Knee-joint ............................................................................................................ 345
Surgical Anatomy of the Knee-joint ..................................................................................................... 345
Tibio-fibular Articulation ...................................................................................................................... 347
Superior Tibio-fibular Articulation ....................................................................................................... 347
Middle Tibio-fibular Ligament or Intertrochlear Membrane .............................................................. 348
Inferior Tibio-fibular Articulation ....................................................................................................... 348
The Tibio-tarsal Articulation or Ankle-joint ......................................................................................... 349
Surface Form of Ankle-joint .................................................................................................................. 352
Surgical Anatomy of Ankle-joint .......................................................................................................... 353
Articulations of the Tarsus ................................................................................................................... 354
Articulation of the Os Calcis and Astragalus or the Calcaeno-astragaloid Articulation .................... 354
Articulation of the Os Calcis with the Cuboid or the Calcaeno-cuboid Articulation ............................. 355
The Ligaments connecting the Os Calcis and Scaphoid or the Calcaneo-scaphoid Articulation Ligaments ................................................................................................................................. 355
Surgical Anatomy .................................................................................................................................. 356
Articulation of the Astragalus with the Scaphoid Bone or the Astragalo-scaphoid Articulation ........ 356
The Articulation of the Scaphoid with the Cuneiform Bones ............................................................. 357
The Articulation of the Scaphoid with the Cuboid ............................................................................ 357
The Articulations of the Cuneiform Bones with Each Other or the Inter-cuneiform Articulations .... 357
The Articulation of the External Cuneiform Bone with the Cuboid ................................................... 358
Surgical Anatomy .................................................................................................................................. 358
Tarso-metatarsal Articulations ............................................................................................................ 359
Articulations of the Metatarsal Bones with Each Other .................................................................... 360
The Synovial Membranes in the Tarsal and Metatarsal Joints ............................................................. 360
Metatarsal-phalangeal Articulations ..................................................................................................... 361
Articulations of the Phalanges ............................................................................................................ 361
Surface Form ........................................................................................................................................ 362
Surgical Anatomy .................................................................................................................................. 362

The Auricular Region ............................................................................................................................ 371
Dissection ............................................................................................................................................. 371
Attrahens Auriculam or Aurem ............................................................................................................. 372
Attahens Auriculam or Aurem .............................................................................................................. 372
Rethahens Auriculam or Aurem ............................................................................................................ 372
The Palpebral Region ............................................................................................................................ 372
Dissection ............................................................................................................................................. 372
Orihens Palpebrarum ............................................................................................................................. 373
Corrugator Superioli .............................................................................................................................. 375
Levator Palpebrarum ............................................................................................................................. 375
Tensor Tarsi or Horner’s Muscle ........................................................................................................... 373
The Orbital Region .................................................................................................................................. 374
Levator Palpebrarum Superioris ........................................................................................................... 375
Superior Rectus ...................................................................................................................................... 375
Inferior Rectus ...................................................................................................................................... 375
The Orbital Region—
External Rectus . 375
Superior Oblique . 376
Inferior Oblique . 376
Fascia of the Orbit . 377
Surgical Anatomy . 377

The Nasal Region . 378
Pyramidalis Nasi . 378
Levator Labii Superioris Alaeque Nasi . 378
Dilator Nari Superior . 378
Dilator Nari Anterior . 378
Compressor Nasi . 378
Compressor Narium Minor . 378
Depressor Alae Nasi . 378
The Superior Maxillary Region . 379
Levator Labii Superioris . 379
Levator Anguli Oris . 379
Zygomaticus Major . 379
Zygomaticus Minor . 379

The Mandibular Region . 380
Dissection . 380
Levator Labii Inferioris or Levator Anguli Oris . 380
Depressor Labii Inferioris or Quadratus Mentii . 380
Depressor Anguli Oris or Triangularis Mentii . 380
The Internasal Region . 381
Dissection . 381
Orbicularis Oris . 381
Buccinator . 382
Risorius or Santorini's Muscle . 383
The Temporo-mandibular Region . 383
Masseteric Fasce . 383
Masseter Muscle . 383
Temporal Fasce . 384
Dissection . 384
Temporal Muscle . 384
The Pterygo-mandibular Region . 385
Dissection . 385
External Pterygoid Muscle . 386
Internal Pterygoid Muscle . 386
Surface Form of Muscles of Head and Face . 387

MUSCLES AND FASCIA OF THE NECK.

Subdivision into Groups . 412

The Superficial Cervical Region . 388
Dissection . 388
Superficial Cervical Fascia . 388
Platysma Myoides . 388
Deep Cervical Fascia . 389
Muscle Anatomy . 391
Sterno-mastoid or Sterno-acleido-mastoid . 391
Surface Form . 393
Surgical Anatomy . 393

The Infra-hyoid Region . 393
Dissection . 393
Sterno-hyoid . 394
Sterno-thyroid . 394
Thyro-hyoid . 395
Omo-hyoid . 395
The Supra-hyoid Region . 396
Dissection . 396
Digastric . 396
Stylo-hyoid . 396
Mylo-hyoid . 397
Dissection . 397
Genio-hyoid . 397
The Lingual Region . 398
Dissection . 399
Genio-hyo-glossus . 399
Hyco-glossus . 399
Chondro-glossus . 399
Stylo-glossus . 399
Palato-glossus or Constrictor Isthmi . 400
Faucium . 400
Muscular Substance of the Tongue . 400
Surgical Anatomy . 402

The Pharyngeal Region . 402
Dissection . 402
Inferior Constrictor . 402
Middle Constrictor . 403
Superior Constrictor . 403
Style-pharyngeus . 403
The Palatal Region . 405
Dissection . 405
Levator Palati . 405
Cricopharynx or Tensor Palati . 406
Palatine Aponeurosis . 406
Azigos Uvula . 407
Palato-glossus or Constrictor Isthmi . 407
Palato-pharyngeus . 407
Salpingo-pharyngeus . 407
Surgical Anatomy . 408
The Anterior Vertebral Region . 408
Rectus Capitis Anticus Major or Longus Capitis . 408
Rectus Capitis Anticus Minor . 409
Rectus Capitis Lateralis . 409
Longus Colli . 409
The Lateral Vertebral Region . 410
Scalenus Anticus . 410
Scalenus Medius . 410
Scalenus Posticus . 411
Surface Form of Muscles of the Neck . 411

MUSCLES AND FASCIA OF THE TRUNK.

Subdivision into Groups . 412

The First Layer . 412
Dissection . 412
Superficial Fascia . 413
Deep Fascia . 413
Trapezius . 413
Ligamentum Nuchae . 413
Latissimus Dorsi . 413
The Second Layer . 416
Dissection . 416
Levator Anguli Scapulae . 416
Rhomboideus Minor . 416
Rhomboideus Major . 416
The Third Layer . 417
Dissection . 417
Serratus Posticus Superior . 417
Serratus Posticus Inferior . 417
Vertebral Aponeurosis . 418
Lumbar Fascia or Aponeurosis . 418
Splenius . 418
Splenius Capitis . 418
Splenius Colli . 418
The Fourth Layer . 419
Dissection . 419
Erector Spinae . 419
Ilio-costalis or Sacro-lumbaris . 421
Musculus Accessorius ad Ilio-costal . 421
Cervicalis Ascendens . 421
Longissimus Dorsi . 421
Transversalis Cervici or Transversalis Colli . 421
Trachelo-mastoid . 421
Spinalis Dorsi . 422
Spinale Colli . 422
Complexus . 422
The Fifth Layer . 422
Dissection . 422
Seminapinai Dorsi . 423
Seminapinai Colli . 423
Multifidus Spinae . 423
Rotatores Spinae . 423
Supracostales . 423
Interspinales . 423
Extensor Coccygis . 424
Intertransversales . 424
Rectus Capitis Posticus Major . 424
### The Fifth Layer—
- Rectus Capitis Posticus Minor
- Obliquus Capitis Inferior
- Obliquus Capitis Superior
- Surface Form of Muscles of the Back

### Muscles and Fascia of the Thorax.
- Intercostal Fascia
- Intercostal Muscles
- External Intercostals
- Internal Intercostals
- Infracostales
- Triangularis Sterni
- Levatores Costarum
- Diaphragm
- Ligamentum Aereum Internum
- Ligamentum Aereum Externum
- Central Tendon of the Diaphragm
- The Openings of the Diaphragm
- Muscles of Inspiration and Expiration

### Muscles of the Abdomen.
- The Superficial Muscles of the Abdomen
- Dissection
- Superficial Fascia
- Deep Fascia
- External or Descending Oblique
- Aponeurosis of External Oblique
- External Abdominal Ring
- External Pilar or Inferior Crux
- Internal Pilar or Superior Crux
- Intercolunmair Fibres
- Poulart’s Ligament
- Gimbernat’s Ligament
- Triangular Fascia or Colles’s Ligament
- Ligament of Cooper
- Suspensory Ligament of the Penis
- Suspensory Ligament of the Clitoris
- Internal or Ascending Oblique
- Aponeurosis of Internal Oblique
- Cremaster Muscle
- Transversus Abdominis
- Dissection
- Rectus Abdominis
- Pyramidalis
- The Linea Alba
- The Lineae Semilunares
- The Lineae Transversae
- The Transversalis Fascia
- Internal or Deep Abdominal Ring
- The Iugular or Spermatic Canal
- The Deep Crural Arch
- Cooper’s Ligament
- Surface Forms of Muscles of the Abdomen
- The Deep Muscles of the Abdomen
- The Fascia Covering the Quadratus Lumbarum
- Quadratus Lumbarum

### Muscles of the Pelvic Outlet.
- The Muscles of the Ischio-rectal Region
- The Corrugator Cutis Ani
- External Sphincter Ani
- Internal Sphincter Ani
- Levator Ani
- Pubococcygeus Muscle
- Iliococcygeus Muscle
- Coccygeus

### The Muscles and Fascia of the Perineum in the Male.
- Superficial Fascia
- The Central Tendinous Point of the Perineum
- Transversus Perinei Superficialis
- Achievator Urinae
- Erector Penis
- Triangular Ligament
- Compressor or Constrictor Urethra

### MUSCLES AND FASCIA OF THE UPPER EXTREMITY.
- Subdivision into Groups
- Dissection of Pectoral Region and Axilla

### The Muscles and Fascia of the Thoracic Region.
- The Anterior Thoracic Region
- Superficial Fascia
- Deep Fascia
- Pectoralis Major
- Dissection
- Coraso-costae Membrane or Claviorpectoral Fascia
- Pectoralis Minor
- Subclavius
- The Lateral Thoracic Region
- Serratus Magnus
- Surgical Anatomy
- Dissection

### Muscles and Fascia of Shoulder and Arm.
- Superficial Fascia
- Deep Fascia
- The Acromial Region
- Dissection
- Deltoide
- Surgical Anatomy
- The Anterior Scapular Region
- Dissection
- The Subscapular Fascia
- The Subscapularis
- The Posterior Scapular Region
- Dissection
- Supraspinatus Fascia
- Supraspinatus Muscle
- Infraspinatus Fascia
- Infraspinatus Muscle
- Teres Minor
- Teres Major

### The Muscles and Fascia of the Arm.
- The Anterior Humeral Region
- Dissection
- Deep Fascia
- Coraceo-brachialis
- Biceps or Biceps Flexor Cubiti
- Brachialis Anticus
- The Posterior Humeral Region
- Triceps or Triceps Extensor Cubiti
- Subscapuloeeus
- Surgical Anatomy

### Muscles and Fascia of the Forearm.
- Dissection
- Deep Fascia
- The Anterior Radio-ulnar Region
- The Superficial Layer
- Pronator Radii Teres
- Surgical Anatomy
- Flexor Carpi Radialis
- Palmaris Longus
- Flexor Carpi Ulnaris
- Flexor Sublimis Digitorum
- The Deep Layer
- Flexor Carpi Ulnaris
- Flexor Profundus Digitorum
- Flexor Longus Pollicis
- Pronator Quadratus
- Surgical Anatomy
CONTENTS

The Radial Region ........................................ 486
  Dissection ........................................... 486
  Supinator Longus .................................... 486
  Extensor Carpi Radialis Longior ..................... 487
  Extensor Carpi Radialis Brevior ..................... 487
The Posterior Radio-ulnar Region ...................... 488
  The Superficial Layer ................................ 488
    Extensor Communis Digitorum ...................... 488
    Extensor Minimi Digitii ........................... 489
    Extensor Carpi Ulnaris ............................ 489
    Anconeus .......................................... 489
  The Deep Layer ....................................... 489
    Supinator Radii Brevis ............................ 489
    Extensor Ossis Metacarpi Pollicis ............... 491
    Extensor Brevis Pollicis .......................... 491
    Extensor Longus Pollicis .......................... 491
    Extensor Indicius ................................ 492
  Surgical Anatomy ...................................... 493

  Muscles and Fascia of the Hand. ........................ 493
  Dissection ........................................... 493
  Ligamentum Carpi Volare ................................ 493
  Anterior Annular Ligament ................................ 493
  The Synovial Membranes of the Flexor Tendons at the Wrist ........................................... 494
  Surgical Anatomy ...................................... 494
  Burse about the Hand and Wrist ...................... 494
  Posterior Annular Ligament ............................ 495
  The Deep Palmar Fascia ................................ 495
    The Superficial Transverse Ligament of the Fingers ........................................... 496
    Surgical Anatomy ................................... 496
  The Radial Region .................................... 497
    Abductor Pollicis .................................. 497
    Opponens Pollicis .................................. 498
    Flexor Brevis Pollicis .............................. 499
    Adductor Obliquus Pollicis ........................ 499
    Adductor Transversus Pollicis ...................... 499
  The Ulnar Region ..................................... 500
    Palmaris Brevis .................................... 500
    Abductor Minimi Digitii ............................ 500
    Flexor Brevis Minimi Digitii ....................... 500
    Opponens Minimi Digitii ............................ 500
  The Middle Palmar Region ................................ 501
    Lumbricales ........................................ 501
    Interossei .......................................... 501
    Surface Form of Muscles of the Upper Extremity ........................................... 502
    Surgical Anatomy of Muscles of the Upper Extremity ........................................... 505

MUSCLES AND FASCIA OF THE LOWER EXTREMIT Y. ........................................... 509

  Subdivision into Groups ................................ 509

  Muscles and Fascia of the Iliac Region ................. 510
  Dissection ........................................... 510
  Iliac Fascia .......................................... 510
  Poas Magnus .......................................... 512
  Poas Parvus .......................................... 512
  Iliacus ............................................... 512
  Surgical Anatomy ...................................... 513

  Muscles and Fascia of the Thigh. ........................ 514
  The Anterior Femoral Region ........................... 514
    Dissection .......................................... 514
    Superficial Fascia ................................... 514
    Deep Fascia or Fascia Lata ......................... 515
    Surgical Anatomy ................................... 517
    Tensor Fasciae Latae ................................ 517
    Sartorius .......................................... 518
    Quadriceps Extensor ................................ 518
    Rectus Femoris ...................................... 518
    Vastus Externus ..................................... 520
    Vastus Intermedius .................................. 520
    Cruriceps .......................................... 520
  Subcutaneous .......................................... 521
  Surgical Anatomy ...................................... 521

  The Internal Femoral Region ........................... 522
    Dissection .......................................... 522
    Gracilis ............................................ 522
    Pectineus .......................................... 522
    Adductor Longus ..................................... 522
    Adductor Magnus ..................................... 523
    Hunter's Canal ...................................... 524
    Surgical Anatomy ................................... 525

  The Gluteal Region ..................................... 525
    Dissection .......................................... 525
    Gluteus Maximus ..................................... 525
    Gluteus Medius ...................................... 526
    Gluteus Minimus ..................................... 526
    Pyriformis .......................................... 527
    Obturator Internus .................................. 528
    Gemelli .............................................. 529
    Gemellus Superior .................................... 529
    Gemellus Inferior .................................... 530
    Quadratus Femoris ................................... 530
    Obturator Externus ................................... 531
    Sartorius .......................................... 531
  The Posterior Femoral Region ........................... 532
    Dissection .......................................... 532
    Biceps or Biceps Flexor Cruri ...................... 532
    Semitendinosus ...................................... 533
    Semimembranosus ..................................... 533
    Surgical Anatomy ................................... 534

  Muscles and Fascia of the Leg. .......................... 534
  The Anterior Tibio-femoral Region ..................... 534
    Dissection .......................................... 535
    Deep Fascia of the Leg ................................ 535
    Tibialis Anticus .................................... 535
    Extensor Proprius Hallucis ......... 535
    Extensor Longus Digitorum ......................... 536
    Peroneus Tertius .................................... 537
  The Posterior Tibio-femoral Region ..................... 537
    Dissection .......................................... 537
    The Superficial Layer ................................ 537
    Gastrocnemius ....................................... 537
    Soleus ............................................... 538
    Tendo-Achillis ....................................... 538
    Plantaris .......................................... 539
    The Deep Layer ...................................... 540
    Deep Transverse Fascia ................................ 540
    Popliteus .......................................... 540
    Flexor Longus Hallucis .............................. 541
    Flexor Longus Digitorum ............................ 541
    Tibialis Posterior ................................... 541
  The Tibial Region ...................................... 542
    Dissection .......................................... 542
    Peroneus Longus ..................................... 542
    Peroneus Brevis ..................................... 543
    Surgical Anatomy of Tendons around Ankle ........... 544

  Muscles and Fascia of the Foot. .......................... 544
  Dissection .......................................... 544
  Anterior Annular Ligament ................................ 544
  Internal Annular Ligament ................................ 545
  External Annular Ligament ................................ 545
  Dissection of the Sole of the Foot ..................... 545
  Plantar Fascia ........................................ 545
  Central Portion of Plantar Fascia ..................... 545
  Lateral Portions of Plantar Fascia ..................... 546
  Burse about the Ankle and Foot ........................ 546
  Surgical Anatomy ...................................... 546
  The Dorsal Region ..................................... 546
    Fascia .............................................. 546
    Extensor Brevis Digitorum ............................ 546
  The Plantar Region .................................... 547
    The First Layer ..................................... 547
    Dissection .......................................... 547
    Abductor Hallucis .................................... 547
    Flexor Brevis Digitorum .............................. 547
    Fibrous Sheaths of the Flexor Tendons .............. 548
    Abductor Minimi Digitii ................................ 548
The Planter Region—The Second Layer 540
Flexor Accessorius 541
Lumbricales 549
The Third Layer 549
Flexor Brevis Hallucis 549
Adductor Obliquus Hallucis 549
Flexor Brevis Minimi Digit 550
Adductor Transversus Hallucis 551

The Plantar Region—The Fourth Layer 551
Interossei Muscles 551
Dorsal Interossei 551
Plantar Interossei 551
Surface Form of Muscles of the Lower Extremity 552
Surgical Anatomy of Muscles of the Lower Extremity 554

THE BLOOD—VASCULAR SYSTEM.

The Circulation of the Blood 557
The Cavity of the Thorax 558
The Upper Opening of the Thorax 558
The Lower Opening of the Thorax 558

The Pericardium.

Structure of the Pericardium 560
Fibrous Layer 560
Serous Pericardium 562
Arteries of the Pericardium 563
Nerves of the Pericardium 563
The Vestigial Fold of the Pericardium 563
Surgical Anatomy of the Pericardium 563

The Heart.

Position of the Heart 564
Size and Weight of the Heart 566
Capacity of the Cavities of the Heart 566
Fat upon the Heart 566

Surface Marking of the Common Carotid Arteries 601
Surgical Anatomy of the Common Carotid Artery 601
The External Carotid Artery 602
Relations 603
Surface Marking 603
Surgical Anatomy 603
Branches 604
Superior Thyroid Artery 604
Branches 604
Surgical Anatomy 605
Lingual Artery 605
Relations 606
Branches 606
Surgical Anatomy 606
Facial or External Maxillary Artery 607
Relations 608
Branches 608
Peculiarities 610
Surgical Anatomy 610
Occipital Artery 610
Branches 611
Posterior Auricular Artery 611
Branches 611
Ascending Pharyngeal Artery 612
Branches 612
Surgical Anatomy 612
Superficial Temporal Artery 612
Branches 613
Surgical Anatomy 613
Internal Maxillary Artery 613
Branches of First Portion 615
Surgical Anatomy 615
Branches of Second Portion 616
Branches of Third Portion 616
Surgical Anatomy 617

Surgical Anatomy of the Triangles of the Neck 618
Anterior Triangle of the Neck 618
Posterior Triangle of the Neck 620

THE ARTERIES.

Distribution of the Arteries 585
Anatomy of the Arteries 586
Histology of the Capillaries and Arteries 586
Blood-vessels of the Blood-vessel Wall 588
Lymphatics of Arteries 588
Nerves of Arteries 588
Arterial Sheath 588

PULMONARY ARTERY.

Right Pulmonary Artery 589
Left Pulmonary Artery 589

THE AORTA.

The Ascending Aorta 591
Branches of the Ascending Aorta 592
The Coronary Arteries 592
Right Coronary Artery 592
Left Coronary Artery 593
Peculiarities of Coronary Arteries 593

The Arch of the Aorta.

Relations of the Arch of the Aorta 594
Peculiarities of the Arch of the Aorta 594
Surgical Anatomy of the Arch of the Aorta 594
Branches of the Arch of the Aorta 595
Peculiarities of the Branches 595
The Innominate Artery 596
Relations 596
Branches 596
Thyroid Artery 596
Peculiarities 597
Surgical Anatomy 597

ARTERIES OF THE HEAD AND NECK.

The Common Carotid Artery.

Relations of the Common Carotid Artery 600
Peculiarities of the Common Carotid Artery 601
## CONTENTS

<table>
<thead>
<tr>
<th>Page</th>
<th>Branches of the Brachial Artery</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>657</td>
<td>Superior Radial Artery</td>
<td>657</td>
</tr>
<tr>
<td>657</td>
<td>Nutrient Artery</td>
<td>658</td>
</tr>
<tr>
<td>658</td>
<td>Inferior Radial Artery</td>
<td>658</td>
</tr>
<tr>
<td>658</td>
<td>Anastomotic Magna</td>
<td>658</td>
</tr>
<tr>
<td>658</td>
<td>Muscular Branches</td>
<td>659</td>
</tr>
<tr>
<td>659</td>
<td>The Anastomosis around the Elbow-</td>
<td>659</td>
</tr>
<tr>
<td>659</td>
<td>Joint</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Page</th>
<th>The Radial Artery</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>661</td>
<td>Radial Recurrent</td>
<td>661</td>
</tr>
<tr>
<td>661</td>
<td>Muscular Branches</td>
<td>661</td>
</tr>
<tr>
<td>661</td>
<td>Anterior Radial</td>
<td>661</td>
</tr>
<tr>
<td>661</td>
<td>Superficialis Volar</td>
<td>661</td>
</tr>
<tr>
<td>661</td>
<td>Posterior Radial</td>
<td>661</td>
</tr>
<tr>
<td>661</td>
<td>Dorsalis Pollicis</td>
<td>661</td>
</tr>
<tr>
<td>661</td>
<td>Dorsalis Indici</td>
<td>662</td>
</tr>
<tr>
<td>662</td>
<td>Princeps Pollicis</td>
<td>662</td>
</tr>
<tr>
<td>662</td>
<td>Radialis Indici</td>
<td>662</td>
</tr>
<tr>
<td>662</td>
<td>Perforating Arteries</td>
<td>662</td>
</tr>
<tr>
<td>662</td>
<td>Palmar Interosseous</td>
<td>662</td>
</tr>
<tr>
<td>662</td>
<td>Palmar Recurrent Branches</td>
<td>662</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Page</th>
<th>The Ulnar Artery</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>663</td>
<td>Anterior Ulnar Recurrent</td>
<td>663</td>
</tr>
<tr>
<td>663</td>
<td>Posterior Ulnar Recurrent</td>
<td>663</td>
</tr>
<tr>
<td>664</td>
<td>Intersosseous Artery</td>
<td>664</td>
</tr>
<tr>
<td>664</td>
<td>Muscular Branches</td>
<td>664</td>
</tr>
<tr>
<td>664</td>
<td>Anterior Carpal</td>
<td>665</td>
</tr>
<tr>
<td>665</td>
<td>Posterior Carpal</td>
<td>665</td>
</tr>
<tr>
<td>665</td>
<td>Deep Palmar Arch</td>
<td>666</td>
</tr>
<tr>
<td>666</td>
<td>Superficial Palmar Arch</td>
<td>666</td>
</tr>
<tr>
<td>666</td>
<td>Relations</td>
<td></td>
</tr>
<tr>
<td>666</td>
<td>Branches</td>
<td>666</td>
</tr>
<tr>
<td>666</td>
<td>Surface Marking</td>
<td>666</td>
</tr>
<tr>
<td>667</td>
<td>Surgical Anatomy</td>
<td>667</td>
</tr>
</tbody>
</table>

## ARTERIES OF THE TRUNK.

<table>
<thead>
<tr>
<th>Page</th>
<th>The Thoracic Aorta</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>677</td>
<td>Relations</td>
<td>677</td>
</tr>
<tr>
<td>677</td>
<td>Surface Marking</td>
<td>677</td>
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<tr>
<td>677</td>
<td>Surgical Anatomy</td>
<td>677</td>
</tr>
<tr>
<td>677</td>
<td>Branches</td>
<td>677</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Page</th>
<th>The Lumbar Artery</th>
<th>Page</th>
</tr>
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<tbody>
<tr>
<td>677</td>
<td>Relations</td>
<td>678</td>
</tr>
<tr>
<td>677</td>
<td>Surface Marking</td>
<td>678</td>
</tr>
<tr>
<td>677</td>
<td>Surgical Anatomy</td>
<td>678</td>
</tr>
</tbody>
</table>

## ARTERIES OF THE TRUNK.

<table>
<thead>
<tr>
<th>Page</th>
<th>The Thoracic Aorta</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>667</td>
<td>Relations</td>
<td>667</td>
</tr>
<tr>
<td>667</td>
<td>Surface Marking</td>
<td>667</td>
</tr>
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<td>667</td>
<td>Surgical Anatomy</td>
<td>667</td>
</tr>
<tr>
<td>667</td>
<td>Branches</td>
<td>667</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Page</th>
<th>The Lumbar Artery</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>677</td>
<td>Relations</td>
<td>678</td>
</tr>
<tr>
<td>677</td>
<td>Surface Marking</td>
<td>678</td>
</tr>
<tr>
<td>677</td>
<td>Surgical Anatomy</td>
<td>678</td>
</tr>
</tbody>
</table>
The Common Iliac Arteries...

Branches of Common Iliac Arteries... 683
Peculiarities of Common Iliac Arteries... 684
Surface Marking of Common Iliac Arteries... 684
Surgical Anatomy of Common Iliac Arteries... 684
The Internal Iliac Artery... 685

Relations... 685
Peculiarities... 686
Surgical Anatomy... 687
Branches... 687
Superior Vesical Artery... 687
Middle Vesical Artery... 688
Inferior Vesical Artery... 688
Middle Hamorrhoidal Artery... 688
Uterine Artery... 688
Vaginal Artery... 688
Surgical Anatomy... 689
Obturator Artery... 689
Branches... 689
Peculiarities... 690
Internal Pudic Artery... 690
Relations... 691
Peculiarities... 691
Surgical Anatomy... 691
Branches... 691
Sciatic Artery... 692
Branches... 692
Lateral Saphenous Artery... 692
Branches... 692
Gluteal Artery... 695
Branches... 695
Surface Marking... 695
Surgical Anatomy... 695
The External Iliac Artery... 695

ARTERIES OF THE LOWER EXTREMITY.
The Femoral Artery...

Scarpa’s Triangle... 698
Hunter’s Canal or the Adductor Canal... 699
The Common Femoral Artery... 700

Relations... 701
The Superficial Femoral Artery... 701

Relations... 701
Peculiarities... 702
Surface Marking... 702
Surgical Anatomy... 702
Branches... 702
Superficial Epigastric... 704
Superficial Circumflex Iliac... 704
Superficial External Pudic... 704
Deep External Pudic... 704
Deep Femoral or Profunda Femoris... 704

Branches... 705

THE VEINS.

Subdivisions of the Veins... 721
Anastomosis of Veins... 722
Histology of the Veins... 722
The Superficial or Cutaneous Veins... 723
The Deep Veins... 723

Veins of the Exterior of the Head and Face... 725

Veins of the Interior of the Head and Face... 725

Veins of the Exterior of the Head and Face...

Frontal Vein... 725
Supraorbital Vein... 726
Angular Vein... 726
Anterior Facial Vein... 726
Commisural Vein... 726
Superficial Temporal Vein... 727
The Pterygoid Plexus and the Internal Maxillary Vein... 727
Temporal Vein... 727
Posterior Auricular Vein... 727
Occipital Vein... 727

The Peculiarities... 708
Surface Marking... 709
Surgical Anatomy... 709
Branches... 709
Superior Muscular Branches... 709
Inferior Muscular Branches... 709
Cutaneous Branches... 710
Superior Articular Arteries... 710
Asygos Articular Artery... 710
Inferior Articular Arteries... 710
Circumpatellar Anastomosis... 710

The Anterior Tibial Artery... 710

Relations... 711
Peculiarities... 711
Surface Marking... 711
Surgical Anatomy... 711
Branches... 712
Posterior Recurrent Tibial
Superior Fibular
Anterior Recurrent Tibial
Muscular Branches... 713
Muscular Arteries... 713

The Dorsalis Pedis Artery... 713

Relations... 713
Peculiarities... 714
Surface Marking... 714
Surgical Anatomy... 714
Branches... 714
Cutaneous Branches... 714
Tarsal Artery... 714
Metatarsal Artery... 715
Communicating Artery... 715

The Posterior Tibial Artery... 715

Relations... 715
Peculiarities... 716
Surface Marking... 716
Surgical Anatomy... 716
Branches... 716
Peroneal Artery... 717
Relations... 717
Peculiarities... 717
Branches... 717
Cutaneous Branches... 718
Nutrient Artery... 718
Muscular Branches... 718
Communicating Branch... 718
Malleolar or Internal Malleolar Artery... 718
Internal Calcaneal Arteries... 718
Internal Plantar Artery... 718
External Plantar Artery... 719
Surface Marking... 719
Surgical Anatomy... 719
Branches... 719

THE PULMONARY VEINS.
The Systemic Veins.

Veins of the Head and Neck.

Veins of the Exterior of the Head and Face... 725
The Superficial Veins of the Neck

External Jugular Vein

Posterior External Jugular Vein

Anterior Jugular Vein

Internal Jugular Vein

Lingual Vein

Pharyngeal Veins

Superior Thyroid Vein

Middle Thyroid Vein

Veins of the Thyroid Gland

Surgical Anatomy

Vertebral Vein

Anterior Vertebral or Anterior Deep Cervical Vein

Posterior Vertebral or Posterior Deep Cervical Vein

The Veins of the Diploe

The Dural or the Meningeal Veins

The Cerebral Veins

Superficial or Cortical Cerebral Veins

Superficial or Superior Cerebral Veins

Medial Cerebral or Medial Cerebral Veins

Subcerebral or Inferior Cerebral Veins

Veins of the Thalamus

Vena Corporis Striati

Choroidal Vein

Basilar Vein

Superficial Cerebellar Veins

Deep Cerebellar Veins

Veins of the Pons

Veins of the Oblongata

The Sinuses of the Dura, Ophthalmic Veins and Emissary Veins

Longitudinal or Superior Longitudinal Sinus

Torcular Herophili

Falcial or Inferior Longitudinal Sinus

Tentorial or Straight Sinus

Lateral Sinus

Surgical Anatomy

Occipital Sinus

Cavernous Sinus

Sphenoidal Sinus or Sinus Alae Parvae

Ophthalmic Veins

Circular Sinus

Superpetrosal or Superior Petrosal Sinus

Subpetrosal or Inferior Petrosal Sinus

Transverse or Basilar Sinus

Emissary Veins

Surgical Anatomy

Veins of the Upper Extremity and Thorax.

The Superficial Veins of the Upper Extremity

Superficial Veins of the Hand and Fingers

Anterior Ulnar Vein

Posterior or Dorsal Ulnar Vein

Common Ulnar Vein

Radial Vein

Median Vein

Medial Cephalic Vein

Median Basilic Vein

Basilic Vein

Cephalic Vein

The Deep Veins of the Upper Extremity

Intercosseous Veins

Deep Palmar Veins

Brachial Vein

Axillary Vein

Branches

Surgical Anatomy

Subclavian Vein

Immobile or Brachio-cephalic Veins

Right Innominate Vein

Left Innominate Vein

Peculiarities

The Deep Veins of the Upper Extremity—

Internal Mammary Vein

Inferior Thyroid Veins

Inferior Mesenteric Veins

Intercostal Veins

Prevertebral or Superior Vena Cava

Relations

Azygos Veins

Surgical Anatomy

Buccal Veins

The Spinal Veins

Dorsal Spinal Veins

Meningo-rachidian Veins

Veins of the Bodies of the Vertebrae or Vena Basilica Vertebrarum

Veins of the Spinal Cord or Medullary Spinal Veins

Veins of the Lower Extremity, Abdomen and Pelvis.

The Superficial Veins of the Lower Extremity

The Superficial Veins of the Foot

Internal or Long Saphenous Vein

External or Short Saphenous Vein

Surgical Anatomy

The Deep Veins of the Lower Extremity

The Deep Veins of the Foot

Posterior Tibial Veins

Anterior Tibial Veins

Popliteal Vein

Femoral Vein

External Iliac Vein

Deep Femoral Vein

Deep Circumflex Iliac Vein

Hypogastric or Internal Iliac Vein

Surgical Anatomy

Obturator Vein

Sciatic Veins

Gluteal Veins

Superior Vesical Plexus

Prostatic or Prostatico-vesical Plexus

Inferior Vesical Plexus

Surgical Anatomy

The Dorsal Veins of the Penis

The Vaginal Plexuses and Veins

The Uterine Plexuses and Veins

Common Iliac Vein

Peculiarities

Postcava, Ascending or Inferior Vena Cava

Relations

Peculiarities

Lumbar Veins

Spermatic Veins

Ovarian Veins

Renal Veins

Suprarenal Veins

Phrenic Veins

Hepatic Veins

The Portal System of Veins.

Superior Mesenteric Vein

Splenic Vein

Inferior Mesenteric Vein

Gastric Veins

Cystic Vein

Portal Vein

The Cardiac Veins.

Great Cardiac or Left Coronary Vein

Posterior or Middle Cardiac Vein

Left Cardiac Vein

Anterior Cardiac Vein

Right Cardiac or Small Coronary Vein

Coronary Sinus

Vena Thebesii
The Lymphatic System.

Subdivision into Superficial and Deep Sets...
Lymphatic or Conglomerate Glands...
Hemolymph nodes...
Surgical Anatomy...

The Thoracic Duct and the Right Lymphatic Duct.
Radicals of Origin and Tributaries of Thoracic Duct...
Structure of the Thoracic Duct...
The Right Lymphatic Duct...
Tributaries...

Lymphatics of the Cranial Region, Face and Neck.
The Lymphatic Glands of the Head and Face...
The Occipital or Suboccipital Glands...
The Posterior Auricular, Retro-auricular or Mastoid Glands...
Parotid Lymph Glands...
The Subparotid Glands...
The Internal Maxillary or Zygomatic Glands...
The Facial Glands or Genial Glands...
The Lymphatic Vessels of the Cranial Region...
The Lymphatic Vessels of the Face, the Interior of the Nose, Tongue, Floor of the Mouth, Pharynx, Larynx and Thyroid Gland...
The Lymphatic Glands of the Neck...
The Superficial Cervical Glands...
The Submaxillary or Lateral Suprathyroid Glands...
The Submental or Median Suprathyroid Glands...
The Retro-pharyngeal or Post-pharyngeal Glands...
The Deep Cervical, Carotid, or Sterno-mastoid Glands...
The Lymphatic Vessels of the Neck...
Surgical Anatomy...

The Lymphatics of the Upper Extremity.
The Lymphatic Glands of the Upper Extremity...
The Superficial Lymphatic Glands...
The Deep Lymphatic or the Axillary Glands...
The Lymphatic Vessels of the Upper Extremity...
The Superficial Lymphatic Vessels of the Upper Extremity...
The Deep Lymphatic Vessels of the Upper Extremity...
Surgical Anatomy...

The Lymphatics of the Lower Extremity.
The Lymphatic Glands of the Lower Extremity...
The Superficial Ingual Lymphatic Glands...
Surgical Anatomy...
The Deep Lymphatic Glands of the Lower Extremity...
The Deep Ingual or Deep Femoral Lymphatic Glands...
The Anterior Tibial Gland...
The Popliteal Glands...
The Gluteal and Ischiatic Glands...
The Lymphatic Vessels of the Lower Extremity...
The Superficial Lymphatic Vessels of the Lower Extremity...
The Deep Lymphatic Vessels of the Lower Extremity...
THE NERVE SYSTEM.

The Spinal Cord and Brain with their Meninges.

Fundamental Facts regarding the Development of the Nerve System

Development of Nerve Tissue

In the Wall of the Neural Tube

In the Neural-crest Tissue

Structure of the Nerve System

The Neurone

Nerve-cell Body

Unipolar cells

Bipolar cells

Multipolar cells

Nerve-cell Body, Internal Morphology

The Dendrites

The Axone

The Collaterals

Nerve-fibres and Nerves.

Origin and Termination of Nerves

The Supporting Tissue Elements of the Nerve System

The Neuroglia

Chemical Composition of Nerves

The Central Nerve System.

Preliminary Considerations

The Spinal Cord.

External Morphology of the Spinal Cord

The Enlargements of the Spinal Cord

Conus

Filum

Fissures and Grooves of the Spinal Cord

Columns of the Spinal Cord

Development of the Spinal Cord

Muscular Supply from Motor Segments of the Cord

Internal Structure of the Spinal Cord

Gray Substance of the Cord

White Substance of the Cord

Longitudinal Fibres of the Cord

Marginal Tract of the Cord

Ground Bundles of the Dorsal Column

Ground Bundles of the Lateral Column

Ground Bundles of the Ventral Column

Myelination of the Axones of the Cord

Dissection of the Spinal Cord

The Membranes of the Cord.

The Spinal Dura

Structure

The Arachnoid

Structure

The Pia of the Cord

The Pia of the Cord—

Structure

Surgical Anatomy

The Brain or Encephalon.

General Appearance and Topography of the Brain

Dimensions of the Brain

The Development of the Brain and the Usual Classifications of its Subdivisions

Brief Consideration of the Phases of Development of the Brain-tube

The Fore-brain

The Mid-brain

The Hind-brain

Flexures of the Brain-tube

Dorsal and Ventral Laminae or Longitudinal Zones of the Brain

Descriptive Anatomy of the Adult Human Brain.

Parts derived from Hind-brain (Rhombencephalon)

The Oblongata

Fissures of Oblongata

Areas of Oblongata

The Pyramids

Lateral Area

Dorsal Area

The Pons and Preoblongata

The Ventral Surface

The Pre-oblongata

The Fourth Ventricle of the Brain

"Floor" of the Fourth Ventricle

Medial Part of the "Roof" of the Fourth Ventricle

Internal Structure of the Postoblongata

Pyramidal Decussation

Decussation of the Lemnisci

The Formatio Reticularis

The Raphé

The Restis

The Nucleus of the Olive or Inferior Olive Nucleus

The Arcuate Fibre System

Internal Structure of the Pons and Pre-oblongata

The Transverse Fibres

The Longitudinal Fibres

The Nuclei Pontis

The Pre-oblongata

The Superior Olivary Nucleus

The Nucleus Incertus

Fibre-tracts in the Pre-oblongata

The Medial Lemniscus

The Lateral Lemniscus

The Medial Longitudinal Bundle

The Cerebellar Peduncle

Summary of Gray Masses in the Pre-oblongata

THE LYMPHATIC SYSTEM.

The Lymphatic Vessels of the Large Intestine

Lymphatics of the Anus and Rectum

The Lymphatics of the Thorax.

The Lymphatic Glands of the Thoracic Wall

The Internal Mammary Glands

The Intercostal Glands

The Diaphragmatic Lymphatics

The Visceral Lymphatics

The Anterior Mediastinal Glands

The Posterior Mediastinal Glands

The Peritracheo-bronchial Glands
The Central Connections of the Cranial Nerves attached to the Hind-brain. page 888
The Nuclei of Origin. page 889
The Nuclei of Termination. page 889
The Hypothalamic Nerve. page 890
The Accessory Nerve. page 890
The Vagus and Glossopharyngeal Nuclei. page 890
The Acoustic Nerve. page 892
The Facial Nerve. page 892
The Abducent Nerve. page 894
The Trigeminal Nerve. page 894
The Cerebellum.
Lobes and Fissures of the Cerebellum. page 895
The Lingula. page 895
The Central Lobe. page 897
The Culmnal Lobe. page 897
The Clival Lobe. page 898
The Caeuminal Lobe. page 898
The Tuberal Lobe. page 898
The Gracile Lobe. page 898
The Pyramidal Lobe. page 898
The Uvular Lobe. page 898
The Nodular Lobe. page 898
The Internal Structure of the Cerebellum. page 899
Isolated Gray Masses or Nuclei of the Cerebellum. page 899
The Cerebellar Peduncles. page 900
The Medullary Vela. page 901
The Fibres Proper of the Cerebellum. page 902
Microscopic Appearance of the Cerebel-
lar Cortex. page 902
Weight of the Cerebellum. page 903
The Mid-brain.
External Morphology. page 904
The Prebrachium. page 905
The Posterior Gyrus. page 905
The Crura. page 905
The Tectum Pontis. page 906
The Cinmbia or Tractus Pedune-
laris Transversus. page 906
Internal Structures of the Mid-brain.
The Aqueduct and Central Gray Aqueduct. page 907
The Substantia Nigra or Intera-

tum. page 907
The Quadrigemina. page 907
The Temporal Lobes. page 908
Fountain Decussation. page 910
The Crus or Pes. page 910
Summary of the Gray Masses in the Mid-brain. page 910
Deep Origin of Cranial Nerves Arising in the Mid-brain. page 910
The Trochlear-nervre Nucleus. page 910
The Oculomotor-nervre Nucleus. page 911
Parts Derived from the Fore-brain.
External Morphology. page 911
The Thalami. page 912
The Tuberculum Anterius. page 913
Internal Structure of the Thalamus and its Conne-
tions. page 914
The Connections of the Thalamus. page 914
The Epiphysis. page 915
Structure. page 915
Postcommissure. page 915
Posterior fornix. page 916
The Albicania. page 916
Third Ventricle. page 916
External Morphology of the Optic Por-
tion of the Hypothalamus. page 917
The Tuber. page 917
The Hypophysis. page 917
The Term. page 917
The Optic Tract and its Central Connections. page 917
Chiasm. page 919
The Cerebral Hemispheres. page 919
External Morphology. page 919
Configuration of Each Hemicere-

brum. page 922
Cerebral Fissures and Gyres. page 922
Cerebral Lobes and Fissures. page 923
The Interlobar Fissures. page 924
The Sylvian Fissure and its Rami. page 924
The Central Fissure. page 926
The Occipital Fissure. page 926
The Calcarine Fissure. page 926
The Frontal Lobe. page 926
The Parietal Lobe. page 930
The Gyres of the Parietal Lobe. page 931
The Oecipital Lobe. page 931
The Temporal Lobe. page 931
The Gyres of the Temporal Lobe. page 932
The Insula. page 933
The Rhinencephalon or Olfactory Lobe. page 934
Internal Configuration of the Cerebral Hemispheres. page 938
The Cortex. page 939
The Callosum. page 939
Development of the Lateral Ventricles. page 941
The Choroid Fissure or Rift. page 946
The Parafalcine and Velum. page 946
The Hippocampus and Fornix. page 947
The Septum Lucidum. page 952
The Precommissural. page 952
The Gray Masses in the Hemicere-

brum. page 952
The Caudatum. page 953
The Lenticulare. page 954
The Amygdala. page 954
The Claustrum. page 955
The Internal Capsule. page 955
The External Capsule. page 958
Intimate Structure of the Cerebral Cortex and its Special Type in Different Regions. page 958
Special Types of Gray Substance. page 959
Summary of the Cerebral Fibre Systems. page 961
Connections of the Striatum. page 964
The Olfactory Pathways. page 964
Peripheral Pathway. page 964
Central Pathway. page 964
Weight of the Brain. page 965
Cortical Localization and Function.
Motor Area. page 966
Sensory Area. page 966
The Language Areas. page 968
The Association Areas. page 969
Cranio-cerebral Topography. page 970
The Meninges or Meningeal Membranes of the Brain.
Dissection. page 972
The Dura of the Brain. page 972
Structure. page 973
The Arteries of the Dura. page 974
The Veins of the Dura. page 974
The Lymphatics of the Dura. page 974
The Nerves of the Dura. page 974
Processes of the Dura. page 975
The Falc. page 975
The Tentorium. page 975
The Falx. page 976
The Diaphragma Sellae. page 976
The Arachnoid of the Brain. page 976
The Subarachnoid Space. page 977
Structure. page 977
The Arachnoid Villi or Pacchionian Bodies. page 979
The Organs of Special Sense.

The Ear.

The Conjointiva.

The Lachrymal Apparatus.

The Lachrymal Glands.

The Lachrymal Sac.

The Nasal Duct.

Surface Anatomy.

The Middle Ear, Drum or Tympanum.

The Tympanic Cavity.

The Drumhead or Membrana Tympani.

The Osseous Membranes of the Tympanum.

The Malleus or Hammer.

The Incus or Anvil.

The Stapes or Stirrup.

The Internal Ear or Labyrinth.

The Osseous Labyrinth.

The Vestibule.

The Semicircular Canals.

The Occultum.

The Membranous Labyrinth.

The Tympanum.

The Saccule.

The Membranous Semicircular Canals.

Surgical Anatomy.

The Skin.

The Corium, Cutis Vera, Dermis or True Skin.

The Cuticle, Seraf Skin or Epidermis.

The Appendages of the Skin.

The Nails.

The Hairs.

The Sudoriferous or Sweat-glands.

The Sebaceous Glands.

The Organs of Digestion.

The Palate.

The Soft Palate or Velum Pendulum.

Palati.

The Tonsil or Amygdala.

The Salivary Glands.

The Parietal Gland.

Surface Form.

The Submaxillary Gland.

The Sublingual Gland.

Structure of Salivary Glands.

Surface Form.

The Pharynx.

The Nasal Part.

The Oral Part.

The Laryngeal Part.

Structure.
CONTENTS

Surgical Anatomy of the Mouth, Cheeks, Lips, Gums, Tonsils, Palate, Salivary Glands and Pharynx 1234

The Esophagus.
Relations 1237
Anomalies 1238
Structure 1238
Movements and Innervations of the Esophagus 1240
Surgical Anatomy 1240

The Abdomen.
Boundaries 1241
Development of the Alimentary Canal, Vis- cera and Peritoneum 1245
Development of the Alimentary Canal 1247

The Peritoneum.
Structure of the Peritoneum 1254
Retro-peritoneal Fossae 1270
Surgical Anatomy 1274

The Stomach.
Relations of the Stomach 1277
Surfaces 1277
The Cardia 1278
The Pylorus 1279
Alterations in Position 1280
Supports of the Stomach 1281
Structure 1281
Movements and Innervation of Stomach 1288
Surface Form 1288
Surgical Anatomy 1288

The Small Intestine.
The Duodenum 1290
The First or Superior Portion 1292
The Second or Descending Portion 1293
The Third, Pre-aortic, Horizontal or Transverse Portion 1293
The Fourth or Ascending Portion 1294
The Jejunum and Ileum 1297
Differences between the Jejunum and Ileum 1297
The Jejunum 1297
The Ileum 1297
Structure of the Small Intestine, including the Duodenum 1298

ORGANS OF VOICE AND RESPIRATION.

The Larynx.
The Cartilages of the Larynx 1370
The Thyroid Cartilage 1370
The Cricoid Cartilage 1371
The Arytenoid Cartilages 1372
The Cornicula Laryngis or Cartilages of Santorini 1373
The Cuneiform Cartilages or Cartilages of Wrisberg 1373
The Epiglottis or the Cartilage of Epiglottis 1373
Structure of the Larynx 1373
Interior of the Larynx 1376

The Trachea and Bronchi.
Relations 1384
The Right Bronchus 1384
The Left Bronchus 1386
Structure of the Trachea 1386
Surface Form of Larynx 1389
Surgical Anatomy of Larynx and Trachea 1389

The Large Intestine.
The Caecum 1308
The Vermiform Appendix 1311
The Ileo-cesal Valve or the Valve of Bauhin 1315
The Colon 1317
The Ascending Colon 1317
The Transverse Colon 1317
The Descending Colon 1317
The Sigmoid Flexure, Pelvic Colon or Sigmoid Colon 1317
The Rectum 1320
The Common Anal Canal 1323
Structure, of the Large Intestine 1324
Movements and Innervations of the Intestines 1330
Surface Form of the Intestines 1331
Surgical Anatomy of the Intestines 1331

The Liver.
The Superior Area or Surface 1336
The Anterior Area or Surface 1336
The Lateral or Right Area or Surface 1336
The Under or Visceral Area or Surface 1336
The Posterior Area or Surface 1336
Fissures of the Liver 1336
Lobes of the Liver 1339
Supports and Movability of the Liver 1342
Anomalies of the Liver 1337
Structure of the Liver 1345
The Excretory Apparatus of the Liver 1349
The Hepatic Duct 1350
The Gall-bladder 1350
The Cystic Duct 1351
Surface Relations of the Liver 1353
Surgical Anatomy of the Liver 1354

The Pancreas.
Dissection 1355
The Right Extremity or Head of the Pancreas 1357
The Neck of the Pancreas 1357
The Body and Tail of the Pancreas 1357
Structure of the Pancreas 1360
Surface Form 1360
Surgical Anatomy 1360

The Spleen.
Surface of the Spleen 1361
Supports and Movability of the Spleen 1363
Surface Form 1366
Surgical Anatomy 1366

The Pleura.
Reflections of the Pleura 1392
Structure of the Pleura 1395
Surgical Anatomy 1395

The Mediastinal Space, Interpleural Space or Mediastinum.
The Superior Mediastinum 1396
The Anterior Mediastinum 1396
The Middle Mediastinum 1396
The Posterior Mediastinum 1397

The Lungs.
Apex of the Lungs 1400
Base of the Lungs 1400
Surfaces of the Lungs 1400
Borders of the Lungs 1400
Lobes of the Lungs 1402
## CONTENTS

<table>
<thead>
<tr>
<th>Page</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Root of the Lung</td>
<td>1402</td>
</tr>
<tr>
<td>The Fetal Lung</td>
<td>1402</td>
</tr>
<tr>
<td>Structure of the Lung</td>
<td>1403</td>
</tr>
<tr>
<td>The Bronchus</td>
<td>1405</td>
</tr>
<tr>
<td>Changes in the Structure of the Bronchi in the Lungs</td>
<td>1403</td>
</tr>
<tr>
<td>Surface Form of the Lungs</td>
<td>1405</td>
</tr>
<tr>
<td>Surgical Anatomy of the Lungs</td>
<td>1406</td>
</tr>
<tr>
<td><strong>THE DUCTLESS GLANDS.</strong></td>
<td></td>
</tr>
<tr>
<td>Accessory Thyroids</td>
<td>1409</td>
</tr>
<tr>
<td>Structure of the Thyroid</td>
<td>1409</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1411</td>
</tr>
<tr>
<td><strong>THE THYROID BODY OR GLAND.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>THE PARATHYROID GLANDS.</strong></td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>1412</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1413</td>
</tr>
<tr>
<td><strong>The Kidneys.</strong></td>
<td></td>
</tr>
<tr>
<td>Surfaces of the Kidneys</td>
<td>1420</td>
</tr>
<tr>
<td>Borders of the Kidneys</td>
<td>1423</td>
</tr>
<tr>
<td>General Structure of the Kidney</td>
<td>1423</td>
</tr>
<tr>
<td>Surface Form</td>
<td>1434</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1434</td>
</tr>
<tr>
<td><strong>The Ureter.</strong></td>
<td></td>
</tr>
<tr>
<td>The Ureter Proper</td>
<td>1435</td>
</tr>
<tr>
<td>Relations of the Ureter</td>
<td>1435</td>
</tr>
<tr>
<td>Structure of the Ureter</td>
<td>1436</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1437</td>
</tr>
<tr>
<td><strong>The Suprarenal Capsule or Gland.</strong></td>
<td></td>
</tr>
<tr>
<td>Relations of the Suprarenal Capsule</td>
<td>1437</td>
</tr>
<tr>
<td>Accessory Suprarenal Glands</td>
<td>1438</td>
</tr>
<tr>
<td>Structure of Suprarenal Glands</td>
<td>1438</td>
</tr>
<tr>
<td><strong>The Cavity of the Pelvis.</strong></td>
<td></td>
</tr>
<tr>
<td>Boundaries</td>
<td>1440</td>
</tr>
<tr>
<td>Contents</td>
<td>1440</td>
</tr>
<tr>
<td><strong>THE URINARY ORGANS.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>The Urinary Bladder.</strong></td>
<td></td>
</tr>
<tr>
<td>Surfaces</td>
<td>1442</td>
</tr>
<tr>
<td>The Fundus or Base</td>
<td>1443</td>
</tr>
<tr>
<td>The Summit or Apex</td>
<td>1445</td>
</tr>
<tr>
<td>The Urethrus or Middle Umbilical Ligament</td>
<td>1445</td>
</tr>
<tr>
<td>Structure of the Bladder</td>
<td>1446</td>
</tr>
<tr>
<td>Objects Seen on the Inner Surface of Bladder</td>
<td>1447</td>
</tr>
<tr>
<td>Surface Form</td>
<td>1449</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1449</td>
</tr>
<tr>
<td><strong>The Male Urethra.</strong></td>
<td></td>
</tr>
<tr>
<td>The First or Prostatic Portion</td>
<td>1450</td>
</tr>
<tr>
<td>The Second, Muscular or Membranous Portion</td>
<td>1451</td>
</tr>
<tr>
<td>The Third, Penile, Pendulous, Cavernous or Spongy Portion</td>
<td>1452</td>
</tr>
<tr>
<td>Structure of Male Urethra</td>
<td>1453</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1454</td>
</tr>
<tr>
<td><strong>The Female Bladder and Urethra.</strong></td>
<td></td>
</tr>
<tr>
<td>The Female Urethra</td>
<td>1455</td>
</tr>
<tr>
<td>Structure</td>
<td>1455</td>
</tr>
<tr>
<td><strong>THE MALE ORGANS OF GENERATION.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>The Prostate Gland.</strong></td>
<td></td>
</tr>
<tr>
<td>The Base</td>
<td>1461</td>
</tr>
<tr>
<td>The Apex</td>
<td>1461</td>
</tr>
<tr>
<td>Surfaces</td>
<td>1461</td>
</tr>
<tr>
<td>The Lateral Lobes</td>
<td>1461</td>
</tr>
<tr>
<td>The So-called Middle Lobe</td>
<td>1461</td>
</tr>
<tr>
<td>Structure</td>
<td>1462</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1462</td>
</tr>
<tr>
<td><strong>Cowper’s Glands.</strong></td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>1463</td>
</tr>
<tr>
<td><strong>The Penis.</strong></td>
<td></td>
</tr>
<tr>
<td>The Root</td>
<td>1464</td>
</tr>
<tr>
<td>The Body of the Penis</td>
<td>1465</td>
</tr>
<tr>
<td>Structure of the Penis</td>
<td>1465</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1470</td>
</tr>
<tr>
<td><strong>The Testicles and their Coverings.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Descent of the Testis.</strong></td>
<td></td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1472</td>
</tr>
<tr>
<td><strong>The Coverings of the Testis.</strong></td>
<td></td>
</tr>
<tr>
<td>The Testicular Bag or Scrotum</td>
<td>1472</td>
</tr>
<tr>
<td>The Intercolunnar or Spermatic Fascia</td>
<td>1474</td>
</tr>
<tr>
<td>The Cremasteric Fascia</td>
<td>1474</td>
</tr>
<tr>
<td>The Infundibuliform Fascia</td>
<td>1475</td>
</tr>
<tr>
<td>The Tunica Vaginalis</td>
<td>1476</td>
</tr>
<tr>
<td><strong>The Spermatic Cord.</strong></td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>1476</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1478</td>
</tr>
<tr>
<td><strong>The Testicles.</strong></td>
<td></td>
</tr>
<tr>
<td>The Tunics of the Testicle</td>
<td>1481</td>
</tr>
<tr>
<td>Structure of the Testicle and Epididymis</td>
<td>1482</td>
</tr>
<tr>
<td><strong>The SEMINAL VESICLES.</strong></td>
<td></td>
</tr>
<tr>
<td>The Ejaculatory Ducts</td>
<td>1487</td>
</tr>
<tr>
<td>Structure</td>
<td>1487</td>
</tr>
<tr>
<td>Surgical Anatomy</td>
<td>1487</td>
</tr>
<tr>
<td><strong>THE FEMALE ORGANS OF GENERATION.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>EXTERNAL ORGANS.</strong></td>
<td></td>
</tr>
<tr>
<td>The Large Lips or Labia Majora</td>
<td>1480</td>
</tr>
<tr>
<td>The Small Lips, Nymphae or Labia Minor</td>
<td>1490</td>
</tr>
<tr>
<td>The Vestibule</td>
<td>1491</td>
</tr>
<tr>
<td>The Clitoris</td>
<td>1493</td>
</tr>
<tr>
<td>Glands of Bartholin</td>
<td>1495</td>
</tr>
<tr>
<td>The Vaginal Bulb</td>
<td>1495</td>
</tr>
</tbody>
</table>
CONTENTS

INTERNAL ORGANS.

The Vagina.
Relations .......................... 1496
Structure .......................... 1496

The Womb or Uterus.
The Fundus ......................... 1499
The Body of the Uterus .......... 1499
The Neck or Cervix Uteri ...... 1500
Folds and Ligaments ............ 1501
The Cavity of the Uterus ....... 1503
The Cavity of the Cervix or Cervical Canal .... 1503
Surgical Anatomy ................. 1508

THE ADNEXA OR APPENDAGES OF UTERUS.
The Fallopian Tube.
Structure of the Fallopian Tube .... 1510

THE SURGICAL ANATOMY OF INGUINAL AND FEMORAL HERNIA.

Dissection .......................... 1523

Inguinal Hernia.
Hernia into Funicular Process .... 1535
Direct Inguinal Hernia ............ 1535

Oblique Inguinal Hernia ......... 1532
Congenital Hernia ................. 1535
Infantile and Encysted Hernia .... 1535

Femoral Hernia.
Varieties of Femoral Hernia .... 1536

SURGICAL ANATOMY OF THE PERINÆUM.

Dissection .......................... 1537

Ischio-rectal Region.

The Perínæum Proper in the Male.
Position of the Viscera at the Outlet of the Pelvis .... 1552

CHRONOLOGICAL TABLE OF THE DEVELOPMENT OF THE FETUS .... 1559
INDEX .............................. 1561
DESCRIPTIVE AND SURGICAL ANATOMY.

OSTEEOLOGY—THE SKELETON.

The entire skeleton in the adult consists of 200 distinct bones. These are:

- The spine or vertebral column (sacrum and coccyx included) ... 26
- Cranium ... 8
- Face ... 14
- Hyoid bone, sternum, and ribs ... 26
- Upper extremities ... 64
- Lower extremities ... 62

200

In this enumeration the patellae are included as separate bones, but the smaller sesamoid bones and the ossicula auditus are not reckoned. The teeth belong to the tegumentary system. Different anatomists make different computations as to the number of bones in the skeleton. Some describe the skeleton as containing 206 distinct bones, adding the ossicles of the ear to the previously stated number. By adding the epipteric bones, the sphenoidal turbinal bones, the sesamoid bones, and others, the number may be greatly augmented.

Bones are divisible, according to their shape, into four classes: long, short, flat, and irregular.

Long Bones.—The long bones are found in the limbs, where they form a system of levers, which sustain the weight of the trunk and confer the power of locomotion. A long bone consists of a shaft and two extremities. The shaft is a hollow cylinder, contracted and narrowed to afford greater space for the bellies of the muscles; the walls consist of dense, compact tissue of great thickness in the middle, but becoming thinner toward the extremities; the spongy tissue is scanty, and the bone is hollowed out in its interior to form the medullary canal. The extremities are generally somewhat expanded for greater convenience of mutual connection, for the purpose of articulation, and to afford a broad surface for muscular attachment. Here the bone is made up of spongy tissue with only a thin coating of compact substance. The long bones are not straight, but curved, the curve generally taking place in two directions, thus affording greater strength to the bone. The bones belonging to this class are the clavicle, humerus, radius, ulna, femur, tibia, fibula, metacarpal and metatarsal bones, and the phalanges.

Short Bones.—Where a part of the skeleton is intended for strength and compactness, and its motion is at the same time slight and limited, it is divided into a number of small pieces united together by ligaments, and the separate bones are short and compressed, such as the bones of the carpus and tarsus. These bones, in their structure, are spongy throughout, excepting at their surface, where
there is a thin crust of compact substance. The patellae also, together with the other sesamoid bones, are by some regarded as short bones.

**Flat Bones.**—Where the principal requirement is either extensive protection or the provision of broad surfaces for muscular attachment, we find the osseous structure expanded into broad, flat plates, as is seen in the bones of the skull and the shoulder-blades. Flat bones are composed of two thin layers of compact tissue enclosing between them a variable quantity of cancellous tissue. In the cranial bones these layers of compact tissue are familiarly known as the **tables of the skull**; the outer table is thick and tough; the inner table is thinner, denser, and more brittle, and hence is termed the **vitreous table**. The intervening cancellous tissue is called the **diploë**. The flat bones are: the occipital, parietal, frontal, nasal, lachrymal, vomer, scapula, os innominatum, sternum, ribs, and patella.

**Irregular Bones.**—The irregular or mixed bones are such as, from their peculiar form, cannot be grouped under either of the preceding heads. Their structure is similar to that of other bones, consisting of a layer of compact tissue externally and of spongy, cancellous tissue within. The irregular bones are: the vertebrae, sacrum, coccyx, temporal, sphenoid, ethmoid, malar, superior maxilla, inferior maxilla, palate, inferior turbinated, and hyoid.

**Surfaces of Bones.**—If the surface of any bone is examined, certain eminences and depressions are seen, to which descriptive anatomists have given the following names.

These eminences and depressions are of two kinds: **articular** and **non-articular**. Well-marked examples of articular eminences are found in the heads of the humerus and femur and of articular depressions in the glenoid cavity of the scapula and the acetabulum. Non-articular eminences are designated according to their form. Thus a broad, rough, uneven elevation is called a **tuberosity**; a small, rough prominence, a **tubercle**; a sharp, slender, pointed eminence, a **spine**; a narrow, rough elevation, running some way along the surface, a **ridge**, **line**, or **crest**.

The non-articular depressions are also of very variable form, and are described as **fossae**, **grooves**, **furrows**, **fissures**, **notches**, **sulci**, etc. These non-articular eminences and depressions may receive blood-vessels, nerves, tendons, ligaments, or portions of organs, or may serve to increase the extent of surface for the attachment of ligaments and muscles. They are usually well marked in proportion to the muscular development of the subject.

A prominent process projecting from the surface of a bone which it has never been separate from or movable upon is termed an **apophysis** (from ἀφέωμαι, an excrescence); but if such process is developed as a separate piece from the rest of the bone, to which it is afterward joined, it is termed an **epiphysis** (from ἐπίθεωμαι, an accretion). The main part of the bone, or shaft, which is formed from the primary centre of ossification, is termed the **diaphysis**, and is separated, during growth, from the epiphysis by a layer of cartilage, at which growth in length of the bone takes place. Some bones are hollow and contain **sinuses**, which are spaces for air. **Canals** or **foramina** are channels or openings in bone through which nerves or vessels pass.

**Structure of Bone.**—Bone is a highly specialized form of connective tissue. In reality, it is white fibrous tissue, calcified and structurally modified until it becomes osseous tissue. Bone is not simply a crude mass resulting from the calcification of cartilage or fibrous tissue; it is a distinct tissue, of a definite structure, the constituent parts of which are arranged symmetrically. Its structure varies somewhat in different vertebrates. ![1](Arquitectura del Aparato de Sustentación en los Vertebrados. Por el Dr. Saturnino García Hurtado. Our description applies to human bone.)
There are two varieties of bone: dense or compact bone (substantia compacta), and cancellous, loose, or spongy bone (substantia spongiosa).

Compact Bone is dense, like ivory, and is always placed upon the exterior of bones. Even this apparently compact tissue is porous; it differs from cancellous bone in the greater density of its tissue and in the arrangement of its osseous plates into Haversian systems. Compact bone is surrounded by periosteum:

**Fig. 1.** Diagram of the structure of osseous tissue. A small part of a transverse section of the shaft of a long bone is shown. At the uppermost part is the periosteum covering the outside of the bone; at the lowermost part is the endosteum lining the marrow-cavity. Between these is the compact tissue, consisting largely of a series of Haversian systems, each being circular in outline and perforated by a central canal. In the first one is shown only the area occupied by a system; in the second is seen the concentric arrangement of the lamellae; and in the others, respectively, canaliculi; lacunae; lacunae and canaliculi; the contents of the canal, artery, vein, lymphatic and areolar tissue; lamellae, lacunae, and canaliculi; and, finally, all of the structures composing a complete system. Between the systems are circumferential and intermediate lamellae, only a few of which are represented as lodging lacunae, though it is to be understood that the lacunae are in all parts. The periosteum is seen to be made up of a fibrous layer and a vascular layer, and to have upon its attached surface a stratum of cells. From the fibrous layer project inward the rivet-like fibres of Sharpey. (F. H. Gerrish.)

The outer portion of the wall of a long bone, the cortex of the head of a bone, and the outer and inner layers of a flat bone are composed of compact osseous tissue, which is the hardest substance in the body with the exception of dentine and enamel; it is tough and elastic, and much force is required to break it.

Cancellous Bone is found in the interior of bones. The name, which means lattice-work, indicates the structure, which consists of slender fibres and lamellae joined to form a reticulum, the small meshes of which are marrow-spaces. The
spicules of cancellous bone contain lacunae and canaliculi, but no Haversian systems. In some regions the inner portion of the wall of a long bone, about the marrow-cavity, is composed of cancellous bone. Toward each extremity of the shaft the amount of cancellous tissue increases, the marrow-cavity diminishes in size, and the cancellous tissue is arranged in lines that approach each other toward the extremity, like the sides of an arch, and form a support for the epiphysis (Fig. 131). In the epiphysis the bone-plates are, as a rule, at right angles to the plane of the articular surface (the lines of greatest pressure); and they are bound together or strengthened by other bone-fibres, which are usually in correspondence with the planes of the articulation (the lines of greatest tension) (Fig. 164). The nearer the bone-spicules are to the medullary cavity the stronger they are (Hurtado).

In the flat and the irregular bones, the cancellous tissue is between the layers of compact bone, and is called the diploë.

A Short Bone is composed chiefly of cancellous tissue, which is encased in a thin coat of compact substance (substantia corticalis).

A Long Bone consists of a shaft, or diaphysis, and two extremities, or epiphyses. The shaft is an osseous tube, the outer layer of which is compact, and the inner layer of which is cancellous. It surrounds the medullary cavity (cavum medullare), which, in the recent condition, contains the medulla, or marrow (medulla ossium), which substance enters into the nearest Haversian canals. This cavity is widest at the centre of the shaft, and narrows toward the ends, where it is encroached upon by the cancellous layer which lies within the compact layer.

There are two varieties of marrow: Yellow marrow (medulla ossium flava) is found in the medullary cavities of the shafts of the long bones. It is composed of a network of fibrous tissue carrying many blood-vessels, fat-cells, and a few large nucleated masses of protoplasm—the true marrow-cells, or myelocytes. The yellow color of the marrow is due to fat. Yellow marrow is derived from red marrow by an increase in fat and diminution in marrow elements; it plays no part in blood-formation. At the periphery of the marrow cavity the fibrous tissue of the network forms a firm, fibrous membrane lining the cavity. This represents an inner periosteum, and is called the endosteaum.

Red marrow (medulla ossium rubra) is found in the diploë of the cranial bones, in the cancellous tissue of the vertebrae, ribs, and sternum, and in the articular ends of the long bones. Red marrow contains much less fat and is less solid than yellow marrow. It consists of a delicate network of connective tissue, supporting a dense capillary plexus; some fat; and numerous cellular elements. The delicate fibrous membrane surrounding red marrow is called the endosteaum. The cellular elements of red marrow (Fig. 2) comprise, first, marrow-cells, or myelocytes, which are protoplasmic masses, capable of amœboid movements, and containing large nuclei. They are not found in normal blood, but are abundant in leukemia; second, small, nucleated, reddish cells called erythroblasts, resembling the nucleated red cells of the blood of the embryo, and eventually by the loss of their nuclei becoming red blood-corpuscles; third, non-nucleated red blood-corpuscles; fourth, giant-cells containing one or more nuclei. They are varieties of leuкоocytes. The leukocyte group also contains the osteoclasts, eosinophiles, and mast-cells.

Gelatinous or mucoid marrow is formed by the absorption of the fat and the cellular elements of yellow marrow, and by the serous infiltration of the intercellular substance. It is produced by starvation, old age, and certain pathological conditions.

Each extremity of a long bone is separated from the shaft by a layer of cartilage known as the cambium layer, the epiphysical cartilage, or the epiphysical disk (Fig. 8). Growth from the cartilages causes an increase in the length of the bone. The cartilages ossify during development, and effect a bony union
between the shaft and the head of the bone. Certain bony processes are separated from the bone by cartilage, which later ossifies.

A **Flat Bone** is composed of two layers of compact bone with a layer of cancellous bone (the diploe) interposed. There is no general marrow-cavity; but the spaces between the bone-spicules intercommunicate and contain marrow.

The **Periosteum** is a fibrous membrane adhering to the surface of the bone in nearly every part except at the cartilage-covered extremities. When strong tendons or ligaments are attached to the bone, the periosteum is incorporated with them. By means of the periosteum many vessels reach and enter the hard bone through Volkmann's canals. This is shown by stripping the periosteum from the surface of living bone, when small bleeding points are seen, each of which marks the entrance of a vessel from the periosteum. It thus becomes obvious that the loosening of the periosteum, by depriving a portion of the bone of its nourishment, may produce necrosis. The membrane is firmly attached to the bone by trabeculae of fibrous tissue, which penetrate the bone at right angles to its surface, and carry blood-vessels. These trabeculae are called the **fibres of Sharpey** (Fig. 3). They do not directly enter the Haversian systems, but only the circumferential and intermediate lamella—parts that are formed by periosteal action. Prolongations from some of these vessels reach the Haversian canals, and even the bone-marrow. In the extremities of a long bone, vessels from the periosteum penetrate the layer of compact bone and reach the cancellous tissue. In the newborn and in the young the periosteum is composed of three layers: an **outer or fibrous layer**, containing some blood-vessels, and composed of bundles of white fibrous tissue; a **middle or fibro-elastic layer**, containing some blood-vessels, fibrous tissue, and much elastic tissue; and an **inner or osteogenetic layer**, which is very vascular and contains numerous cells, which are converted into osteoblasts. These are the cells that form osseous tissue.
Transverse Section of Compact Bone (Figs. 1, 4, and 6).—As previously stated, dense bone differs from cancellous bone in the fact that the bone-plates of the former are arranged in Haversian systems, so named from the anatomist Havers. A Haversian system consists of a central canal, running in a more or less longitudinal or slightly curved or spiral direction and called the Haversian canal; from five to ten bone-plates, or lamellae, arranged concentrically around the canal; gaps, called lacunae, between the lamellae, which spaces contain bone-corpuscles; minute channels, or canaliculi, radiating from the lacunae and passing through the lamellae—some reaching other lacunae, some reaching the Haversian canal, and others passing to adjacent Haversian systems. The canaliculi contain processes from the bone-corpuscle. From a study of transverse sections it would be thought that the lamellae always run longitudinally in straight lines or in curves determined by pressure and tension; but Prof. Dixon proved that in the human femur many of the bone-plates are arranged spirally, and thus increased strength is obtained. The same is probably true of other bones.

There are four varieties of lamellae: (1) the periosteal, peripheral, superficial, or external; (2) the Haversian, or concentric; (3) the interstitial, ground, or intermedial; and (4) the perimedullary, or internal. The periosteal lamellae are sometimes called primary, as they are the first to appear, and are formed by the direct transformation of the inner layer of the periosteum into bone. In the shaft of a long bone there are several layers of periosteal lamellae, but no one layer is extensive enough to surround the bone completely.

In the outer surface of the layer of periosteal lamellae depressions exist that are known as Howship's foveolae, or lacunae. These depressions are made by large cells, called osteoclasts, which destroy bone. There are no Haversian canals in this outer layer, but there are some large channels that convey blood-vessels into the bone, and are known as Volkmann's canals. Many small arteries from the periosteum enter the periphery of the shaft, and also of the epiphyses. A large trunk enters the shaft by the nutrient foramen (foramen nutriciæ), pass along the nutrient canal (canalis nutriciæ), and reaches the medullary canal. This vessel is called the nutrient artery.

The Haversian or concentric lamellae are circular layers arranged around a central space, or canal, known as the Haversian canal. There is no fixed number of these layers, there being usually from five to ten. The layers of each system are parallel to one another, but the layers of different systems cross at various
angles. Between these layers are small, irregular spaces, called lacunae; and extending radially out from the lacunae and piercing the various lamellae are delicate canals, known as canaliculi, which connect the lacunae. The lacuna nearest to the Haversian canal communicates with it by means of canaliculi; and canaliculi also communicate with other Haversian systems. The Haversian canal contains blood-vessels—an artery or a vein, or both an artery and a vein—and a nerve. The vessel in the canal is covered with endothelial cells, and the canal itself is lined with them. The space thus formed is a lymph-space, and into these lymph-spaces the canaliculi empty. Beneath the periosteum and at the periphery of the medullary cavity there are lymph-spaces that are in direct communication with the canaliculi of the Haversian systems. In each lacuna is a bone-cell—a corpuscle that almost fills the space, and sends arms, or processes, out into the canaliculi (Fig. 5). This bone-cell is an osteoblast.

The interstitial or intermediate lamellae occupy the spaces between the Haversian systems. They represent the remains of peripheral lamellae. They are usually short and very irregular, but possess lacunae and canaliculi, which are arranged as in the Haversian systems. The perimedullary lamellae are irregular and few in number.

The osteoblasts are irregular, flattened, stellate masses of protoplasm, possessing a number of processes. The protoplasm is granular, and each cell contains a large and distinct nucleus. Osteoblasts are met with in the deeper layer of the periosteum, in the endosteum, and in the lacunae.

Longitudinal Section of Compact Bone (Figs. 6 and 7).—We do not see concentric rings, as in a transverse section, but rows of lacunae parallel to the course of the Haversian canals—and these canals appear like half-tubes instead of circular spaces. The tubes are seen to branch and communicate, so that each separate Haversian canal runs only a short distance. In other respects the structure closely resembles that of a transverse section.

Lamellae of Cancellous Bone.—There are no Haversian canals, and canaliculi open into the medullary spaces, which act as do the Haversian canals in compact bone.

Blood-vessels of Bone.—Small arteries derived from the periosteum enter the minute orifices of the compact bone (Volkmann’s canals) and reach the
Haversian canals of the bony substance. Prolongations from these vessels reach the marrow and communicate with branches from the nutrient artery. The cancellous tissue is supplied by fewer but larger vessels, which are derived from the periosteum, and which often penetrate the cortex of compact bone and ramify in the cavities of the spongy tissue.

The medullary canal of a long bone is supplied by a large artery (sometimes more than one) called the nutrient artery. It enters the bone by the nutrient foramen, which is usually near the centre of the shaft, runs in an oblique canal through the compact structure, giving off branches to this structure, and enters the medullary cavity, and sends branches upward and downward. These branches communicate with branches from the periosteal vessels and subdivide into capillaries, which pass into comparatively large vessels. The walls of the vessels are very thin, and in some places deficient; the venous blood enters the spaces of the red marrow, and the current becomes extremely slow. Small veins collect the venous blood and emerge from the bone.

In the humerus the nutrient canal is directed toward the elbow-joint; in the radius and the ulna the nutrient canals are directed toward the elbow-joint; in the femur, the canal is directed toward the hip-joint; and in the tibia and the fibula, the canals are directed toward the ankle-joint. As Professor Cunningham states it: "In the upper limb the vessels flow toward the elbow; while in the
lower limb they pass from the knee." The red marrow of the extremities and the medulla of the entire shaft, and the bone of the shaft, except the circumferential lamellae, are supplied by the nutrient artery. The circumferential lamellae, wholly, and the cancellous tissue of the extremities, in part, and the medulla of the shaft to a very small extent are supplied by vessels from the periosteum. The extremities of a bone also receive articular arteries. In most of the flat bones, and in some of the short bones, one or more large apertures exist for the passage of blood-vessels to the central parts of the bone.

Veins emerge from the long bones in three places: 1. One or two large veins accompany the nutrient artery. 2. Numerous veins emerge at the articular extremities. 3. Many small veins arise in and emerge from compact substance. The latter two classes do not accompany arteries. The veins in the marrow and in the bone are devoid of valves; but immediately after emerging from the bone they have numerous valves.

In the flat cranial bones the veins are numerous and large; as seen in diploic canals, the walls of which are composed of osseous tissue, perforated, here and there, for branches from adjacent canelli. In all cancellous tissue the venous channels are similarly arranged, and the veins have very thin coats and are without valves. When the bone is divided, the vessels remain open; they do not retract into their bony canals, and readily absorb any septic matter that may be present.

The lymphatics are chiefly periosteal; but some enter the bone, along with the vessels. Cruikshank has traced them into the substance of the bone and Klein has described them as running in the Haversian canals. The perivascular spaces of the Haversian canals are lymph-spaces.

Nerves, medullated (myelinic) and non-medullated (amyelinic), are found in bone. They are distributed freely to the periosteum, and some of the fibres terminate in this structure as Pacinian corpuscles. Nerves accompany the nutrient arteries into the interior of the bone, and also reach the marrow from the periosteum by way of Volkmann's canals and the Haversian canals. They certainly supply the arterial coats. It is not, as yet, determined whether nerves do or do not terminate in bone-tissue. Stroh maintains that occasionally they terminate in bone-corpuscles. According to Kölliker nerves are most numerous in the articular extremities of the long bones, in the vertebrae, and the large flat bones.

Chemical Composition of Bone.—Bone consists of an animal and an earthy part intimately combined.

The animal part may be obtained by immersing the bone for a considerable time in dilute mineral acid, after which process the bone comes out exactly the same shape as before, but perfectly flexible, so that a long bone (one of the ribs, for example) can easily be tied into a knot. If now a transverse section is made, the same general arrangement of the Haversian canals, lamelle, lacunae, and canaliculi is seen, though not so plainly, as in the ordinary section.

The earthy part may be obtained separate by calcination, by which the animal matter is completely burned out. The bone will still retain its original form, but it will be white and brittle, will have lost about one-third of its original weight, and will crumble with the slightest force. The earthy matter confers on bone its hardness and rigidity, and the animal matter its tenacity.

The mineral matter consists of phosphate, carbonate, and fluoride of calcium, chloride of sodium, and phosphate of magnesium.

The animal basis is largely composed of ossein, or fat collagen. When boiled with water, especially under pressure, fat collagen is almost entirely resolved into gelatin.

The organic matter of bone forms about one-third; the inorganic matter, two-thirds. The exact composition, according to Professor Cunningham, is, of
organic matter, 31.04 parts; of inorganic matter, 68.97 parts. Of the earthy matter, five-sixths is calcium phosphate. Even after the removal of all the marrow a small percentage of fat is still found in bone.

Some of the diseases to which bones are liable mainly depend on the disproportion between the two constituents of bone. Thus in the disease called rickets, so common in the children of the poor, the bones become bent and curved, either from the superincumbent weight of the body or under the action of certain muscles. This depends upon some defect of nutrition by which bone becomes deprived of its normal proportion of earthy matter, while the animal matter is of unhealthy quality. In the vertebrae of a rickety subject Bostock found in 100 parts 79.75 animal and 20.25 earthy matter. Osteomalacia is a disease of adults characterized by the decalcification of existing bone and by the failure in calcification of new osteoid material. In this disease the bone shows a diminution in inorganic and an increase in organic material. Senile atrophy renders bones porous and brittle, and portions of bone may actually be absorbed, as is seen in the disappearance of the alvéole in old age. In senile atrophy of the calvaria the outer table becomes very thin, porous, and brittle, and the inner table often becomes rough and thicker from the formation of new bone. In senile atrophy of a long bone there is absorption of bone from the surface by osteoclasts in Howship's lacune, and absorption of the inner surface. The bone becomes porous and the medulla becomes more fatty. This change is not, as was so long taught, a decrease in organic matter and an increase in mineral matter, but is an actual alteration in the structure of the bone.

Ossification and Growth of Bone.—For the early development of the skeleton the reader is referred to text-books on embryology. Embryonic connective-tissue cells of the mesoblast develop membrane. Membrane may become bone directly or cartilage may be deposited, which cartilage by the process of ossification is formed into bone. The tissue which is eventually to become bone contains cellular elements which evolve into osteoblasts, or bone-forming cells. Osteoblasts exist in the connective tissues which become bone by intramembranous ossification, and in the deeper layers of the tissue called perichondrium which invests cartilage and which becomes the osteogenetic layer of the periosteum. In view of the fact that in the fetal skeleton some bones are preceded by membrane (parietal bones, frontal bone, upper part of tabular surface of occipital bone, most of bones of the face), and others are preceded by rods of cartilage (the long bones), two kinds of ossification are described—viz., the intramembranous and the intracartilaginous. Professor Cunningham says all true bone may be correctly regarded as of membranous origin, though its appearance is preceded in some instances by the deposition of cartilage; in this case calcification of the cartilage is an essential stage in the process of bone formation, but the ultimate conversion into true bone, with characteristic Haversian systems, leads to the absorption and disappearance of this primitive calcified cartilage. Intramembranous ossification forms membrane bones, that is, forms bone directly from fibrous tissue, there being no intermediate cartilaginous stage.

Intracartilaginous ossification consists in the ossification of cartilage.
Intramembranous Ossification.—In the case of bones which are developed in membrane no cartilaginous mould precedes the appearance of the bone-tissue. The membrane, which occupies the place of the future bone, is of the nature of connective tissue, and ultimately forms the periosteum. At this stage it is seen to be composed of fibres and granular cells in a matrix. The outer portion is more fibrous, while internally the cells or osteoblasts predominate; the whole tissue is richly supplied with blood-vessels. At the outset of the process of bone-formation a little network of bony spicule is first noticed radiating from the point or centre of ossification. When these rays of growing bone are examined with a microscope, they are found to consist at their growing point of a network of fine, clear fibres and granular corpuscles, with an intervening ground substance (Fig. 9). The fibres are termed osteogenetic fibres, and are made up of fine fibrils differing little from those of white fibrous tissue. Like them, they are probably deposited in the matrix through the influence of the cells—in this case the osteoblasts. The osteogenetic fibres soon assume a dark and granular appearance from the deposition of calcareous granules in the fibres and in the intervening matrix, and as they calcify they are found to enclose some of the granular corpuscles or osteoblasts. By the fusion of the calcareous granules the bony tissue again assumes a more transparent appearance, but the fibres are no longer so distinctly seen. The involved osteoblasts form the corpuscles of the future bone, the spaces in which they are enclosed constituting the lacuna. As the osteogenetic fibres grow out to the periphery they continue to calcify, and give rise to fresh bone-spicules. Thus a network of bone is formed, the meshes of which contain the blood-vessels and a delicate connective tissue crowded with osteoblasts. The bony trabecula thicken by the addition of fresh layers of bone formed by the osteoblasts on their surface, and the meshes are correspondingly encroached upon. Subsequently successive layers of bony tissue are deposited under the periosteum and around the larger vascular channels, which become the Haversian canals, so that the bone increases much in thickness.

Intracartilaginous Ossification.—Just before ossification begins the bone is entirely cartilaginous, and in the long bone, which may be taken as an example, the process commences in the centre and proceeds toward the extremities, which for some time remain cartilaginous. Subsequently a similar process commences in one
or more places in those extremities and gradually extends through them. The extremities do not, however, become joined to the shaft by bony tissue until growth has ceased, but are attached to it by a layer of cartilaginous tissue termed the epiphyseal cartilage (Fig. 8).

The first step in the ossification of the cartilage is that the cartilage-cells, at the point where ossification is commencing and which is termed a centre of ossification, enlarge and arrange themselves in rows (Fig. 10). The matrix in which they are embedded increases in quantity, so that the cells become further separated from each other. A deposit of calcareous material now takes place in this matrix, between the rows of cells, so that they become separated from each other by longitudinal columns of calcified matrix, presenting a granular and opaque appearance. Here and there the matrix between two cells of the same row also becomes calcified, and transverse bars of calcified substance stretch across from one calcareous column to another. Thus there are longitudinal groups of the cartilage-cells enclosed in oblong cavities, the walls of which are formed of calcified matrix, which cuts off all nutrition from the cells, and they, in consequence, waste, leaving spaces called the primary areole (Sharpey).

At the same time that this process is going on in the centre of the solid bar of cartilage of which the foetal bone consists, certain changes are taking place on
its surface. This is covered by a very vascular membrane, the perichondrium, entirely similar to the embryonic connective tissue already described as constituting the basis of membrane-bone, on the inner surface of which, that is to say, on the surface in contact with the cartilage, are gathered the formative cells, the osteoblasts. By the agency of these cells a thin layer of bony tissue is being formed between the perichondrium and the cartilage, by the intramembranous mode of ossification just described. There are, then, in this first stage of ossification, two processes going on simultaneously: in the centre of the cartilage the formation of a number of oblong spaces, formed of calcified matrix and containing the withered cartilage-cells, and on the surface of the cartilage the formation of a layer of true membrane-bone. The second stage consists in the prolongation into the cartilage of processes of the deeper or osteogenetic layer of the perichondrium, which has now become periostea (Fig. 10, ir). The processes consist of blood-vessels and cells—osteoblasts, or bone-formers, and osteoclasts, or bone-destroyers. The latter are similar to the giant-cells (myelo-plaques) found in marrow, and they excavate passages through

![Diagram](image)

**Fig. 12.—Transverse section from the femur of a human embryo about eleven weeks old.** a. A medullary sinus cut transversely, and b, another, longitudinally. c. Osteoblasts. d. Newly formed osseous substance of a lighter color. e. That of greater age. g. Lacunae with their cells. g. A cell still united to an osteoblast.

the new-formed bony layer by absorption, and pass through it into the calcified matrix (Fig. 10). Wherever these processes come in contact with the calcified walls of the primary areolae they absorb it, and thus cause a fusion of the original cavities and the formation of larger spaces, which are termed the secondary areole (Sharpey), or medullary spaces (Müller). In these secondary spaces the original cartilage-cells, having disappeared, become filled with embryonic marrow, consisting of osteoblasts and vessels, and derived in
the manner described above, from the osteogenetic layer of the periosteum (Fig. 11).

Thus far there has been traced the formation of enlarged spaces (secondary areolae), the perforated walls of which are still formed by calcified cartilage-matrix, containing an embryonic marrow, derived from the processes sent in from the osteogenetic layer of the periosteum, and consisting of blood-vessels and round-cells, osteoblasts (Fig. 11). The walls of these secondary areolae are at this time of only inconsiderable thickness, but they become thickened by the deposition of layers of new bone on their interior. This process takes place in the following manner: Some of the osteoblasts of the embryonic marrow, after undergoing rapid division, arrange themselves as an epithelioid layer on the surface of the wall of the space (Fig. 12). This layer of osteoblasts form a bony stratum, and thus the wall of the space becomes gradually covered with a layer of true osseous substance. On this a second layer of osteoblasts arrange themselves, and in their turn form an osseous layer. By the repetition of this process the original cavity becomes very much reduced in size, and at last only remains as a small circular hole in the centre, containing the remains of the embryonic marrow—that is, a blood-vessel and a few osteoblasts. This small cavity constitutes the Haversian canal of the perfectly ossified bone. The successive layers of osseous matter which have been laid down and which encircle this central canal constitute the lamellae of which, as we have seen, each Haversian system is made up. As the successive layers of osteoblasts form osseous tissue, certain of the osteoblastic cells remain included between the various bony layers. These persist as the corpuscles of the future bone, the spaces enclosing them forming the lacunae (Figs. 12 and 14). The canaliculi, at first extremely short, are supposed to be extended by absorption, so as to meet those of neighboring lacunae.

Such are the changes which may be observed at one particular point, the centre of ossification. While they have been going on here a similar process has been set up in the surrounding parts and has been gradually proceeding toward the end of the shaft, so that in the ossifying bone all the changes described above may be seen in different parts, from the true bone in the centre of the shaft to the hyaline cartilage at the extremities. The bone thus formed differs from the bone of the adult in being more spongy and less regularly lamellated.

Thus far, then, we have followed the steps of a process by which a solid bony mass is produced, having vessels running into it from the periosteum, Haversian canals in which those vessels run, medullary spaces filled with foetal marrow, lacunae with their contained bone-cells, and canaliculi growing out of these lacunæ.

This process of ossification, however, is not the origin of the whole of the skeleton, for even in those bones in which the ossification proceeds in a great measure from a single centre, situated in the cartilaginous shaft of a long bone, a considerable part of the original bone is formed by intramembranous ossification.

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**Fig. 14.**—Osteoblasts from the parietal bone of a human embryo thirteen weeks old. a. Bony septa with the cells of the lacunæ. b. Layers of osteoblasts. c. The latter in transition to bone-corpuscles. (After Gegenbauer.)
beneath the perichondrium or periosteum; so that the girth of the bone is increased by bony deposit from the deeper layer of this membrane. The shaft of the bone is at first solid, but a tube is hollowed out in it by absorption around the vessels passing into it, which becomes the medullary canal. This absorption is supposed to be brought about by large "giant-cells," the so-called osteoclasts of Kolliker (Fig. 11). They vary in shape and size, and are known by containing a large number of clear nuclei, sometimes as many as twenty. The occurrence of similar cells in some tumors of bones has led to such tumors being denominated "myeloid."

As more and more bone is removed by this process of absorption from the interior of the bone to form the medullary canal, so more and more bone is deposited on the exterior from the periosteum, until at length the bone has attained the shape and size which it is destined to retain during adult life. As the ossification of the cartilaginous shaft extends toward the articular ends it carries with it, as it were, a layer of cartilage, or the cartilage grows as it ossifies, and thus the bone is increased in length. During this period of growth the articular end, or epiphysis, remains for some time entirely cartilaginous; then a bony centre appears in it, and it commences the same process of intracartilaginous ossification; but this process never extends to any great distance. The epiphyses remain separated from the shaft by a narrow cartilaginous layer for a definite time (Fig. 8). This layer ultimately ossifies, the distinction between shaft and epiphysis is obliterated, and the bone assumes its completed form and shape. The same remarks also apply to the processes of bone which are separately ossified, such as the trochanters of the femur. The bones, having been formed, continue to grow until the body has acquired its full stature. They increase in length by ossification continuing to extend in the epiphyseal cartilage, which goes on growing in advance of the ossifying process. They increase in circumference by deposition of new bone, from the deeper layer of the periosteum, on their external surface, and at the same time an absorption takes place within, by which the medullary cavity is increased.

The medullary spaces which characterize the cancellous tissue are produced by the absorption of the original foetal bone in the same way as the original medullary canal is formed. The distinction between the cancellous and compact tissue appears to depend essentially upon the extent to which this process of absorption has been carried; and we may perhaps remind the reader that in morbid states of the bone inflammatory absorption produces exactly the same change, and converts portions of bone naturally compact into cancellous tissue.

The number of ossific centres is different in different bones. In most of the short bones ossification commences by a single point in the centre, and proceeds toward the circumference. In the long bones there is a central point of ossification for the shaft or diaphysis; and one or more for each extremity, the epiphysis. That for the shaft is the first to appear. The union of the epiphyses with the shaft takes place in the reverse order to that in which their ossification began, with the exception of the fibula, and appears to be regulated by direction of the nutrient artery of the bone. Thus the nutrient arteries of the bones of the arm and forearm are directed toward the elbow, and the epiphyses of the bones forming this joint become united to the shaft before those at the shoulder and wrist. In the lower limb, on the other hand, the nutrient arteries pass in a direction from the knee; that is, upward in the femur, downward in the tibia and fibula; and in them it is observed that the upper epiphysis of the femur and the lower epiphysis of the tibia and fibula become first united to the shaft.

Where there is only one epiphysis, the medullary artery is directed toward that end of the bone where there is no additional centre, as toward the acromial end of the clavicle, toward the distal end of the metacarpal bone of the thumb.
and great toe, and toward the proximal end of the other metacarpal and metatarsal bones.

Besides these epiphyses for the articular ends, there are others for projecting parts or processes, which are formed separately from the bulk of the bone. For an account of these the reader is referred to the description of the individual bones in the sequel.

A knowledge of the exact periods when the epiphyses become joined to the shaft is often of great importance in medico-legal inquiries. It also aids the surgeon in the diagnosis of many of the injuries to which the joints are liable; for it not infrequently happens that on the application of severe force to a joint the epiphysis becomes separated from the shaft, and such an injury may be mistaken for a fracture or dislocation.

**THE VERTEBRAL OR SPINAL COLUMN OR THE SPINE (COLUMNA VERTEBRALIS).**

The spine is a flexuous and flexible column formed of a series of bones called vertebrae (from *vertere*, to turn).

The vertebrae are thirty-three in number, and have received the names cervical, dorsal or thoracic, lumbar, sacral, and coccygeal, according to the position which they occupy; seven being found in the cervical region, twelve in the thoracic, five in the lumbar, five in the sacral, and four in the coccygeal.

This number is sometimes increased by an additional vertebra in one region, or the number may be diminished in one region, the deficiency being supplied by an additional vertebra in another. These observations do not apply to the cervical portion of the spine, the number of bones forming which is seldom increased or diminished.

The vertebrae in the upper three regions of the spine remain separate throughout life, and are known as true or movable vertebrae; but those found in the sacral and coccygeal regions are in the adult firmly united, so as to form two bones—five entering into the formation of the upper bone or sacrum, and four into the terminal bone of the spine or coccyx. The fused vertebrae are known as false or immovable vertebrae.

**GENERAL CHARACTERS OF A VERTEBRA.**

Each vertebra consists of two essential parts—an anterior solid segment, the body, or centrum, and a posterior segment, the arch (arcus vertebrae), or the neural arch. The neural arch is formed of two pedicles and two laminae, supporting seven processes—viz., four articular, two transverse, and one spinous.

The bodies of the vertebrae are piled one upon the other, forming a strong pillar for the support of the cranium and trunk; the arches forming a hollow cylinder behind the bodies for the protection of the spinal cord (spinal canal or neural canal). The different vertebrae are connected together by means of the articular processes and the intervertebral fibrocartilages; while the transverse and spinous processes serve as levers for the attachment of muscles which move the different parts of the spine. Lastly, between each pair of vertebrae apertures exist through which the spinal nerves pass from the cord. Each of these constituent parts must now be separately examined.

**Body, or Centrum (corpus vertebrae).—The body is the largest part of a vertebra.** Above and below it is flattened; its upper and lower surfaces are rough for the attachment of the intervertebral fibro-cartilages, and each presents a rim around its circumference. In front it is convex from side to side, concave from above downward. Behind it is flat from above downward and slightly concave from
side to side. Its anterior surface is perforated by a few small apertures, for the passage of nutrient vessels; while on the posterior surface is a single large, irregular aperture, or occasionally more than one, for the exit of veins from the body of the vertebra—the *venae basis vertebrae*.

**Pedicles.**—The pedicles are two short, thick pieces of bone, which project backward, one on each side, from the upper part of the body of the vertebra, at the line of junction of its posterior and lateral surfaces. Each pedicle (*radix arcus vertebrae*) is a root of the vertebral arch. The concavities above and below the pedicles are the *superior* and *inferior intervertebral notches* or *grooves* (*incisura vertebralis superior et inferior*); they are four in number, two on each side, the inferior ones being generally the deeper. When the vertebrae are articulated the notches of each contiguous pair of bones form the *intervertebral foramina* (*foramina intervertebralia*), which communicate with the spinal canal and transmit the spinal nerves and bloodvessels.

**Laminae.**—The laminae are two broad plates of bone which complete the neural arch by fusing together in the middle line behind. They enclose a foramen, the *spinal* or *vertebral foramen* (*foramen vertebrale*), which serves for the protection of the spinal cord. When the vertebrae are joined they form, with their ligaments, the *vertebral canal* (*spinal or neural canal, canalis vertebralis*). The laminae are connected to the body by means of the pedicles. Their upper and lower borders are rough, for the attachment of the ligamenta subflava.

**Processes. Spinous Process** (*processus spinosus*).—The spinous process projects backward from the junction of the two laminae, and serves for the attachment of muscles and ligaments.

**Articular Processes.**—The articular processes (*zygapophyses*), four in number, two on each side, spring from the junction of the pedicles with the laminae. Each *superior process* (*processus articularis superior*) projects upward, its *articular surface* (*facies articularis superior*) being directed more or less backward; each *inferior process* (*processus articularis inferior*) projects downward, its *articular surface* (*facies articularis inferior*) looking more or less forward.

**Transverse Processes** (*processus transversi*).—The transverse processes, two in number, project one at each side from the point where the lamina joins the pedicle, between the superior and inferior articular processes. They also serve for the attachment of muscles and ligaments.

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The *Cervical Vertebrae* (*Vertebrae Cervicales*) (Fig. 15).

The cervical vertebrae are smaller than those in any other region of the spine, and may be readily distinguished by the foramen in the transverse process, which does not exist in the transverse process of either a dorsal or lumbar vertebra.

**Body.**—The body (*centrum*) is small, comparatively dense, and broader from side to side than from before backward. The *anterior* and *posterior surfaces* are flattened and of equal depth; the former is placed on a lower level than the latter, and its inferior border is prolonged downward, so as to overlap the upper and fore part of the vertebra below. Its *upper surface* is concave transversely, and presents a projecting lip on each side; its *lower surface* is convex from side to side, concave from before backward, and presents laterally a shallow concavity which receives the corresponding projecting lip of the adjacent vertebra.

**Pedicles.**—The pedicles are directed outward and backward, and are attached to the body midway between the upper and lower borders, so that the superior intervertebral notch is as deep as the inferior, but it is, at the same time, narrower.

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1 It may, perhaps, be as well to remind the reader that the direction of a surface is determined by that of a line drawn at right angles to it.—En. of 18th English Edition.
Laminae.—The laminae are narrow, long, thinner above than below, and overlap each other, enclosing the spinal foramen, which is very large, and of a triangular form.

Processes. Spinous Process.—The spinous process is short, and 'bifid at the extremity, to afford greater extent of surface for the attachment of muscles, the two divisions being often of unequal size. They increase in length from the fourth to the seventh vertebra.

Articular Processes.—The articular processes are flat, oblique, and of an oval form: the superior are directed backward and upward; the inferior forward and downward.

Transverse Processes.—The transverse processes are short, directed downward, outward, and forward, bifid at their extremity, and marked by a groove along their upper surface, which runs downward and outward from the superior intervertebral notch and serves for the transmission of one of the cervical nerves. They are situated in front of the articular processes and on the outer side of the pedicles. The transverse processes are pierced at their base by a foramen, for the transmission of the vertebral artery, vein, and a plexus of sympathetic nerves. This foramen is known as the transverse foramen, the costotransverse foramen, and the vertebrarterial foramen (foramen transversarium). Each process is formed by two roots: the anterior root, sometimes called the costal process, arising from the side of the body, and the homologue of the rib in the thoracic region of the spine; the posterior root springs from the junction of the pedicle with the lamina, and corresponds with the transverse process in the thoracic region. It is by the junction of the two that the foramen for the vertebral vessels is formed. The extremity of each of the anterior roots forms the anterior tubercle (tuberculum anterius) and the extremity of each of the posterior roots the posterior tubercle (tuberculum posterius) of the transverse processes.¹

1 The peculiar vertebra in the cervical regions are the first, or atlas; the second, or axis; and the seventh, or vertebra prominens. The great modifications in the form of the atlas and axis are designed to admit of the nodding and rotatory movements of the head.

Atlas.—The atlas (Fig. 16) is so named from supporting the globe of the head. The chief peculiarities of this bone are that it has neither body nor spinous process. The body is detached from the rest of the bone, and forms the odontoid process of

¹ The anterior tubercle of the transverse process of the sixth cervical vertebra is of large size, and is sometimes known as "Chassaignac's" or the "carotid tubercle" (tuberculum caroticum). It is in close relation with the carotid artery, which lies in front and a little external to it; so that, as was first pointed out by Chassaignac, the vessel can with ease be compressed against it.—Ed. of 15th English Edition.
the second vertebra; while the parts corresponding to the pedicles join in front to form the anterior arch. The atlas is ring-like, and consists of an anterior arch, a posterior arch, and two lateral masses. The anterior arch (arcus anterior) forms about one-fifth of the ring; its anterior surface is convex, and presents about its centre a tubercle (tuberculum anterius), for the attachment of the Longus colli muscle; posteriorly it is concave, and marked by a smooth, oval facet, called the circular facet (fovea dentis), covered with cartilage, for articulation with the odontoid process of the

axis. The upper and lower borders give attachment to the anterior occipito-atlantal and the anterior atlanto-axial ligaments, which connect it with the occipital bone above and the axis below. The posterior arch (arcus posterior) forms about two-fifths of the circumference of the bone; it terminates behind in a tubercle (tuberculum posterius), which is the rudiment of a spinous process, and gives origin to the Rectus capitis posticus minor. The diminutive size of this process prevents any interference in the movements between the atlas and the cranium. The posterior part of the arch presents above and behind a rounded edge for the attachment of the posterior occipito-atlantal ligament, while in front, immediately behind each superior articular process, is a groove (sulcus arterie vertebralis), sometimes converted into a foramen by a delicate bony spiculum, which arches backward from the posterior extremity of the superior articular process. These grooves represent the superior intervertebral notches, and are peculiar from being situated behind the articular processes, instead of in front of them, as in the other vertebrae. They serve for the transmission of the vertebral artery, which, ascending through the foramen in the transverse process, winds round the lateral mass in a direction backward and inward. They also transmit the suboccipital (first spinal) nerve. On the under surface of the posterior arch, in the same situation, are two other grooves, placed behind the lateral masses, and representing the inferior intervertebral notches of other vertebrae. They are much less marked than the superior. The lower border also gives attachment to the posterior atlanto-axial ligament, which connects it with the axis. The lateral masses (massae laterales) are the most bulky and solid parts of the atlas, in order to support the weight of the head; they present two articulating surfaces above, and two below. Each superior process (fovea articularis superior) is of large size, oval, concave, and approaches its companion in front, but diverges from it behind; it is directed upward, inward, and a little backward, forming a kind of cup for the corresponding condyle of the occipital bone. The two processes are admirably adapted to the nodding movements of the head. Not infrequently they are partially subdivided by a more or less deep indentation, which encroaches upon each lateral margin. Each inferior articular process (facies articularis inferior)
is circular in form, flattened or slightly concave, and directed downward and inward, articulating with the axis. The inferior processes permit the rotatory movements. Just below the inner margin of each superior articular surface is a small tubercle, for the attachment of the transverse ligament, which, stretching across the ring of the atlas, divides it into two unequal parts or arches; the anterior or smaller segment receiving the odontoid process of the axis, the posterior allowing the transmission of the spinal cord and its membranes. This part of the spinal canal is of considerable size, to afford space for the spinal cord; and hence lateral displacement of the atlas may occur without compression of this structure. The transverse processes are of large size, project directly outward and downward from the lateral masses, and serve for the attachment of special muscles which assist in rotating the head. They are long, not bifid, and perforated at their base by a canal for the vertebral artery, which is directed from below, upward, and backward.

**Axis.**—The axis (epistropheus) (Fig. 17) is the pivot upon which the first vertebra, carrying the head, rotates, hence the name, axis. The most distinctive character of this bone is the strong, prominent process, tooth-like in form (hence the name odontoid process, or dens), which rises perpendicularly from the upper surface of the body. The body is deeper in front than behind, and prolonged downward anteriorly so as to overlap the upper and fore part of the next vertebra. It presents in front a median longitudinal ridge, separating two lateral depressions, for the attachment of the Longus colli muscle of either side. The odontoid process presents two articulating surfaces covered with cartilage: one in front, of an oval form, for articulation with the atlas (facies articularis anterior); another behind (facies articularis posterior), for the transverse ligament—the latter frequently encroaching on the sides of the process. The apex is pointed, and gives attachment to the middle odontoid ligament (ligamentum apicis dentis). Below the apex the process is somewhat enlarged, and presents on either side a rough impression for the attachment of the lateral fasciculi of the odontoid or check ligaments, which connect it to the occipital bone; the base of the process, where it is attached to the body, is constricted, so as to prevent displacement from the transverse ligament, which binds it in this situation to the anterior arch of the atlas. Sometimes, however, this process does become displaced, especially in children, in whom the ligaments are more relaxed: instant death is the result of this accident. The internal structure of the odontoid process is more compact than that of the body. The pedicles are broad and strong, especially their anterior extremities, which coalesce with the sides of the body and the
root of the odontoid process. The *laminae* are thick and strong, and the spinal foramen large, but smaller than that of the atlas. The *transverse processes* are very small, not bifid, and each is perforated by the foramen for the vertebral artery, which is directed obliquely upward and outward. The *superior articular surfaces* (*facies articularres superiores*) are round, slightly convex, directed upward and outward, and are peculiar in being supported on the body, pedicles, and transverse processes. The *inferior articular surfaces* (*facies articularres inferiores*) have the same direction as those of the other cervical vertebrae. The *superior intervertebral notches* are very shallow, and lie behind the articular processes; the inferior in front of them, as in the other cervical vertebrae. The *spinous process* is of large size, very strong, deeply channelled on its under surface, and presents a bifid, tubercular extremity for the attachment of muscles which serve to rotate the head upon the spine.

**Seventh Cervical** (Fig. 18).—

The most distinctive character of this vertebra is the existence of a very long and prominent spinous process; hence the name *vertebra prominens*. This process is thick, nearly horizontal in direction, not bifurcated, and has attached to it the lower end of the ligamentum nuchae. The *transverse process* is usually of large size, its posterior tubercles are large and prominent, while the anterior are small and faintly marked; its upper surface has usually a hollow groove, and it seldom presents more than a trace of bifurcation at its extremity. The foramen in the transverse process is sometimes as large as in the other cervical vertebrae, but is usually smaller on one or both sides, and is sometimes wanting. On the left side it occasionally gives passage to the vertebral artery; more frequently the vertebral vein traverses it on both sides; but the usual arrangement is for both artery and vein to pass in front of the transverse process, and not through the foramen. Occasionally the anterior root of the transverse process exists as a separate bone, and attains a large size. It is then known as a *cervical rib*.

**The Thoracic or Dorsal Vertebrae** (*Vertebrae Thoracales*).

The thoracic vertebrae are intermediate in size between those in the cervical and those in the lumbar region, and increase in size from above downward, the upper vertebrae in this segment of the spine being much smaller than those in the lower part of the region. A thoracic vertebra may be at once recognized by the presence on each side of the body of one or more facets or half-facets for the heads of the ribs.

**Bodies.**—The bodies of the thoracic vertebrae resemble those in the cervical and lumbar regions at the respective ends of this portion of the spine; but in the middle of the thoracic region their form is very characteristic, being heart-shaped, and as broad in the antero-posterior as in the lateral direction. They are thicker behind than in front, flat above and below, convex and prominent in front, deeply con-
cave behind, slightly constricted in front and at the sides, and marked on each side, near the root of the pedicle, by two demi-facets, one above, the other below (fovea costalis superior et inferior). These are covered with cartilage in the recent state, and, when articulated with the adjoining vertebrae, form, with the intervening fibro-cartilage, oval surfaces for the reception of the heads of the corresponding ribs. The tenth, eleventh, and twelfth thoracic vertebrae each possesses one complete facet for the head of the rib, instead of two demi-facets.

![Diagram of a thoracic vertebra](image)

**Pedicles.**—The pedicles are directed backward, and the inferior intervertebral notches are of large size, and deeper than in any other region of the spine.

**Laminae.**—The laminae are broad, thick, and imbricated—that is to say, overlapping one another like tiles on a roof. The spinal foramen is small, and of a circular form.

**Processes. Spinous Processes.**—Each spinous process is long, triangular on transverse section, directed obliquely downward, and terminates in a tubercular extremity. They overlap one another from the fifth to the eighth vertebra, but are less oblique in direction above and below.

**Articular Processes.**—The articular processes are flat, nearly vertical in direction, and project from the upper and lower part of the pedicles; the superior being directed backward and slightly outward and upward, the inferior forward and a little inward and downward.

**Transverse Processes.**—The transverse processes arise from the same parts of the arch as the posterior roots of the transverse processes in the neck, and are situated behind the articular processes and pedicles; they are thick, strong, and of great length, directed obliquely backward and outward, presenting a clubbed extremity, which is tipped on its anterior part by a small concave surface, for articulation with the tubercle of a rib (fovea costalis transversalis). The twelfth, the eleventh, and sometimes the tenth thoracic vertebra has no facet on the transverse process. Besides the articular facet for the rib, three indistinct tubercles may be seen arising from the transverse processes: one at the upper border, one at the lower border, and one externally. In man they are comparatively of small size, and serve only for the attachment of muscles. But in some animals they attain considerable magnitude, either for the purpose of more closely
connecting the segments of this portion of the spine or for muscular and ligamentous attachment.

The peculiar thoracic vertebrae are the first, ninth, tenth, eleventh, and twelfth (Fig. 20).

**First Thoracic Vertebra.**—The first thoracic vertebra presents, on each side of the body, a single entire articular facet for the head of the first rib and a half-facet for the upper half of the second. The body is like that of a cervical vertebra, being broad transversely, its upper surface is concave, and lipped on each side. The **articulai surfaces** are oblique, and the **spinous process** thick, long, and almost horizontal.

**Ninth Thoracic Vertebra.**—The ninth thoracic vertebra has no demi-facet below. In some subjects, however, the ninth has two demi-facets on each side; when this occurs the tenth has only a demi-facet at the upper part.
Tenth Thoracic Vertebra.—The tenth thoracic vertebra has (except in the cases just mentioned) an entire articular facet on each side, above, which is partly placed on the outer surface of the pedicle. It has no demi-facet below.

Eleventh Thoracic Vertebra.—In the eleventh thoracic vertebra the body approaches in its form and size to the lumbar. The articular facets for the heads of the ribs, one on each side, are of large size, and placed chiefly on the pedicles, which are thicker and stronger in this and the next vertebra than in any other part of the thoracic region. The spinous process is short, and nearly horizontal in direction. The transverse processes are very short, tubercular at their extremities, and have no articular facets for the tubercles of the ribs.

Twelfth Thoracic Vertebra.—The twelfth thoracic vertebra has the same general characters as the eleventh, but may be distinguished from it by the inferior articular processes, being convex and turned outward, like those of the lumbar vertebra; by the general form of the body, laminae, and spinous process, approaching to that of the lumbar vertebra; and by the transverse processes being shorter, and marked by three elevations, the superior, inferior, and external tubercles, which correspond to the mammillary, accessory, and transverse processes of the lumbar vertebra. Traces of similar elevations are usually to be found upon the other thoracic vertebrae (vide ut supra).

The Lumbar Vertebrae (Vertebrae Lumbales) (Fig. 21).

The lumbar vertebrae are the largest segments of the vertebral column, and can at once be distinguished by the absence of the foramen in the transverse process, the characteristic point of the cervical vertebrae, and by the absence of any articulating facet on the side of the body, the distinguishing mark of the thoracic vertebrae.

Body.—The body is large, and has a greater diameter from side to side than from before backward, slightly thicker in front than behind, flattened or slightly concave above and below, concave behind, and deeply constricted in front and at the sides, presenting prominent margins, which afford a broad basis for the support of the superincumbent weight.

Pediciles.—The pedicles are very strong, directed backward from the upper part of the bodies; consequently, the inferior intervertebral notches are of considerable depth.

Laminae.—The laminae are broad, short, and strong, and the spinal foramen triangular, larger than in the thoracic, smaller than in the cervical, region.
Processes. Spinous Processes.—The spinous processes are thick and broad, somewhat quadrilateral, horizontal in direction, thicker below than above, and terminating by a rough, uneven border.

Articular Processes.—The superior articular processes are concave, and look backward and inward; the inferior are convex, and look forward and outward; the former are separated by a much wider interval than the latter, embracing the lower articulating processes of the vertebra above.

Transverse Processes.—The transverse processes are long, slender, directed transversely outward in the upper three lumbar vertebrae, slanting a little upward in the lower two. They are situated in front of the articular processes, instead of behind them, as in the thoracic vertebrae, and are homologous with the ribs. Of the three tubercles noticed in connection with the transverse processes of the twelfth thoracic vertebra, the superior one on each side becomes connected in this region with the back part of the superior articular process, and has received the name of mammillary process (processus mammillaris); the inferior is represented by a small process pointing downward, situated at the back part of the base of the transverse process, and called the accessory process (processus accessorius); these are the true transverse processes, which are rudimental in this region of the spine. The external one is the so-called transverse process, the homologue of the rib, and hence sometimes called the costal process (processus costarius) (Fig. 22). Although in man the costal processes are comparatively small, in some animals they attain considerable size, and serve to lock the vertebrae more closely together.

Fifth Lumbar Vertebra.—The fifth lumbar vertebra is characterized by having the body much thicker in front than behind, which accords with the prominence of the sacro-vertebral articulation; by the smaller size of its spinous process; by the wide interval between the inferior articulating processes; and by the greater size and thickness of its transverse processes, which spring from the body as well as from the pedicles.
Structure of the Vertebrae.—The body is composed of light, spongy, cancellous tissue, having a thin coating of compact tissue on its external surface perforated by numerous orifices, some of large size, for the passage of vessels; its interior is traversed by one or two large canals, for the reception of veins, which converge toward a single large, irregular aperture or several small apertures at the posterior part of the body of each bone. The arch and processes projecting from it have, on the contrary, an exceedingly thick covering of compact tissue (Fig. 23).

![Bony structure of a lumbar vertebra. (Poirier and Charpy.)](image)

Development.—Each vertebra is formed of four primary centres of ossification (Fig. 24), one for each lamina and its processes, and two for the body. Ossification commences in the laminae about the sixth week of foetal life, in the situation where the transverse processes afterward project, the ossific granules shooting backward to the spine, forward into the pedicles, and outward into the transverse and articular processes. Ossification in the body commences in the middle of the cartilage about the eighth week by two closely approximated centres, which speedily coalesce to form one central ossific point. According to some authors, ossification commences in the laminae only in the upper vertebrae—i.e., in the cervical and upper thoracic. The first ossific points in the lower vertebrae are those which are to form the body, the osseous centres for the laminae appearing at a subsequent period. At birth these three pieces are perfectly separate. During the first year the laminae become united behind, the union taking place first in the lumbar region and then extending upward through the thoracic and lower cervical regions. About the third year the body is joined to the arch on each side in such a manner that the body is formed from the three original centres of ossifica-

1 By many observers it is asserted that the bodies of the vertebra are developed from a single centre which speedily becomes bilobed, so as to give the appearance of two nuclei; but that there are two centres, at all events sometimes, is evidenced by the fact that the two halves of the body of the vertebra may remain distinct throughout life and be separated by a fissure through which a protrusion of the spinal membrane may take place, constituting an anterior spina bifida.—Ed. of the 15th English Edition.
tion, the amount contributed by the pedicles increasing in extent from below upward. Thus the bodies of the sacral vertebrae are formed almost entirely from the central nuclei; the bodies of the lumbar are formed laterally and behind by the pedicles; in the thoracic region the pedicles advance as far forward as the articular depressions for the head of the ribs, forming these cavities of reception; and in the neck the lateral portions of the bodies are formed entirely by the advance of the pedicles. The line along which union takes place between the body and the neural arch is named neuro-central suture. Before puberty no other changes occur, excepting a gradual increase in the growth of these primary centres; the upper and under surfaces of the bodies and the ends of the transverse and spinous processes being tipped with cartilage, in which ossific granules are not as yet deposited. At sixteen years (Fig. 26) three secondary centres appear, one for the tip of each transverse process, and one for the extremity of the spinous process. In some of the lumbar vertebrae, especially the first, second, and third, a second ossifying centre appears at the base of the spinous process. At twenty-one years (Fig. 25) a thin, circular, epiphyseal plate of bone is formed in the layer of cartilage situated on the upper and under surfaces of the body, the former being the thicker of the two. All these become joined, and the bone is completely formed between the twenty-fifth and thirtieth year of life.

Exceptions to this mode of development occur in the first, second, and seventh cervical, and in the vertebrae of the lumbar region.

Atlas (Fig. 27).—The number of centres of ossification of the atlas is very variable. It may be developed from two, three, four, or five centres. The most frequent arrangement is by three centres. Two of these are destined for the two lateral or neural masses, the ossification of which commences about the seventh week near the articular processes, and extend backward; these portions of bone are separated from one another behind, at birth, by a narrow interval filled in with cartilage. Between the third and fourth years they unite either directly or through the medium of a separate centre developed in the cartilage in the middle line. The anterior arch, at birth, is altogether cartilaginous, and in this a separate nucleus appears about the end of the first year after birth, and, extending laterally, joins the neural processes in front of the pedicles. Sometimes there are two nuclei developed in the cartilage, one on either side of the median line, which join to form a single mass. And occasionally there is no separate centre, but the anterior arch is formed by the gradual extension forward and ultimate junction of the two neural processes.

Axis.—The axis (Fig. 28) is developed by seven centres. The body and arch of this bone are formed in the same manner as the corresponding parts in the other vertebrae: one centre (or two, which speedily coalesce) for the lower part of the body, and one for each lamina. The centres for the laminae appear about the

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**Fig. 27.** Atlas.

- By 3 centres.
  - 1 for anterior arch (1st year), not constant.
  - 1 for each lateral mass before birth.

**Fig. 28.** Axis.

- By 7 centres.
  - 2d year.
  - 6th month.
  - 1 for each lateral mass.
  - 1 for body (4th month).
  - 1 for under surface of body.

**Fig. 29.** Lumbar vertebra.

- for tubercles on superior articular process.
seventh or eighth week, that for the body about the fourth month. The odontoid process consists, originally of an extension upward of the cartilaginous mass in which the lower part of the body is formed. At about the sixth month of foetal life two osseous nuclei make their appearance in the base of this process; they are placed laterally, and join before birth to form a conical bilobed mass deeply cleft above; the interval between the cleft and the summit of the process is formed by a wedge-shaped piece of cartilage, the base of the process being separated from the body by a cartilaginous interval, which gradually becomes ossified at its circumference, but remains cartilaginous in its centre until advanced age. Finally, as Humphry has demonstrated, the apex of the odontoid process has a separate nucleus, which appears in the second year and joins about the twelfth year. In addition to these there is a secondary centre for a thin epiphysial plate on the under surface of the body of the bone. J. Bland Sutton and others maintain that the odontoid process is the "dissociated body of the atlas."  

Seventh Cervical.—The anterior or costal part of the transverse process of the seventh cervical is developed from a separate osseous centre at about the sixth month of foetal life, and joins the body and posterior division of the transverse process between the fifth and sixth years. Sometimes this process continues as a separate piece, and, becoming lengthened outward, constitutes what is known as a cervical rib. This separate ossific centre for the costal process has also been found in the fourth, fifth, and sixth cervical vertebrae.  

Lumbar Vertebrae.—The lumbar vertebrae (Fig. 29) have two additional centres (besides those peculiar to the vertebrae generally) for the mammillary tubercles, which project from the back part of the superior articular processes. The transverse process of the first lumbar is sometimes developed as a separate piece, which may remain permanently unconnected with the remaining portion of the bone, thus forming a lumbar rib—a peculiarity that is rarely met with.  

Progress of Ossification in the Spine Generally.—Ossification of the laminae of the vertebrae commences in the cervical region of the spine, and proceeds gradually downward. Ossification of the bodies, on the other hand, commences a little below the centre of the spinal column (about the ninth or tenth thoracic vertebra), and extends both upward and downward. Although the ossific nuclei make their first appearance in the lower thoracic vertebrae, the lumbar and first sacral vertebrae are those in which these nuclei are largest at birth.  

Attachment of Muscles.—To the Atlas are attached nine pairs: the Longus colli, Rectus capitis anticus minor, Rectus lateralis, Obliquus capitis superior and inferior, Splenius colli, Levator anguli scapulae, First Intertransverse, and Rectus capitis posticus minor.  

To the Axis are attached eleven pairs: the Longus colli, Levator anguli scapulae, Splenius colli, Scalenus medius, Transversalis colli, Intertransversales, Obliquus capitis inferior, Rectus capitis posticus major, Semispinalis colli, Multifidus spinae, Interspinales.  

To the remaining vertebrae, generally, are attached thirty-five pairs and a single muscle: anteriorly, the Rectus capitis anticus major, Longus colli, Scalenus anticus medius and posticus, Psoas magnus and parvus, Quadratus lumborum, Diaphragm, Obliquus abdominis internus, and Transversalis abdominis; posteriorly, the Trapezius, Latissimus dorsi, Levator anguli scapulae, Rhomboideus major and minor, Serratus posticus superior and inferior, Splenius, Erector spinae, Ilio-costalis, Longissimus dorsi, Spinalis dorsi, Cervicalis ascendens, Transversalis colli, Trachelo-mastoide, Complexus, Biventer cervicis, Semispinalis dorsi and colli, Multifidus spinae, Rotatores spinae, Interspinales, Supraspinales, Intertransversales, Levatores costarum.  

2 Ligaments: their Nature and Morphology.
The Sacral and Coccygeal Vertebrae (False or Immovable Vertebrae).

The sacral and coccygeal vertebrae consist, at an early period of life, of nine separate pieces, which are united in the adult so as to form two bones, five entering into the formation of the sacrum, four into that of the coccyx. Occasionally, the coccyx consists of five bones.1

Sacrum (os sacrum).—The os sacrum (sacer, sacred), the sacred bone. So called, according to some, because it was the part selected in sacrifices. Another view is that the name is derived from an opinion of the Jewish rabbis, that this part of the skeleton strongly resists decay and becomes the germ from which the new body will be raised. The sacrum is a large, triangular bone (Fig. 30), situated at the lower part of the vertebral column, and at the upper and back part of the pelvic cavity, where it is inserted like a wedge between the two innominate bones; its upper part or base articulating with the last lumbar vertebra, its apex with the coccyx. It is composed of five segments of bone (sacral vertebrae, or vertebrae sacrales). The sacrum is curved upon itself, and placed very obliquely, its upper extremity projecting forward, and forming, with the last lumbar vertebra, a very prominent angle, called the promontory (promontorium), or sacro-vertebral angle; while its central part is directed backward, so as to give increased capacity to the pelvic cavity. It presents for examination an anterior and posterior surface, two lateral surfaces, a base, an apex, and a central canal.

Surfaces. Anterior or Pelvic Surface (facies pelvina).—The anterior surface is concave from above downward, and slightly so from side to side. In the middle are seen four transverse ridges (lineae transversae), indicating the original division of the bone into five separate pieces. The portions of bone intervening

1 Sir George Humphry describes this as the usual composition of the coccyx. On the Skeleton, p. 456.
between the ridges correspond to the bodies of the vertebrae. The body of the first segment is of large size, and in form resembles that of a lumbar vertebra; the succeeding ones diminish in size from above downward, are flattened from before backward, and curved so as to accommodate themselves to the form of the sacrum, being concave in front, convex behind. At each end of the ridges above mentioned are seen the anterior sacral foramina (foramina sacralia anteriora), analogous to the intervertebral foramina, four in number on each side, somewhat rounded in form, diminishing in size from above downward, and directed outward and forward; they transmit the anterior branches of the sacral nerves and the lateral sacral arteries. External to these foramina is the lateral mass (pars lateralis), consisting at an early period of life of separate segments; these become blended, in the adult, with the bodies, with each other, and with the posterior transverse processes. Each lateral mass is traversed by four broad, shallow grooves, which lodge the anterior sacral nerves as they pass outward, the grooves being separated by prominent ridges of bone, which give attachment to the slips of the Pyriformis muscle.

If a vertical section is made through the centre of the sacrum (Fig. 31), the bodies are seen to be united at their circumference by bone, a wide interval being left centrally, which, in the recent state, is filled by intervertebral substance. In some bones this union is more complete between the lower segments than between the upper ones.

**Posterior or Dorsal Surface (facies dorsalis).**—The posterior surface (Fig. 32) is convex and much narrower than the anterior. In the middle line are three or four tubercles, which represent the rudimentary spinous processes of the sacral vertebrae. Of these tubercles, the first is usually prominent, and perfectly distinct from the rest; the second and third are either separate or united into a tubercular ridge (crista sacralis media), which diminishes in size from above downward; the fourth usually, and the fifth always, remaining undeveloped. The gap which results from failure of the laminae to meet in the mid-line is called the hiatus sacralis. External to the spinous processes on each side are the laminae, broad and well marked in the first three pieces; sometimes the fourth, and generally the fifth, are only partially developed and fail to meet in the middle line. These partially developed laminae are prolonged downward as rounded processes, the sacral cornua (cornua sacralia), and are connected to the cornua of the coccyx. Between them the bony wall of the lower end of the sacral canal is imperfect. External to the laminae is a linear series of indistinct tubercles representing the articular processes (crista sacrales articulares); the upper pair are large, well developed, and correspond in shape and direction to the superior articulating processes of a lumbar vertebra; the second and third are small; the fourth and fifth (usually blended together) are situated on each
side of the sacral canal and assist in forming the sacral cornua. External to the articular processes are the four posterior sacral foramina (foramina sacralia posteriora); they are smaller in size and less regular in form than the anterior, and transmit the posterior branches of the sacral nerves. On the outer side of

![Diagram of the sacrum](image)

**Fig. 32.** Sacrum, posterior surface.

the posterior sacral foramina is a series of tubercles, the rudimentary transverse processes of the sacral vertebra (cristae sacrales laterales). The first pair of transverse tubercles are large, very distinct, and correspond with each superior angle of the bone; they together with the second pair, which are of small size, give attachment to the horizontal part of the sacro-iliac ligament; the third gives attachment to the oblique fasciuli of the posterior sacro-iliac ligaments; and the fourth and fifth to the great sacro-sciatic ligaments. The interspace between the spinous and transverse processes on the back of the sacrum presents a wide, shallow concavity, called the sacral groove: it is continuous above with the vertebral groove, and lodges the origin of the Multifidus spinae.

**Lateral Surface.**—The lateral surface, broad above, becomes narrowed into a thin edge below. Its upper half presents in front a broad, ear-shaped surface for articulation with the ilium. This is called the auricular surface (facies auricularis), and in the fresh state is coated with fibro-cartilage. It is bounded posteriorly by deep and uneven impressions, for the attachment of the posterior sacro-iliac ligaments. The chief prominence is called the tuberosity (tuberositas sacralis). The lower half is thin and sharp, and terminates in a projection called the inferior lateral angle; below this angle is a notch, which is converted into a foramen by articulation with the transverse process of the upper piece of the coccyx, and transmits the anterior division of the fifth sacral nerve. This lower, sharp border gives attachment to the greater and lesser sacro-sciatic ligaments, and to some fibres of the Gluteus maximus posteriorly, and to the Coccygeus in front.
Base (basis oss. sacri).—The base of the sacrum, which is broad and expanded, is directed upward and forward. In the middle is seen a large oval articular surface, which is connected with the under surface of the body of the last lumbar vertebra by a fibro-cartilaginous disk. It is bounded behind by the large, triangular orifice of the sacral canal. The orifice is formed behind by the laminae and spinous process of the first sacral vertebra: the superior articular processes project from it on each side; they are oval, concave, directed backward and inward, like the superior articular processes of a lumbar vertebra; and in front of each articular process is an intervertebral notech, which forms the lower part of the foramen between the last lumbar and first sacral vertebra. Lastly, on each side of the large oval articular plate is a broad and flat triangular surface of bone, which extends outward, supports the Psoas magnus muscle and lumbo-sacral cord, and is continuous on each side with the iliac fossa. This is called the ala of the sacrum (ala sacralis), and gives attachment to a few of the fibres of the Iliacus muscle. The posterior part of the ala represents the transverse process of the first sacral segment.

Apex (apex oss. sacri).—The apex, directed downward and slightly forward, presents a small, oval, concave surface for articulation with the coccyx.

Spinal Canal.—The spinal canal in this region is called the sacral canal (canalis sacralis). It runs throughout the greater part of the bone; it is large and triangular in form above, small and flattened, from before backward, below. In this situation its posterior wall is incomplete, from the non-development of the laminae and spinous processes (hiatus sacralis). It lodges the sacral nerves, and is perforated by the anterior and posterior sacral foramina, through which these pass out.

Structure.—It consists of much loose, spongy tissue within, invested externally by a thin layer of compact tissue.

Differences in the Sacrum of the Male and Female.—The sacrum in the female is shorter and wider than in the male; the lower half forms a greater angle with the upper, the upper half of the bone being nearly straight, the lower half presenting the greatest amount of curvature. The bone is also directed more obliquely backward, which increases the size of the pelvic cavity; but the sacro-vertebral angle projects less. In the male the curvature is more evenly distributed over the whole length of the bone, and is altogether greater than in the female.

Peculiarities of the Sacrum.—This bone, in some cases, consists of six pieces; occasionally, the number is reduced to four. Sometimes the bodies of the first and second segments are not joined or the laminae and spinous processes have not coalesced. Occasionally, the upper pair of transverse tubercles are not joined to the rest of the bone on one or both sides; and, lastly, the sacral canal may be open for nearly the lower half of the bone, in consequence of the imperfect development of the laminae and spinous processes. The sacrum, also, varies considerably with respect to its degree of curvature. From the examination of a large number of skeletons it would appear that in one set of cases the anterior surface of this bone was nearly straight, the curvature, which was very slight, affecting only its lower end. In another set of cases the bone was curved throughout its whole length, but especially toward its middle. In a third set the degree of curvature was less marked, and affected especially the lower third of the bone.

Development (Fig. 33).—The sacrum, formed by the union of five vertebrae, has thirty-five centres of ossification.

The bodies of the sacral vertebrae each have three ossific centres: one for the central part, and one for the epiphysaeal plates on its upper and under surface. Occasionally the primary centres for the bodies of the first and second piece of the sacrum are double.
The arch of each sacral vertebra is developed by two centres, one for each lamina. These unite with each other behind, and subsequently join the body.

The lateral masses have six additional centres, two for each of the first three vertebrae. These centres make their appearance above and to the outer side of the anterior sacral foramina (Fig. 33), and are developed into separate segments (Fig. 34); they are subsequently blended with each other, and with the bodies and transverse processes to form the lateral mass.

Lastly, each lateral surface of the sacrum is developed by two epiphyseal plates (Fig. 35): one for the auricular surface, and one for the remaining part of the thin lateral edge of the bone.

Period of Development.—At about the eighth or ninth week of foetal life ossification of the central part of the bodies of the first three vertebrae commences, and at a somewhat later period that of the last two. Between the sixth and eighth months ossification of the laminae takes place; and at about the same period the centres for the lateral masses for the first three sacral vertebrae make their appearance. The period at which the arch becomes completed by the junction of the laminae with the bodies in front and with each other behind varies in different segments. The junction between the laminae and the bodies takes place first in the lower vertebrae as early as the second year, but is not affected in the uppermost until the fifth or sixth year. About the sixteenth year the epiphyses for the upper and under surfaces of the bodies are formed, and between the eighteenth and twentieth years those for each lateral surface of the sacrum make their appearance. The bodies of the sacral vertebrae are, during early life, separated from each other by intervertebral disks. But about the eighteenth year the two lowest segments become joined together by ossification extending through the disk. This process gradually extends upward until all the segments become united, and the bone is completely formed from the twenty-fifth to the thirtieth year of life.

Articulations.—With four bones: the last lumbar vertebra, coccyx, and the two innominate bones.

Attachment of Muscles.—To eight pairs: in front, the Pyriformis and Coccygeus, and a portion of the Iliacus to the base of the bone; behind, the Gluteus maximus, Latissimus dorsi, Multifidus spinae, and Erector spinae, and sometimes the Extensor coccygis.

Coccyx (os coccygis).—The coccyx (kök'kēs, cuckoo), so called from having been compared to a cuckoo’s beak (Fig. 36), is usually formed of four small segments of bone, the most rudimentary parts of the vertebral column (vertebrae coccygeae or caudate vertebrae). In each of the first three segments may be traced a rudimentary body, articular and transverse processes; the last piece (some-
times the third) is a mere nodule of bone, without distinct processes. All the segments are destitute of pedicles, laminae, and spinous processes, and, consequently, of intervertebral foramina and spinal canal. The first segment is the largest; it resembles the lowermost sacral vertebra, and often exists as a separate piece; the last three, diminishing in size from above downward, are usually blended together so as to form a single bone. The gradual diminution in the size of the pieces gives this bone a triangular form, the base of the triangle joining the end of the sacrum. It presents for examination an anterior and posterior surface, two borders, a base, and an apex.

**Surfaces. Anterior Surface.**—The anterior surface is slightly concave, and marked with three transverse grooves, indicating the points of junction of the different pieces. It has attached to it the anterior sacro-coccygeal ligament and Levator ani muscle, and supports the lower end of the rectum.

**Posterior Surface.**—The posterior surface is convex, marked by transverse grooves similar to those on the anterior surface; and presents on each side a lineal row of tubercles, the rudimentary articular processes of the coccygeal vertebrae. Of these, the superior pair are large, and are called the *cornua of the coccyx* (*cornua coccygea*); they project upward, and articulate with the cornua of the sacrum, the junction between these two bones completing the fifth posterior sacral foramen for the transmission of the posterior division of the fifth sacral nerve.

**Borders.**—The lateral borders are thin, and present a series of small eminences, which represent the transverse processes of the coccygeal vertebrae. Of these, the first on each side is the largest, flattened from before backward, and often ascends to join the lower part of the thin lateral edge of the sacrum, thus completing the fifth anterior sacral foramen for the transmission of the anterior division of the fifth sacral nerve; the others diminish in size from above downward, and are often wanting. The borders of the coccyx are narrow, and give attachment on each side to the sacro-sciatic ligaments, to the Coccygeus muscles in front of the ligaments, and to the Gluteus maximus behind them.

**Base.**—The base presents an oval surface for articulation with the sacrum. This articulation is known as the *sacro-coccygeal symphysis* (*symphysis sacro-coccygea*).

**Apex.**—The apex is rounded, and has attached to it the tendon of the external Sphincter muscle. It is occasionally bifid, and sometimes deflected to one or other side.

**Development.**—The coccyx is developed by *four* centres, one for each piece. Occasionally one of the first three pieces of this bone is developed by two centres, placed side by side. The ossific nuclei make their appearance in the following order: in the first segment, shortly after birth; in the second piece, at from five
to ten years; in the third, from ten to fifteen years; in the fourth, from fifteen to twenty years. As age advances these various segments become united with each other from below upward, the union between the first and second segments being frequently delayed until after the age of twenty-five or thirty. At a late period of life, especially in females, the coccyx often becomes joined to the end of the sacrum.

**Articulation.**—With the sacrum.

**Attachment of Muscles.**—To four pairs and one single muscle: on either side, the Coccyeus; behind, the Gluteus maximus and Extensor coccygis, when present; at the apex, the Sphincter ani; and in front, the Levator ani.

### The Vertebral Column or Spine in General.

The spinal column (*columna vertebalis*), formed by the junction of the vertebrae, is situated in the median line, at the posterior part of the trunk; its average length is about two feet two or three inches, measuring along the curved anterior surface of the column. Of this length the cervical part measures about five, the thoracic about eleven, the lumbar about seven inches, and the sacrum and coccyx the remainder. The female spine is about one inch less than that of the male.

Viewed in front, the ventral surface presents two pyramids joined together at their bases, the upper one being formed by all the vertebrae from the second cervical to the last lumbar, the lower one by the sacrum and coccyx. When examined more closely, the upper pyramid is seen to be formed of three smaller pyramids. The uppermost of these consists of the six lower cervical vertebrae, its apex being formed by the axis or second cervical, its base by the first thoracic. The second pyramid, which is inverted, is formed by the four upper thoracic vertebrae, the base being at the first thoracic, the smaller end at the fourth. The third pyramid commences at the fourth thoracic, and gradually increases in size to the fifth lumbar.

Viewed laterally (Fig. 37), the spinal column presents several curves which correspond to the different regions of the column, and are called cervical, thoracic, lumbar, and pelvic. The **cervical curve** commences at the apex of the odontoid process, and terminates at the
middle of the second thoracic vertebra; it is convex in front, and is the least marked of all the curves. The thoracic curve, which is concave forward, commences at the middle of the second, and terminates at the middle of the twelfth thoracic vertebra. Its most prominent point behind corresponds to the spine of the seventh thoracic vertebra. The lumbar curve commences at the middle of the last thoracic vertebra, and terminates at the sacro-vertebral angle. It is convex anteriorly; the convexity of the lower three vertebrae being much greater than that of the upper two. The pelvic curve commences at the sacro-vertebral articulation and terminates at the point of the coccyx. It is concave anteriorly. The thoracic and pelvic curves are the primary curves, and begin to be formed at an early period of foetal life, and are due to the shape of the bodies of the vertebrae. The cervical and lumbar curves are compensatory or secondary, and are developed after birth in order to maintain the erect position. They are due mainly to the shape of the intervertebral disks.

Some writers teach that the spine has a normal deviation to the right side. Quain, Hyrtl, and others maintain this view. The curve is said to be in the thoracic region. Bichat assigned muscular action as the chief cause of the curve. Most persons use the right arm in preference to the left, especially in making long-continued efforts, when the body is curved to the right side. In support of this explanation is the observation made by Béclard that in some individuals who were left-handed the lateral curvature was directed to the left side. Sappey and others deny the existence of this curve.

The movable part of the spinal column presents for examination an anterior, a posterior, and two lateral surfaces; a base, a summit, and the spinal canal.

**Surfaces.** Anterior Surface.—The anterior or ventral surface presents the bodies of the vertebrae separated in the recent state by the intervertebral disks. The bodies are broad in the cervical region, narrow in the upper part of the thoracic, and broadest in the lumbar region. The whole of this surface is convex transversely, concave from above downward in the thoracic region, and convex in the same direction in the cervical and lumbar regions.

**Posterior Surface.**—The posterior or dorsal surface presents in the median line the spinous processes. These are short, horizontal, with bifid extremities, in the cervical region. In the thoracic region they are directed obliquely above, assume almost a vertical direction in the middle, and are horizontal below, as are also the spines of the lumbar vertebrae. They are separated by considerable intervals in the loins, by narrower intervals in the neck, and are closely approximated in the middle of the thoracic region. Occasionally one of these processes deviates a little from the median line—a fact to be remembered in practice, as irregularities of this sort are attendant also on fractures or displacements of the spine. On either side of the spinous processes, extending the whole length of the column, is the vertebral groove formed by the laminae in the cervical and lumbar regions, where it is shallow, and by the lamina and transverse processes in the thoracic region, where it is deep and broad. In the recent state these grooves lodge the deep muscles of the back. External to each vertebral groove are the articular processes, and still more externally is the transverse process. In the thoracic region the latter processes stand backward, on a plane considerably posterior to that of like processes in the cervical and lumbar regions. In the cervical region the transverse processes are placed in front of the articular processes, and on the outer side of the pedicles, between the intervertebral foramina. In the thoracic region they are posterior to the pedicles, intervertebral foramina, and articular processes. In the lumbar region they are placed also in front of the articular processes, but behind the intervertebral foramina.

**Lateral Surfaces.**—The lateral surfaces are separated from the posterior surface by the articular processes in the cervical and lumbar regions, and by the trans-
verse processes in the thoracic region. These surfaces present in front the sides of the bodies of the vertebra, marked in the thoracic region by the facets for articulation with the heads of the ribs. More posteriorly are the intervertebral foramina, formed by the juxtaposition of the intervertebral notches, oval in shape, smallest in the cervical and upper part of the thoracic regions, and gradually increasing in size to the last lumbar vertebra. They are situated between the transverse processes in the neck, and in front of them in the back and loins, and transmit the spinal nerves.

**Base.**—The base of that portion of the vertebral column formed by the twenty-four movable vertebrae is formed by the under surface of the body of the fifth lumbar vertebra; and the **summit** by the upper surface of the atlas.

**Spinal Canal (canalis vertebrales).**—The vertebral or spinal canal follows the different curves of the spine; it is largest in those regions in which the spine enjoys the greatest freedom of movement, as in the neck and loins, where it is wide and triangular; and is narrow and rounded in the back, where motion is more limited. The centre of gravity of the spine is in the upper lumbar region, slightly to the right of the median plane (Struthers).

**Surface Form.**—The only parts of the vertebral column which lie closely under the skin, and so directly influence surface form, are the apices of the spinous processes. These are always distinguishable at the bottom of a median furrow, which, more or less evident, runs down the mesial line of the back from the external occipital protuberance above to the middle of the sacrum below. In the cervical region the furrow is between the Trapezius muscles; in the back and loins it is between the Erector spine muscles. In the neck the furrow is broad, and terminates in a conspicuous projection, which is caused by the spinous process of the seventh cervical vertebra (vertebra prominens). Above this the spinous process of the sixth cervical vertebra may sometimes be seen to form a projection; the other cervical spines are sunken, and are not visible, though the spine of the axis can be felt, and generally also the spines of the third, fourth, and fifth cervical vertebrae. In the thoracic region the furrow is shallow, and during stooping disappears, and then the spinous processes become more or less visible. The markings produced by these spines are small and close together. In the lumbar region the furrow is deep, and the situation of the lumbar spines is frequently indicated by little pits or depressions, especially if the muscles in the loins are well developed and the spine incurved. They are much larger and farther apart than in the thoracic region. In the sacral region the furrow is shallower, presenting a flattened area which terminates below at the most prominent part of the posterior surface of the sacrum, formed by the spinous process of the third sacral vertebra. At the bottom of the furrow may be felt the irregular surface of the bone. Below this, in the deep groove leading to the anus, the coccyx may be felt. The only other portions of the vertebral column which can be felt from the surface are the transverse processes of three of the cervical vertebrae—viz., the first, the sixth, and the seventh. The transverse process of the atlas can be felt as a rounded nodule of bone just below and in front of the apex of the mastoid process, along the anterior border of the sternomastoid. The transverse process of the sixth cervical vertebra is of surgical importance. If deep pressure be made in the neck in the course of the carotid artery, opposite the cricoid cartilage, the prominent anterior tubercle of the transverse process of the sixth cervical vertebra can be felt. This has been named Chassaignac's tubercle, and against it the carotid artery may be most conveniently compressed by the finger. The transverse process of the seventh cervical vertebra can also often be felt. Occasionally the anterior root, or costal process, is large and segmented off, forming a cervical rib.

**Surgical Anatomy.**—It is frequently necessary to locate certain vertebrae. Several of them can be easily found and identified. The seventh cervical spine is conspicuously prominent, and when the skin above it has been marked with a blue pencil the spine of the sixth cervical above and of the first thoracic below may be located. The spine of the third thoracic vertebra is on a level with the root of the spine of the scapula. The spine of the fourth lumbar vertebra is on a level with the highest point of the iliac crest. When one or two vertebrae have been definitely recognized the other ones can be found by counting the spines from a fixed point or from fixed points. Over the fifth lumbar spine there is no prominence, but a depression. The third sacral spine is on a level with the posterior superior spines of the ilium. The level at which the spinal cord terminates should be known to the surgeon if he proposes to tap the spinal theca (lumbar puncture), for diagnostic or therapeutic purposes or as a preliminary to the injection of cocaine or eucaine (spinal anaesthesis). In an adult the cord terminates at the lower border of the first lumbar vertebra, and the theca terminates opposite the body of the third sacral vertebra. In a child the cord terminates opposite the body of the third lumbar vertebra, and the theca ends at
about the same level as in an adult. Hence, in either a child or an adult, a puncture below the level of the fourth lumbar vertebra will inflict no injury upon the cord. In children the puncture is made just beneath the vertebral spine, and in adults about one-half an inch to either side of the vertebral spine, although, even in adults, the needle is made to enter the dura in the middle line. In either case the needle is directed upward and forward. As previously pointed out, the surgical anatomy of an infant's spine is not identical with the surgical anatomy of an adult's spine. An infant's spine is larger comparatively than an adult's spine, because the lower limbs are less developed in the former (A. H. Tubby). The umbilicus of an infant is opposite the body of the fourth lumbar vertebra; in an adult it is opposite the spine of the third lumbar vertebra. In an infant the base of the sternum is on a level with the top of the seventh cervical spine, and in an adult of the second thoracic spine (A. H. Tubby).

Occasionally the coalescence of the laminae is not completed, and consequently a cleft is left in the arches of the vertebrae and in the dura, through which a protrusion of the arachnoid membrane and sometimes of the spinal cord itself takes place, constituting a malformation known as spina bifida or hydrocephalus. This disease is most common in the lumbo-sacral region; but it may occur in the thoracic or cervical region, or the arches throughout the whole length of the canal may remain unapproximated. In some rare cases, in consequence of the non-coalescence of the two primary centres from which the body is formed, a similar condition may occur in front of the canal, the bodies of the vertebrae being found cleft and the tumor projecting into the thorax, abdomen, or pelvis, between the lateral halves of the bodies affected.

The construction of the spinal column of a number of pieces, securely connected together and enjoying only a slight degree of movement between any two individual pieces, though permitting of a very considerable range of movement as a whole, allows a sufficient degree of mobility without any material diminution of strength. The main joints of which the spine is composed, together with the very varied movements to which it is subjected, render it liable to sprains, which may complicate other injuries or may exist alone; but so closely are the individual vertebrae articulated that these sprains are seldom severe, and an amount of violence sufficiently great to produce tearing of the ligaments would tend to cause a dislocation or fracture. The further safety of the column and its less liability to injury is provided for by its disposition in curves instead of in one straight line. For it is an elastic column, and must first bend before it breaks: under these circumstances, being made up of three curves, it represents three columns, and greater force is required to produce bending of a short column than of a longer one that is equal to it in breadth and material. Again, the safety of the column is provided for by the interposition of the intervertebral disks between the bodies of the vertebrae, which act as admirable buffers in counteracting the effects of violent jars or shocks. Fracture dislocation of the spine may be caused by direct or indirect violence, or by a combination of the two, as when a person, falling from a height, strikes against some prominence and is doubled over it. The fractures from indirect violence are the more common, and here the bodies of the vertebrae are compressed, whilst the arches are torn asunder; whilst in fractures from direct violence the arches are compressed and the bodies of the vertebrae separated from each other. It will therefore be seen that in both classes of injury the spinal marrow is the part least likely to be injured, and may escape damage even where there has been considerable lesion of the bony framework. For, as Mr. Jacobson states, "being lodged in the centre of the column, it occupies neutral ground in respect to forces which might cause fracture. For it is a law in mechanics that when a beam, as of timber, is exposed to breakage and the force does not exceed the limits of the strength of the material, one division resists compression, another laceration of the particles, while the third, between the two, is in a negative condition." Applying this principle to the spine it will be seen that, whether the fracture dislocation be produced by direct violence or by indirect force, one segment, either the anterior or posterior, will be exposed to compression, the other to laceration, and the intermediate part, where the cord is situated, will be in a neutral state. When a fracture dislocation is produced by indirect violence the displacement is almost always the same, the upper segment being driven forward on the lower, so that the cord is compressed between the body of the vertebra below and the arch of the vertebra above.

The parts of the spine most liable to be injured are (1) the dorso-lumbar region, for this part is near the middle of the column, and there is therefore a greater amount of leverage, and moreover the portion above is comparatively fixed, and the vertebrae which form it, though much smaller, have nevertheless to bear almost as great a weight as those below; (2) the cervico-thoracic region, because here the flexible cervical portion of the spine joins the more fixed thoracic region; and (3) the atlanto-axial region, because it enjoys an extensive range of movement, and, being near the skull, is influenced by violence applied to the head. In fracture-dislocation spinous processes and portions of the laminae may be removed (laminection) in order to free the cord from pressure, and to permit the surgeon to explore, to arrest hemorrhage, to remove bone fragments, or to apply sutures. Laminection is also resorted to in some cases of paraplegia due to Pott's disease of the spine.

THE SKULL.

The skeleton of the head is called the skull. The cranium is the skull without the mandible. The calvaria or cerebral cranium is the skull without the bones of the face. The skull is supported on the summit of the vertebral column, and is of an oval shape, wider behind than in front. It is composed of a series of flattened or irregularly shaped bones which, with one exception (the lower jaw), are immovably joined together. It is divided into two parts, the cerebral cranium or calvaria and the visceral cranium or face, the former of which constitutes a case for the accommodation and protection of the brain, while opening on the face are the orifices of the nose and mouth; between the cerebral cranium above and the face below the orbital cavities are situated. The cerebral cranium (χρόνιον, a helmet) is composed of eight bones—viz., the occipital, two parietal, frontal, two temporal, sphenoid, and ethmoid. The face is composed of fourteen bones—viz., the two nasal, two superior maxillary, two lachrymal, two malar, two palatine, two inferior turbinated, vomer, and inferior maxillary or mandible. The ossiculi auditis, the teeth, and Wormian bones are not included in this enumeration.

\[
\text{Cranium, 8 bones} \\
\begin{aligned}
\text{Occipital.} \\
\text{Two Parietal.} \\
\text{Frontal.} \\
\text{Two Temporal.} \\
\text{Sphenoid.} \\
\text{Ethmoid.}
\end{aligned}
\]

\[
\text{Skull, 22 bones} \\
\begin{aligned}
\text{Two Nasal.} \\
\text{Two Superior Maxillary.} \\
\text{Two Lachrymal.} \\
\text{Two Malar.} \\
\text{Two Palatine.} \\
\text{Two Inferior Turbinated.} \\
\text{Vomer.} \\
\text{Inferior Maxillary or Mandible.}
\end{aligned}
\]

\[
\text{Face, 14 bones} \\
\begin{aligned}
\text{Occipital.} \\
\text{Two Parietal.} \\
\text{Frontal.} \\
\text{Two Temporal.} \\
\text{Sphenoid.} \\
\text{Ethmoid.}
\end{aligned}
\]

The Hyoid Bone, situated at the root of the tongue and attached to the base of the skull by ligaments, has also to be considered in this section.

THE CEREBRAL CRANIUM (CRANIUM CEREBRALE) (THE CALVARIA).

The Occipital Bone (Os Occipitale).

The occipital bone (ob, caput, against the head) is situated at the back part and base of the cranium, is trapezoid in shape and is much curved on itself (Fig. 38). It presents at its front and lower part a large oval aperture, the foramen magnum (foramen occipitale magnum), by which the cranial cavity communicates with the spinal canal. The portion of bone behind this opening is flat and expanded and forms the tabula, tabular portion, or squamous part (squama occipitalis); the portion in front is a thick, elongated mass of bone, the basilar process (pars basilaris); while on each side of the foramen is situated a lateral or condylic portion (pars lateralis), bearing the condyle, by which the bone articulates with the atlas. The bone presents for examination two surfaces, four borders, and four angles.

Surfaces. External Surface.—The external surface is convex. Midway between the summit of the bone and the posterior margin of the foramen magnum is a prominent tubercle, the inion or external occipital protubercance (protuberantia
The occipital bone, a vertical ridge, the external occipital crest (crista occipitalis externa). This protuberance and crest give attachment to the ligamentum nuchae, and vary in prominence in different skulls. Passing outward from the occipital protuberance is a semicircular ridge on each side, the superior curved or superior nuchal line (linea nuchae superior). Above this line there is often a second less distinctly marked ridge, called the highest curved line (linea nuchae suprema); to it the epicranial aponeurosis is attached. The bone between these two lines is smoother and denser than the rest of the surface. Running parallel with these from the middle of the crest is another semicircular ridge on each side, the inferior curved or inferior nuchal line (linea nuchae inferior). The surface of the bone above the linea suprema is rough and porous, and in the recent state is covered by the}

![Occipital bone](Fig. 38.—Occipital bone. Outer surface.)

Occipito-frontalis muscle. It is called the occipital portion or the planum occipitale. The superior and inferior curved lines, together with the surfaces of bone between and below them, serve for the attachment of several muscles. The superior curved line gives attachment internally to the Trapezius, externally to the muscular origin of the Occipito-frontalis, and to the Sterno-clidomastoid to the extent shown in Fig. 38; the depressions between the curved lines to the Complexus internally, the Splenius capitis and Obliquus capitis superior externally. The inferior curved line and the depressions below it afford insertion to the Rectus capitis posticus, major and minor. The portion of the tabula below the superior curved line is called the nuchal plane (planum nuchale), and it gives attachment to certain of the neck muscles.

The foramen magnum (foramen occipitale magnum) is a large, oval aperture, its long diameter extending from before backward. It transmits the lower portion
of the oblongata and its membranes, the accessory nerves, the vertebral arteries, the anterior and posterior spinal arteries, and the occipito-axial ligaments. Its back part is wide for the transmission of the oblongata, and the corresponding margin rough for the attachment of the dura enclosing it; the fore part is narrower, being encroached upon by the condyles; it has projecting toward it, from below, the odontoid process, and its margins are smooth and bevelled internally to support the oblongata. The middle of the anterior wall of the foramen magnum is called by Broca the \textit{basion}. The \textit{lateral or condylic portions (partes laterales)} are on either side of the foramen magnum and bear the condyles for articulation with the atlas. Each condyle (\textit{condylius occipitalis}) is convex, oval, or reniform in shape, and directed downward and outward. The condyles converge in front, and encroach slightly upon the anterior segment of the foramen. On the inner border of each condyle is a rough tubercle for the attachment of the ligaments (\textit{cheek}) which connect this bone with the odontoid process of the axis; while external to them is a rough tubercular prominence, the \textit{transverse or jugular process (processus jugularis)}, channelled in front by a deep notch (\textit{incisura jugularis}), which forms part of the \textit{jugular foramen} or \textit{foramen lacerum posterius}. The under surface of this process presents an eminence (\textit{processus intrajugularis}) which represents the paramastoid process of some mammals. The eminence is occasionally large, and extends as low as the transverse process of the atlas. This surface affords attachment to the Rectus capitis lateralis muscle and to the lateral occipito-atlantal ligament; its upper or cerebral surface presents a deep groove which lodges part of the lateral sinus, while its external surface is marked by a quadrilateral rough facet, covered with cartilage in the fresh state, and articulating with a similar surface on the petrous portion of the temporal bone. On the outer side of each condyle, near its fore part, is a foramen, the \textit{anterior condyloid foramen (canalis hypoglossi or the hypoglossal canal)}; it is directed downward, outward, and forward, and transmits the hypoglossal nerve, and occasionally a meningeal branch of the ascending pharyngeal artery. This foramen is sometimes double. Behind each condyle is a fossa\footnote{This fossa presents many variations in size. It is usually shallow, and the foramen small; occasionally wanting on one or both sides. Sometimes both fossae and foramen are large, but confined to one side only; more rarely, the fossae and foramen are very large on both sides.—Ex. of 15th English Edition.} (\textit{fossa condyloideus}), sometimes perforated at the bottom by a foramen, the \textit{posterior condyloid foramen (canalis condyloideus)}, for the transmission of a vein to the lateral sinus. The \textit{basilar process (pars basilaris)} is a strong quadrilateral plate of bone, which is wider behind than in front, and is situated in front of the foramen magnum. Its under surface, which is rough, presents in the median line a tubercular ridge, the \textit{pharyngeal spine or tubercle (tuberculum pharyngeum)}, for the attachment of the tendinous raphé and Superior constrictor of the pharynx; and on each side of it rough depressions for the attachment of the Rectus capitis anterior, major and minor.

\textbf{Internal Surface}.—The internal or cerebral surface (Fig. 39) is deeply concave. The posterior or tabular part is divided by a \textit{crucial ridge} into four fossae. The two superior fossae receive the occipital lobes of the cerebrum, and present slight eminences and depressions corresponding to their convolutions. The two inferior, which receive the hemispheres of the cerebellum, are larger than the former, and comparatively smooth; both are marked by slight grooves for the lodgement of arteries. At the point of meeting of the four divisions of the crucial ridge is an eminence, the \textit{internal occipital protuberance (protuberantia occipitalis interna)}. It nearly corresponds to that on the outer surface, though it is often on a slightly higher level, and is perforated by one or more large vascular foramina. From this eminence the superior division of the crucial ridge runs upward to the superior angle of the bone; it presents a deep groove, the \textit{sagittal sulcus} (sulcus sagittal
talis), for the superior longitudinal sinus. The margins of the groove give attachment to the falk cerebri. The inferior division, the internal occipital crest (crista occipitalis interna), runs to the posterior margin of the foramen magnum, on the edge of which it becomes gradually lost; this ridge, which is bifurcated below, serves for the attachment of the falcula. It is usually marked by a single groove, which commences at the back part of the foramen magnum and lodges the occipital sinus. Occasionally the groove is double where two sinuses exist. A transverse groove (sulcus transversus) passes outward on each side to the lateral angle. The grooves are deep channels for the lodgement of the lateral sinuses, their prominent margins affording attachment to the tentorium. At the point of meeting of these grooves is a depression, the torcular, placed a little to one or the other side of the internal occipital protuberance. More anteriorly is the foramen magnum, and on each side of it, but nearer its anterior than its posterior part, the internal openings of the anterior condyloid foramen. On the superior aspect of the lateral portion of the bone the jugular tubercle (tuberculum jugulare) is seen. This corresponds to the portion of bone which roofs in the anterior condyloid foramen. The internal openings of the posterior condyloid

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1 Usually one of the transverse grooves is deeper and broader than the other; occasionally, both grooves are of equal depth and breadth, or both equally indistinct. The broader of the two transverse grooves is nearly always continuous with the vertical groove for the superior longitudinal sinus.—En. of 15th English Edition.

2 The columns of blood coming in different directions were supposed to be pressed together at this point (torcular, a wine-press).—En. of 15th English Edition.
foramina are a little external and posterior to the openings of the anterior condyloid foramina, protected by a small arch of bone. At this part of the internal surface there is a very deep groove in which the posterior condyloid foramen, when it exists, has its termination. This groove is continuous, in the complete skull, with the transverse groove on the posterior part of the bone, and lodges the end of the same sinus, the lateral. In front of the foramen magnum is the basilar process, presenting a shallow depression, the basilar groove (clivus), which slopes from behind, upward and forward, and supports the oblongata and part of the pons Varolii, and on each side of the basilar process is a narrow channel, which, when united in a similar way to the petrous portion of the temporal bone, forms a groove (sulcus petrosus inferior) which lodges the inferior petrosal sinus.

Borders. Superior Border.—The superior border, lambdoidal margin (margo lambdoideus), extends on each side from the superior to the lateral angle, is deeply serrated for articulation with the parietal bone, and forms, by this union, the lambdoid suture.

Inferior Border.—The inferior border extends from the lateral to the inferior angle; its upper half, mastoid margin (margo mastoides), is rough, and articulates with the mastoid portion of the temporal, forming the masto-occipital suture; the inferior half articulates with the petrous portion of the temporal, forming the petro-occipital suture; these two portions are separated from one another by the jugular process. In front of this process is a deep notch, which, with a similar one on the petrous portion of the temporal, forms the jugular foramen (foramen lacerum posterior). This notch is occasionally subdivided into two parts by a small process of bone (processus intrajugularis), and it generally presents an aperture at its upper part, the internal opening of the posterior condyloid foramen.

Angles. Superior Angle.—The superior angle is received into the interval between the posterior superior angles of the two parietal bones; it corresponds with that part of the skull in the foetus which is called the posterior fontanelle (lambda).

Inferior Angle.—The inferior angle is represented by the square-shaped surface of the basilar process. At an early period of life a layer of cartilage separates this part of the bone from the sphenoid, but in the adult the union between them is osseous.

Lateral Angles.—The lateral angles correspond to the outer ends of the transverse grooves, and are received into the interval between the posterior inferior angles of the parietal and the mastoid portion of the temporal. The junction of the occipital, parietal, and temporal bones was named the asterion by Broca.

Structure. — The occipital bone consists of two compact laminae, called the outer and inner tables, having between them the diploe tissue; this bone is especially thick at the ridges, protuberances, condyles, and anterior part of the basilar process; while at the bottom of the fossae, especially the inferior, it is thin, semitransparent, and destitute of diploe.

Development (Fig. 40).—At birth the bone consists of four distinct parts: a tabular squamous or expanded portion, which lies behind the foramen magnum; two condyllic parts, which form the sides of the foramen; and a basilar part, which lies...
in front of the foramen. The number of nuclei for the tabular part vary. As a rule, there are four, but there may be only one (Blandin) or as many as eight (Meckel). They appear about the eighth week of fetal life, and soon unite to form a single piece, which is, however, fissured in the direction indicated in Fig. 40. The basilar and two condyloid portions are each developed from a single nucleus, which appears a little later. The upper portion of the tabular surface—that is to say, the portion above the transverse fissure—is developed from membrane, and may remain separated from the rest of the bone throughout life, when it constitutes the interparietal bone, which is called the os incae, because of its frequent occurrence in Peruvian skulls. The rest of the bone is developed from cartilage. At about the fourth year the tabular and the two condyloid pieces join, and about the sixth year the bone consists of a single piece. At a later period, between the eighteenth and twenty-fifth years, the occipital and sphenoid become united, forming a single bone.

Articulations.—With six bones: two parietal, two temporal, sphenoid, and atlas.

Attachment of Muscles.—To twelve pairs: to the superior curved line are attached the Occipito-frontalis, Trapezius, and Sterno-cleido-mastoid. To the space between the curved lines, the Complexus,¹ Splenius capitis, and Obliquus capitis superior; to the inferior curved line, and the space between it and the foramen magnum, the Rectus capitis posticus, major and minor; to the transverse process, the Rectus capitis lateralis; and to the basilar process, the Rectus capitis anticus, major and minor, and Superior constrictor of the pharynx.

The Parietal Bone (Os Parietale).

The parietal bones (paries, a wall) are paired bones and form, by their union, the sides and roof of the cerebral cranium. Each bone is of an irregular quadrilateral form, and presents for examination two surfaces, four borders, and four angles.

Surfaces. External Surface (facies parietalis).—The external surface (Fig. 41) is convex, smooth, and marked about its centre by an eminence called the parietal eminence (tuberculum parietale), which indicates the point where ossification commenced. Crossing the middle of the bone in an arched direction are two well-marked curved lines or ridges, the upper and lower temporal lines or ridges (linea temporalis superior et inferior); the former gives attachment to the temporal fascia, while the latter indicates the upper limit of the origin of the Temporal muscle. These lines form the temporal crest. Above these ridges the surface of the bone is rough and porous, and covered by the aponeurosis of the Occipito-frontalis; between them the bone is smoother and more polished than the rest; below them the bone forms part of the temporal fossa. This portion of bone is called the planum temporale, and affords attachment to the Temporal muscle. The superior stephanion is the intersection of the upper temporal ridge with the coronal suture. The inferior stephanion is the intersection of the lower temporal ridge with the coronal suture. At the back part of the superior border, close to the sagittal suture, is a small foramen, the parietal foramen (foramen parietale), which transmits the emissary vein of Santorini from the scalp to the superior longitudinal sinus. It sometimes also transmits a small branch of the occipital artery. Its existence is not constant, and its size varies considerably. The point on the sagittal suture, between the parietal foramina, is the obelion.

Internal or Cerebral Surface (facies cerebralis).—The internal surface (Fig. 42) is concave, presents depressions for lodging the convolutions of the cerebrum and numerous furrows, for the ramifications of the middle meningeal artery; the

¹ To these the Biventer cervicis should be added, if it is regarded as a separate muscle.—Ed. of 15th English Edition.
THE PARIETAL BONE

Articulates with opposite parietal bone.

Parietals with frontal bone.

Upper Temporal Ridge

Lower Temporal Ridge

Squamous portion of temporal bone.

Sphenoid

Fig. 41.—Left parietal bone. External surface.

Articulates with occipital bone.

Anterior superior angle.

Posterior inferior angle.

Anterior inferior angle.

Pacchionian Depressions

Groove for Ml. Mening Arly.

Fig. 42.—Left parietal bone. Internal surface.
latter runs upward and backward from the anterior inferior angle and from the central and posterior part of the lower border of the bone. The depression for the middle meningeal artery at the anterior and inferior portions of the cerebral surface of the bone is called the sulcus arteriosus. Sometimes a distinct canal exists for the artery, but it never remains a canal for a long distance. Along the upper margin of the bone is part of a shallow groove, which, when joined to the opposite parietal, forms a channel for the superior longitudinal sinus (the sulcus sagittalis). The elevated edges of the groove afford attachment to the falx. Near the groove are seen several depressions, Pacchionian depressions (foveolae granulares [Pacchioni]). They are most frequently found in the skulls of old persons, and lodge the arachnoid villi (Pacchionian bodies). The internal opening of the parietal foramen is also seen when that aperture exists. On the inner surface of the posterior inferior portion of the bone is a portion of the groove for the lodging of the lateral sinus.

**Borders. Superior Border.**—The superior border, sagittal margin (margo sagittalis), the longest and thickest, is dentated to articulate with its fellow of the opposite side, forming the sagittal suture.

**Inferior Border.**—The inferior border, squamous margin (margo squamosus), is divided into three parts: of these, the anterior is thin and pointed, bevelled at the expense of the outer surface, and overlapped by the tip of the great wing of the sphenoid; the middle portion is arched, bevelled at the expense of the outer surface, and overlapped by the squamous portion of the temporal; the posterior portion is thick and serrated for articulation with the mastoid portion of the temporal.

**Anterior Border.**—The anterior border, frontal margin (margo frontalis), deeply serrated, is bevelled at the expense of the outer surface above and of the inner below; it articulates with the frontal bone, forming the coronal suture.

**Posterior Border.**—The posterior border, occipital margin (margo occipitalis), deeply denticulated, articulates with the occipital, forming the lambdoid suture.

**Angles. Anterior Superior Angle (angulus frontalis).**—The anterior superior or frontal angle, thin and pointed, corresponds with that portion of the skull which in the foetus is membranous, and is called the anterior fontanelle (bregma).

**Anterior Inferior Angle (angulus sphenoidalis).**—The anterior inferior or sphenoidal angle is thin and lengthened, being received in the interval between the great wing of the sphenoid and the frontal. Its inner surface is marked by a deep groove, sometimes a canal, for the anterior branch of the middle meningeal artery. At the anterior inferior angle the parietal, temporal, and frontal bones and the greater wing of the sphenoid bone meet. This spot is called the pterion.

**Posterior Superior Angle (angulus occipitalis).**—The posterior superior or occipital angle corresponds with the junction of the sagittal and lambdoid sutures. In the foetus this part of the skull is membranous, and is called the posterior fontanelle (lambda).

**Posterior Inferior Angle (angulus mastoideus).**—The posterior inferior or mastoid angle articulates with the mastoid portion of the temporal bone, and generally presents on its inner surface a broad, shallow groove for lodging part of the lateral sinus.

**Development.**—The parietal bone is formed in membrane, being developed by one centre, which corresponds with the parietal eminence, and makes its first appearance about the seventh or eighth week of fetal life. Ossification gradually extends from the centre to the circumference of the bone: the angles are consequently the parts last formed, and it is in their situation that the fontanelles exist previous to the completion of the growth of the bone. Occasionally the parietal bone is divided into two parts, upper and lower, by an antero-posterior suture.
Articulations.—With five bones: the opposite parietal, the occipital, frontal, temporal, and sphenoid.

Attachment of Muscles.—One only, the Temporal.

The Frontal Bone (Os Frontale).

The frontal bone (frons, the forehead) resembles a cockle-shell in form, and consists of two portions—a vertical or frontal portion, situated at the anterior part of the cranium, forming the forehead; and a horizontal or orbital portion, which enters into the formation of the roof of the orbits and nasal fossae.

Vertical Portion of the Frontal Bone (Pars Frontalis).

Surfaces. External Surface (facies frontalis) (Fig. 43).—In the median line, traversing the bone from the upper to the lower part, is occasionally seen a slightly elevated ridge, and in young subjects a suture, the frontal (metopic) suture, which represents the line of union of the two lateral halves of which the bone consists at an early period of life; in the adult this suture is usually obliterated and the bone forms one piece; traces of the obliterated suture are, however, generally perceptible at the lower part. On either side of this ridge, a little below the centre of the bone, is a rounded eminence, the frontal eminence (tuber frontale). These eminences vary in size in different individuals, and are occasionally unsymmetrical in the same subject. They are especially prominent in cases of well-marked cerebral development. The whole surface of the bone above this part is smooth, and covered by the aponeurosis of the Occipitofrontalis muscle. Below the frontal eminence and separated from it by a slight
groove is the **superciliary ridge** (*arcus superciliaris*), broad internally, where it is continuous with the nasal eminence, but less distinct as it arches outward. These ridges are caused by the projection outward of the frontal air sinuses, and give attachment to the Orbicularis palpebrarum and Corrugator supercilii. Between the two superciliary ridges is a smooth, flat surface, the **glabella**. Nearly corresponding with the glabella is the **ophryon**, a point in the mid-line on a level with the upper border of the eyebrows, which is the centre of the narrowest transverse diameter of the forehead. Beneath the superciliary ridge is the **orbital margin** or **supraorbital arch** (*margo supraorbitalis*), a curved and prominent margin, which forms the upper boundary of the orbit and separates the vertical from the horizontal portion of the bone. The outer part of the arch is sharp and prominent, affording to the eye, in that situation, considerable protection from injury; the inner part is less prominent. At the junction of the internal and middle third of this arch is a notch, sometimes converted into a foramen, and called the **supraorbital notch** or **foramen** (*incisura supraorbitalis* or *foramen supraorbitale*). It transmits the supraorbital artery, vein, and nerve. A small aperture is seen in the upper part of the notch, which transmits a vein from the diploë to join the supraorbital vein. To the median side of the supraorbital notch there is often a notch (*incisura frontalis*) for the passage of the frontal artery and frontal nerve. The supraorbital arch terminates externally in the **external angular process** (*processus zygomaticus*) and internally in the **internal angular process**. The external angular process is strong, prominent, and articulates with the malar bone; running upward and backward from it are two well-marked lines, which, commencing together from the external angular process as the **temporal ridge**, **crest** or **line** (*linea temporalis*), soon diverge from each other and run in a curved direction across the bone. These are the **upper** and **lower temporal ridges**; the upper gives attachment to the temporal fascia, the lower to the Temporal muscle. Beneath them is a slight concavity that forms the anterior part of the temporal fossa and gives origin to the Temporal muscle. The internal angular processes are less marked than the external, and articulate with the lachrymal bones. Between the internal angular processes is a rough, uneven interval, the **nasal notch**, which articulates in the middle line with the nasal bone, and on either side with the nasal process of the superior maxillary bone. From the concavity of this notch projects a process, the **nasal process**, which extends beneath the nasal bones and nasal processes of the superior maxillary bones and supports the bridge of the nose. On the under surface of this is a long, pointed process, the **nasal** or **frontal spine** (*spina nasalis or frontalis*), and on either side a small grooved surface enters into the formation of the roof of the nasal fossa. The nasal spine forms part of the septum of the nose, articulating in front with the nasal bones and behind with the perpendicular plate of the ethmoid. The junction of the nasal and frontal bones is called the **nasion**.

**Internal Surface** (*cerebral surface, facies cerebralis*) (Fig. 44).—Along the middle line is a vertical groove, the **sulcus sagittalis**, the edges of which unite below to form a ridge, the **frontal crest** (*crista frontalis*); the groove lodges the superior longitudinal sinus, whilst its margins afford attachment to the falx. The crest terminates below at a small notch which is converted into a foramen by articulation with the ethmoid. It is called the **foramen cecum**, and varies in size in different subjects: it is sometimes partially or completely impervious, lodges a

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1 Some confusion is occasioned to students commencing the study of anatomy by the name "sinuses" having been given to two perfectly different kinds of spaces connected with the skull. It may be as well, therefore, to state here at the outset, that the "sinuses" in the interior of the cranium which produce the grooves on the inner surface of the bones are venous channels along which the blood runs in its passage back from the brain, while the "sinuses" external to the cranial cavity (the frontal sphenoidal, ethmoidal, and maxillary) are hollow spaces in the bones themselves which communicate with the nostrils, and contain air.—Ed. of 16th English Edition.
process of the falx, and when open transmits a vein from the lining membrane of the nose to the superior longitudinal sinus. On either side of the groove the bone is deeply concave, presenting depressions for the convolutions of the brain, and numerous small furrows for lodging the ramifications of the anterior branches of the middle meningeal arteries. Several small irregular fossae are seen also on either side of the groove, for the reception of the arachnoid villi.

**Border.**—The border of the vertical portion is thick, strongly serrated, bevelled at the expense of the internal table above, where it rests upon the parietal bones, and at the expense of the external table at each side, where it receives the lateral pressure of those bones; this border is continued below into a triangular rough surface which articulates with the great wing of the sphenoid.

**Structure.**—The vertical portion and external angular processes are very thick, consisting of diploic tissue contained between two compact laminae.

**Horizontal or Orbital Portion of the Frontal Bone (Pars Orbitalis).**

This portion of the bone consists of two thin plates, the orbital plates, which form the vault of the orbit, separated from one another by a median gap, the ethmoidal notch.

**Surfaces. External Surface.**—The inferior or external surface of each orbital plate (facies orbitalis) consists of a smooth, concave, triangular lamina of bone, marked at its anterior and external part (immediately beneath the external angular process) by a shallow depression, the lachrymal fossa (fossa glandulæ lacrimalis) for lodging the lachrymal gland; and at its anterior and internal part
by a depression (sometimes a small tubercle), the trochlear fossa (fovea trochlearis), for the attachment of the cartilaginous pulley of the Superior oblique muscle of the eye. The ethmoidal notch (incisura ethmoidalis) separates the two orbital plates; it is quadrilateral, and filled up, when the bones are united, by the cribiform plate of the ethmoid. The margins of this notch present several half-cells, which, when united with corresponding half-cells on the upper surface of the ethmoid, complete the ethmoidal cells; two grooves are also seen crossing these edges transversely; they are converted into canals by articulation with the ethmoid, and are called the anterior and posterior ethmoidal foramina or canals (foramen ethmoidale anterius and foramen ethmoidale posterius): they open on the inner wall of the orbit. The anterior one transmits the nasal nerve and anterior ethmoidal vessels, the posterior one the posterior ethmoidal vessels. In front of the ethmoidal notch, on each side of the nasal spine, is the opening of the frontal sinus (sinus frontalis). These are two irregular cavities, which extend upward and outward, a variable distance, between the two tables of the skull, and are separated from one another by a thin, bony septum (septum sinus frontalis), which is often displaced to one side. Within the sinuses imperfect trabeculae of bone often exist. The sinuses are beneath and give rise to the prominences above the supraorbital arches called the superciliary ridges (arcus superciliares). The frontal air sinuses are absent at birth, become apparent about the seventh year of life, and from this period until the age of twenty increase gradually in size. Sometimes, however, the sinuses remain very small or never develop at all—or one side may be large and the other small—or one may exist on one side and be absent on the other. The right sinus is usually the larger. These cavities are larger in men than in women. The floor of each sinus is very thin and is over the orbit and the upper border of the lateral mass of the ethmoid. The thinnest portion of the floor is at the upper and inner angle of the orbit, and at this point pus is apt to point in cases of empyema of the sinus. The frontal sinuses are lined by mucous membrane and each sinus communicates with the middle meatus of the nose by the infundibulum and part of the semilunar hiatus. In some cases the sinuses communicate with each other by means of an aperture in the septum and occasionally join the sinus in the crista galli of the ethmoid.\footnote{1 Dr. D. Kerfoot Shute. Article on the Skull, in Reference Handbook of the Medical Sciences.}

Internal Surface (cerebral surface, facies cerebralis).—The internal surface of the horizontal portion presents the convex upper surfaces of the orbital plates, separated from each other in the middle line by the ethmoidal notch, and marked by eminences and depressions for the convolutions of the frontal lobes of the brain.

Border.—The border of the horizontal portion is thin, serrated, and articulates with the lesser wing of the sphenoid.

Structure.—The horizontal portion is thin, translucent, and composed entirely of compact tissue; hence the facility with which instruments can penetrate the cranium through this part of the orbit.

Development (Fig. 45).—The frontal bone is formed in membrane, being developed by two centres, one for each lateral half, which make their appearance about the seventh or eighth week, above the orbital arches. From this point ossification extends, in a radiating manner, upward into the forehead and back-
ward over the orbit. At birth the bone consists of two pieces, which afterward become united, along the middle line, by a suture which runs from the vertex to the root of the nose. This suture usually becomes obliterated within a few years after birth; but it occasionally remains throughout life, constituting the **metopic** suture. Secondary centres of ossification appear for the nasal spine—one on either side of the internal angular process where it articulates with the lachrymal bone; and sometimes there is one on either side at the lower end of the coronal suture. This latter centre sometimes remains ununited, and is known as the **pterion ossicle**, or it may join with the parietal, sphenoid, or temporal bone.

**Articulations.**—With twelve bones: two parietal, the sphenoid, the ethmoid, two nasal, two superior maxillary, two lachrymal, and two malar.

**Attachment of Muscles.**—To three pairs: the Corrugator superciliii, Orbicularis palpebrarum, and Temporal, on each side.

**The Temporal Bone (Os Temporale).**

The temporal bones (*tempus, time*) are paired bones, situated at the sides and base of the skull. Each presents for examination a **squamous, mastoid, and petrous** portion.

**Squamous Portion of the Temporal Bone (Squama Temporalis).**

The squamous portion (*squama, a scale*), the anterior and upper part of the bone, is scale-like in form, and thin and translucent in texture (Fig. 46).

**Surfaces. Outer Surface** (*facies temporalis*).—Its outer surface is smooth, convex, and grooved at its back part for the middle or deep temporal artery (*sulcus a. temporalis mediae*); it affords attachment to a portion of the Temporal muscle and forms part of the temporal fossa. At its back part may be seen a curved ridge—part of the temporal ridge or line; it serves for the attachment of the temporal...
fascia and limits the origin of the Temporal muscle. The boundary between the squamous and mastoid portions of the bone, as indicated by traces of the original suture, lies fully half an inch below this ridge. Projecting from the lower part of the squamous portion is a long, arched process of bone, the zygoma or zygomatic process (processus zygomaticus). This process is at first directed outward, its two surfaces looking upward and downward; it then appears as if twisted upon itself, and runs forward, its surfaces now looking inward and outward. The superior border of the process is long, thin, and sharp, and serves for the attachment of the temporal fascia. The inferior, short, thick, and arched, has attached to it some fibres of the Masseter muscle. Its outer surface is convex and subcutaneous; its inner is concave, and also affords attachment to the Masseter. The extremity, broad and deeply serrated, articulates with the malar bone. The zygomatic process is connected to the temporal bone by three divisions, called its roots—an anterior, middle, and posterior. The anterior, which is short, but broad and strong, is directed inward, to terminate in a rounded eminence, the eminentia articularis or articular eminence (tuberculum articolare) (Fig. 46). This eminence forms the front boundary of the glenoid or mandibular fossa (fossa mandibularis), and in the recent state is covered with cartilage. The middle root is known as the post-glenoid process or tubercle, and is very prominent in young bones. It separates the mandibular portion of the glenoid fossa from the external auditory meatus, and terminates at the commencement of a well-marked fissure, the Glaserian (petro-tympanic) fissure (fissura petro-tympanica [Glaseri]). The posterior root, which is strongly marked, runs from the upper border of the zygoma backward over the external auditory meatus. It is termed the supramastoid or temporal crest, and forms part of the lower temporal ridge. At the junction of the anterior root with the zygoma is a projection, called the tubercle, for the attachment of the external lateral ligament of the lower jaw; and between the anterior and middle roots is an oval depression, forming part of the glenoid (mandibular) fossa (γύνη, a socket), for the reception of the condyle of the lower jaw. This fossa is bounded, in front, by the eminentia articularis; behind, by the tympanic plate, which separates it from the external auditory meatus; it is divided into two parts by a narrow slit, the Glaserian or petro-tympanic fissure. The anterior or mandibular part, formed by the squamous portion of the bone, is smooth, covered in the recent state with cartilage, and articulates with the condyle of the lower jaw. This part of the glenoid fossa presents posteriorly a small conical eminence, the post-glenoid process, already referred to. This process is the representative of a prominent tubercle which, in some of the mammalia, descends behind the condyle of the jaw, and prevents it being displaced backward during mastication (Humphry). The posterior part of the glenoid fossa, which lodges a portion of the parotid gland, is formed chiefly by the tympanic plate, which constitutes the anterior wall of the tympanum and external auditory meatus. The plate of bone terminates above in the Glaserian fissure, and below forms a sharp edge, the vaginal process of the styloid (vagina processus styloidei), which gives origin to some of the fibres of the Tensor palati muscle. The Glaserian fissure, which leads into the tympanum, lodges the processus gracilis of the malleus, and transmits the tympanic branch of the internal maxillary artery. The chorda tympani nerve passes through a separate canal, parallel to the Glaserian fissure, the canal of Huguer (canaliculus chordae tympani), on the outer side of the Eustachian tube, in the retiring angle between the squamous and petrous portions of the temporal bone.¹ Between the posterior bony wall of the external auditory meatus

¹ This small fissure must not be confounded with the large canal which lies above the Eustachian tube and transmits the Tensor tympani muscle.
and the posterior root of the zygoma is the area called the suprameatal triangle of Prof. Macewen. Through this space the surgeon pushes the gouge in order to carry it into the antrum of the mastoid process.

**Internal Surface** (cerebral surface, facies cerebralis).—The internal surface of the squamous portion (Fig. 47) is concave, presents numerous eminences and depressions for the convolutions of the cerebrum, and two well-marked grooves for the branches of the middle meningeal artery.

**Borders. Superior Border.**—The superior border, parietal margin (margo parietalis), is thin, bevelled at the expense of the internal surface, so as to overlap the lower border of the parietal bone, forming the squamous suture.

**Anterior Inferior Border.**—The anterior inferior border, sphenoidal margin (margo sphenoidalis), is thick, serrated, and bevelled, alternately at the expense of the inner and outer surfaces, for articulation with the great wing of the sphenoid.

**Posterior Inferior Border.**—The posterior inferior border, occipital margin (margo occipitalis), is serrated and articulates with the occipital bone.

**The Mastoid Portion of the Temporal Bone (Pars Mastoidea).**

The mastoid portion (μαστόσ, a nipple or teat) is situated at the posterior part of the bone (Figs. 46, 48, and 49).

**Surfaces. Outer Surface.**—The outer surface of the mastoid is rough, and gives attachment to the Occipito-frontalis and Retrahens aurem muscles. It is perforated by numerous foramina; one of these, of large size, situated at the posterior border of the bone, is termed the mastoid foramen (foramen mastoideum); it transmits a vein to the lateral sinus and a small artery from the occipital to supply the dura. The position and size of this foramen are very variable. It is not always present; sometimes it is situated in the occipital bone or in the suture between the temporal and the occipital. The mastoid portion is con-
tinued below into a conical projection, the **mastoid process** (*processus mastoideus*), the size and form of which vary somewhat. The mastoid process begins to develop during the second year and does not attain full size until after puberty. This process serves for the attachment of the Sterno-mastoid, Splenius capitis, and Trachelo-mastoid muscles. On the inner side of the mastoid process is a deep groove, the **digastric fossa** (*incisura mastoidea*), for the attachment of the Digastric muscle; and, running parallel with it, but more internal, the **occipital groove** (*sulcus a. occipitalis*), which lodges the occipital artery. The **suprameatal triangle** of Prof. Macewen is bounded by the posterior root of the zygoma, the posterior bony wall of the external auditory meatus, and an imaginary line joining these two. Through this triangle the surgeon enters his instrument in order to reach the mastoid antrum. Behind the suprameatal spine is a depression known as the **mastoid fossa** (*fossa mastoidea*), which contains numerous small openings for bloodvessels.

![Diagram of the petrous and mastoid portions of the temporal bone, showing the communication of the cavity of the tympanum with the mastoid antrum.](image)

**Internal Surface.**—The internal surface of the mastoid portion presents a deep, curved groove, the **sigmoid fossa** or **sulcus** (*sulcus sigmoideus*), which lodges part of the lateral sinus; and into it may be seen opening the mastoid foramen, which transmits an emissary vein from the lateral sinus to the posterior auricular or occipital vein and a small artery, the mastoid branch of the occipital artery (*ramus mastoideus*). The groove for the lateral sinus is separated from the innermost of the mastoid air-cells by only a thin lamina of bone, and even this may be partly deficient. A section of the mastoid process (Figs. 48 and 49) shows it to be hollowed out into a number of cellular spaces, communicating with each other, called the **mastoid cells** (*cellulae mastoideae*), which exhibit the greatest possible variety as to their size and number, and which do not exist at birth, but develop with the growth of the mastoid process. At the upper and front part of the bone these cells are large and irregular, and contain air. They diminish in size toward the lower part of the bone, those situated at the apex of the mastoid process being quite small and usually containing marrow. These **pneumatic cells** extend far beyond the mastoid. Some may reach the floor of the Eustachian
canal; others the jugular portion of the occipital bone; others the roof of the external auditory canal, and some pass up toward the squamous portion. Occasionally they are entirely absent, and the mastoid is solid throughout. In addition to these pneumatic cells may be seen a large, irregular cavity (Figs. 48 and 49), situated at the upper and front part of the section. It is called the mastoid or tympanic antrum (antrum tympanicum), and must be distinguished from the mastoid cells, though it communicates with them. The mastoid cells are not developed until after puberty, but the mastoid antrum is almost as large at birth as it is in the adult.

It is filled with air, and is lined with a prolongation of the mucous membrane of the tympanum, which extends into it through an opening, by which it communicates with the cavity of the tympanum. The mastoid antrum is bounded above by a thin plate of bone, the tegmen tympani, which separates it from the middle fossa of the base of the skull on the anterior surface of the petrous portion of the temporal bone; below by the mastoid process; externally by the squamous portion of the bone just below the supramastoid crest; and internally by the external semicircular canal of the internal ear, which projects into its cavity. The opening by which it communicates with the tympanum is situated at the superior internal angle of the posterior wall of that cavity; it is a triangular opening into that portion of the tympanic cavity which is known as the tympanic attic or epitympanic recess or space (aditus ad antrum)—that is to say, that portion of the tympanum which is above the level of the membrana tympani.

In consequence of the communication which exists between the tympanum and mastoid cells, inflammation of the lining membrane of the former cavity may easily travel backward to that of the antrum, leading to caries and necrosis of their walls and the risk of transference of the inflammation to the lateral sinus or encephalon.

1 Dr. D. Kerfoot Shute, in Reference Handbook of the Medical Sciences.
Borders. Superior Border.—The superior border of the mastoid portion is broad and rough, its serrated edge sloping outward, for articulation with the posterior inferior angle of the parietal bone.

Posterior Border.—The posterior border, also, uneven and serrated, articulates with the inferior border of the occipital bone between its lateral angle and jugular process.

The Petrous Portion of the Temporal Bone (Pars Petrosa [Pyramis]) (Fig. 47).

The petrous portion (πετρος, a stone), so named from its extreme density and hardness, is a pyramidal process of bone wedged in at the base of the skull between the sphenoid and occipital bones. Its direction from without is inward, forward, and a little downward. It presents for examination a base, an apex, three surfaces, and three borders, and contains, in its interior, the essential parts of the organ of hearing.

Base.—The base is applied against the internal surface of the squamous and mastoid portions, its upper half being concealed; but its lower half is exposed by the divergence of those two portions of the bone, which brings into view the oval, expanded orifice of a canal leading into the tympanum, the meatus auditorius externus (meatus acusticus externus). The curved tympanic plate or part (pars tympanica) forms the anterior wall, the floor, and a part of the posterior wall of this meatus, while the squamous portion of the temporal completes it above and behind. The entrance to the meatus is bounded throughout the greater part of its circumference by the auditory process, which is the name applied to the free rough margin of the tympanic plate, and which gives attachment to the cartilaginous portion of the meatus. Superiorly the entrance to the meatus is limited by the posterior root of the zygoma. At the upper and posterior portion of the bony meatus is a spine of bone known as the suprameatal spine or spine of Henle (spina suprameatum), which is a valuable surgical landmark. In most skulls it is distinctly marked.

Apex (apex pyramidis).—The apex of the petrous portion, rough and uneven, is received into the angular interval between the posterior border of the greater wing of the sphenoid and the basilar process of the occipital; it presents the anterior or internal orifice of the carotid canal (foramen caroticum internum), and forms the posterior and external boundary of the foramen lacerum medium.

Surfaces. Anterior Surface (facies anterior pyramidis).—The anterior surface of the petrous portion (Fig. 47) forms the posterior part of the middle fossa of the skull. This surface is continuous with the squamous portion, to which it is united by a suture, the petro-squamous suture, the remains of which are distinct even at a late period of life. It presents six points for examination: (1) An eminence (eminentia arcuata) near the centre, which indicates the situation of the superior semicircular canal. (2) In front and a little to the outer side of this eminence a depression indicating the position of the tympanum; here the layer of bone which separates the tympanum from the cranial cavity is extremely thin, and is known as the tegmen tympani. (3) A shallow groove, sometimes double, leading outward and backward to an oblique opening, the hiatus Fallopii (hiatus canalis facialis), for the passage of the greater petrosal nerve and the petrosal branch of the middle meningeal artery. (4) A smaller opening (apertura superior canaliculi tympanicii), occasionally seen external to the latter, for the passage of the smaller petrosal nerve. (5) Near the apex of the bone, the termination of the carotid canal, the internal carotid foramen (foramen caroticum internum), the wall of which in this situation is deficient in front. (6) Above the canal a shallow depression, the trigeminal depression (impressio trigemini), for the reception of the Gasserian ganglion.
Posterior Surface (facies posterior pyramidis).—The posterior surface forms the front part of the posterior fossa of the skull, and is continuous with the inner surface of the mastoid portion of the bone. It presents three points for examination: 1. About its centre, a large orifice, the meatus auditoreus internus (meatus acusticus internus), whose size varies considerably; its margins are smooth and rounded, and it leads into a short canal, about four lines in length, which runs directly outward and is closed by a vertical plate, the lamina cribrosa, which is divided by a horizontal crest, the falciform crest (crista falciformis), into two unequal portions (Fig. 50). Each portion is subdivided by a little vertical crest into two parts, named, respectively, anterior and posterior. The lower portion presents three sets of foramina: one group just below the posterior part of the crest, the area cribrosa media, consisting of a number of small openings for the nerves to the sacculle; below and posterior to this, the foramen singulare, or opening for the nerve to the posterior semicircular canal; in front and below the first, the tractus spiralis foraminosus, consisting of a number of small, spirally arranged openings which terminate in the canalis centralis cochleae and transmit the nerve to the cochlea; the upper portion, that above the crista, presents behind a series of small openings the area cribrosa superior, for the passage of filaments to the utricle and superior and external semicircular canal, and, in front, one large opening, the commencement of the aquaeductus Fallopii (canalis facialis), for the passage of the facial nerve. 2. Behind the meatus auditorius, a small slit (apertura externa aquaeductus vestibuli), almost hidden by a thin plate of bone, leading to a canal, the aquaeductus vestibuli, which transmits the ductus endolympaticus together with a small artery and vein. 3. In the interval between these two openings, but above them, is an angular depression (fossa subarcuata) which lodges a process of the dura, and transmits a small vein into the cancellous tissue of the bone. In the child this depression is represented by a large fossa, the floccular fossa, which extends backward as a blind tunnel under the superior semicircular canal.

Inferior Surface (facies inferior pyramidis).—The inferior or basilar surface (Fig. 51) is rough and irregular, and forms part of the base of the skull. Passing from the apex to the base, this surface presents eleven points for examination: 1. A rough surface, quadrilateral in form, which serves partly for the attachment of the Levator palatii and Tensor tympani muscles. 2. The large, circular aperture of the carotid canal, the external carotid foramen (foramen caroticum externum); the canal ascends at first vertically, and then, making a bend, runs horizontally forward and inward; it transmits the internal carotid artery and the carotid plexus. Within the carotid canal are several openings (canaliculi carotici tympanicii) which transmit tympanic branches of the internal carotid artery and of the carotid plexus. 3. The opening of the aquaeductus cochleae (apertura externa canaliculi cochleae), a small triangular opening, lying on the inner side of the latter, close to the posterior and inner border of the petrous portion; it transmits a vein from the cochlea, which joins the internal jugular. 4. Behind these openings a deep depression, the
jugular fossa (fossa jugularis), which varies in depth and size in different skulls; it lodges the lateral sinus, and, with a similar depression on the margin of the jugular process of the occipital bone, forms the foramen lacerum posterius or jugular foramen. 5. A foramen which is the opening of a small canal (canaliculus tympanicus),

for the passage of Jacobson's nerve (the tympanic branch of the glosso-pharyngeal); this foramen is seen in front of the bony ridge dividing the carotid canal from the jugular fossa. 6. A small foramen on the wall of the jugular fossa, for the entrance of the auricular branch of the vagus (Arnold's) nerve. 7. Behind the jugular fossa a smooth, square-shaped facet, the jugular surface; it is covered with cartilage in the recent state, and articulates with the jugular process of the occipital bone. 8. The vaginal process (vagina processus styloidea), a very broad, sheath-like plate of bone, which extends backward from the carotid canal, gives attachment to part of the Tensor palati muscle; this plate divides behind into two laminae, the outer of which is continuous with the tympanic plate, the inner with the jugular process. 9. Between these laminae is the ninth point for examination, the styloid process (processus styloideus), a sharp spine, about an inch in length; it is directed downward, forward, and inward, varies in size and shape, and sometimes consists of several pieces united by cartilage; it affords attachment to three muscles, the Stylo-pharyngeus, Stylo-hyoideus, and Stylo-glossus, and two ligaments, the stylo-hyoid and stylo-maxillary. 10. The stylo-mastoid foramen (foramen stylomastoideum), a rather large orifice, placed between the styloid and mastoid processes; it is the termination of the aqueductus Fallopii, and transmits the facial nerve and stylo-mastoid artery. 11. The auricular fissure (fissura tympanomastoidea), situated between the tympanic plate and mastoid process, for the exit of the auricular branch of the vagus nerve. This fissure is the
external opening of the *canalicul sus mastoideus*, which passes to the aqueduct of Fallopius.

**Borders.** Superior Border (*angulus superior pyramidis*).—The superior, the longest, is grooved for the superior petrosal sinus, and has attached to it the tentorium; at its inner extremity is a semilunar notch, upon which the trigeminal nerve lies.

**Posterior Border** (*angulus posterior pyramidis*).—The posterior border is intermediate in length between the superior and the anterior. Its inner half is marked by a groove, which, when completed by its articulation with the occipital, forms the channel for the inferior petrosal sinus. Its outer half presents a deep excavation, the *jugular fossa* (*fossa jugularis*), which, with a similar notch on the occipital, forms the foramen lacerum posterius. A projecting eminence of bone occasionally stands out from the centre of the notch, and divides the foramen into two parts.

**Anterior Border** (*angulus anterior pyramidis*).—The anterior border is divided into two parts—an outer, joined to the squamous portion by a suture, the remains of which are distinct; an inner, free, articulating with the spinous process of the sphenoid. At the angle of junction of the petrous and squamous portions is seen the opening of the *canalis musculotubarius*. This canal is completely or partially divided into two canals, separated from one another by a thin plate of bone, the *processus cochleariformis* (*septum canalis musculotubarius*); they both lead into the tympanum, the upper one (*semicanalis m. tensoris tympani*) transmitting the Tensor tympani muscle, the lower one (*semicanalis tubae auditivae*) forming the bony part of the Eustachian tube or canal.

**Structure.**—The squamous portion is like that of the other cranial bones: the mastoid portion, cellular; and the petrous portion, dense and hard.

**Development** (Fig. 52).—The temporal bone is developed by ten centres, exclusive of those for the internal ear and the ossicula; viz., one of the squamous portion including the zygoma, one for the tympanic plate, six for the petrous and mastoid parts, and two for the styloid process. Just before the close of foetal life the temporal bone consists of four parts: 1. The *squamoszygomatic* part, ossified in membrane from a single nucleus, which appears at its lower part about the second month. 2. The *tympanic plate*, an imperfect ring, in the concavity of which is a groove, the *sulcus tympanicus*, for the attachment of the circumference of the tympanic membrane. This is also ossified from a single centre, which appears about the third month. 3. The *petro-mastoid* part is developed from six centres, which appear about the fifth or sixth month. Four of these are for the petrous portion, and are placed around the labyrinth, and two for the mastoid (Vrolik). According to Huxley, the centres are more numerous, and are disposed so as to form three portions: (1) including most of the labyrinth, with a part of the petrous and mastoid, he has named *prootic*; (2) the rest of the petrous, the *opisthotic*; and (3) the remainder of the mastoid, the *epiotic*. The petro-mastoid is ossified in cartilage. 4. The *styloid process* is also ossified in cartilage from two centres: one for the base, which appears before birth, and is termed the
tympanohyal; the other, comprising the rest of the process, is named the stylohyal, and does not appear until after birth. Shortly before birth the tympanic plate joins with the squamous. The petrous and mastoid join with the squamous during the first year, and the tympanohyal portion of the styloid process about the same time. The stylohyal does not join the rest of the bone until after puberty, and in some skulls never becomes united. The subsequent changes in this bone are, that the tympanic plate extends outward and backward, so as to form the meatus auditorius. The extension of the tympanic plate, however, does not take place at an equal rate all around the circumference of the ring, but occurs most rapidly on its anterior and posterior portions, and these outgrowths meet and blend, and thus, for a time, there exists in the floor of the meatus a foramen, the foramen of Huschke; this foramen may persist throughout life. The glenoid cavity is at first extremely shallow, and looks outward as well as downward; it becomes deeper and is ultimately directed downward. Its change in direction is accounted for as follows: the part of the squamous temporal which supports it lies at first below the level of the zygoma. As, however, the base of the skull increases in width, this lower part of the squama is directed horizontally inward to contribute to the middle fossa of the skull, and its surfaces therefore come to look upward and downward. The mastoid portion is at first quite flat, and the stylo-mastoid foramen and rudimentary styloid process lie immediately behind the entrance to the auditory meatus. With the development of the air-cells the outer part of the mastoid portion grows downward and forward to form the mastoid process, and the styloid process and stylo-mastoid foramen now come to lie on the under surface. The descent of the foramen is necessarily accompanied by a corresponding lengthening of the aqueduct of Fallopius.

The downward and forward growth of the mastoid process also pushes forward the tympanic plate, so that the portion of it which formed the original floor of the meatus and containing the foramen of Huschke is ultimately found in the anterior wall. With the gradual increase in size of the petrous portion the flaccular fossa or tunnel under the superior semicircular canal becomes filled up and almost obliterated.

Articulations.—With five bones—occipital, parietal, sphenoid, inferior maxillary, and malar.

Attachment of Muscles.—To fifteen: to the squamous portion, the Temporal; to the zygoma, the Masseter; to the mastoid portion, the Occipitofrontalis, Sterno-mastoid, Splenius capitis, Trachelo-mastoid, Digastricus, and Retrahens aurem; to the styloid process, the Stylo-pharyngeus, Stylo-hyoideus, and Stylo-glossus; and to the petrous portion, the Levator palati, Tensor tympani, Tensor palati, and Stapedius.

The Sphenoid Bone (Os Sphenoidale).

The sphenoid bone (σφήν, a wedge) is situated at the anterior part of the base of the skull, articulating with all the other cranial bones, which it binds firmly and solidly together. In its form it somewhat resembles a bat with its wings extended; and is divided into a central portion or body, two greater and two lesser wings extending outward on each side of the body, and two processes—the pterygoid processes—which project from it below.

The Body of the Sphenoid Bone.

The body (corpus) is of large size and hollowed out in its interior so as to form a mere shell of bone. It presents for examination four surfaces—a superior, an inferior, an anterior, and a posterior.
Surfaces. Superior Surface (facies cerebralis) (Fig. 53).—In front is seen a prominent spine, the ethmoidal spine, for articulation with the cribiform plate of the ethmoid; behind this a smooth surface presenting, in the median line, a slight longitudinal eminence, with a depression on each side for lodging the olfactory lobes. This surface is bounded behind by a ridge, which forms the anterior border of a narrow, transverse groove, the optic groove (sulcus chiasmatis), behind which lies the optic chiasm; the groove is continuous on each side with the optic foramen (foramen opticum), for the passage of the optic nerve and ophthalmic artery. Behind the optic groove is a small eminence, olive-like in shape, the olivary process or eminence (tuberculum sellæ); and still more posteriorly, a deep depression, the pituitary fossa, or sella turcica (fossa hypophyseos), which lodges the circular sinus and the pituitary body (hypophysis). This fossa is perforated by numerous foramina, for the transmission of nutrient vessels into the substance of the bone. It is bounded in front by the olivary eminence, and also by two small eminences, one on either side, called the middle clinoid processes (processus clinoidei medii) (xilus, a bed), which are sometimes connected by a spiculum of bone to the anterior clinoid processes. It is bounded behind by a square-shaped plate of bone, the dorsum ephippii or dorsum sellæ, terminating at each superior angle in a tubercle, the posterior clinoid process (processus clinoideus posterior). The size and form of these processes vary considerably in different individuals. They deepen the pituitary fossa, and serve for the attachment of prolongations from the tentorium. The sides of the dorsum ephippii are notched for the passage of the abducent nerves, and below present a sharp process, the petrosal process, which is joined to the apex of the petrous portion of the temporal bone, forming the inner boundary of the middle lacerated foramen. Behind this plate the bone presents a shallow depression, which slopes obliquely backward, and is continuous with the basilar groove of the occipital bone; it is called the clivus, and supports the upper part of the pons. On either side of the body is a broad groove, curved something like the italic letter f; it lodges the internal carotid artery and the cavernous sinus, and is called the carotid or cavernous groove (sulcus caroticus). Along the outer margin of this groove, at its posterior part, is a ridge of bone in the angle between the body and greater wing, called the lingula (lingula sphenoidalis).

Posterior Surface.—The posterior surface, quadrilateral in form, is joined to the basilar process of the occipital bone. During childhood these bones are separated
by a layer of cartilage; but in after-life (between the eighteenth and twenty-fifth years) this becomes ossified, ossification commencing above and extending downward; and the two bones then form one piece.

**Anterior Surface.**—The anterior surface (Fig. 54) presents, in the middle line, a vertical ridge of bone, the ethmoidal or sphenoidal crest (crista sphenoidalis), which articulates in front with the perpendicular plate of the ethmoid, forming part of the septum of the nose. On either side of it are irregular openings leading into the sphenoidal cells or sinuses (sinus sphenoidales). These are two large, irregular cavities hollowed out of the interior of the body of the sphenoid bone, often extending into the pterygoid processes and base of the greater wings of the bone, and separated from one another by a more or less complete perpendicular bony septum (septum sinus sphenoidalis). Occasionally they extend into the basilar process of the occipital nearly as far as the foramen magnum. Their form and size vary considerably; they are seldom symmetrical, and are often partially subdivided by irregular, osseous laminae. One sinus or both sinuses may be absent. The septum is seldom quite vertical, being commonly bent to one or the other side. These sinuses do not exist in very young children, but appear, according to Laurent, in the seventh year, and, according to Tillaux, not until the twentieth year. After once appearing they increase in size as age advances. They are partially closed, in front and below, by two thin, curved plates of bone, the sphenoidal, spongy, or turbinated bones (concha sphenoidales). At the upper part of each is a round opening (apertura sinus sphenoidalis) by which the sinus communicates with the upper and back part of the nose, and occasionally with the posterior ethmoidal cells or sinuses. The lateral margins of this surface present a serrated edge, which articulates with the os planum of the ethmoid, completing the posterior ethmoidal cells; the lower margin, also rough and serrated, articulates with the orbital process of the palate bone, and the upper margin with the orbital plate of the frontal bone.

**Inferior Surface.**—The inferior surface presents, in the middle line, a triangular spine, the rostrum (rostrum sphenoidalis), which is continuous with the sphenoidal crest on the anterior surface, and is received into a deep fissure between the ake

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1 In this figure, both the anterior and inferior surfaces of the body of the sphenoid bone are shown, the bone being held with the pterygoid processes almost horizontal.—Ed. of 10th English Edition.
of the vomer. On each side may be seen a projecting lamina of bone, which runs horizontally inward from near the base of the pterygoid process; these plates, termed the vaginal processes, articulate with the edges of the vomer. Close to the root of the pterygoid process is a groove (sulcus pterygopalatinus), formed into a complete canal when articulated with the sphenoidal process of the palatine bone; it is called the pterygo-palatine canal, and transmits the pterygo-palatine vessels and pharyngeal nerve.

The Greater or Temporal Wings of the Sphenoid Bone (Alæ Magnæ).

The greater wings are two strong processes of bone which arise from the sides of the body, and are curved in a direction upward, outward, and backward, each being prolonged behind into a sharp-pointed extremity, the alar or sphenoidal spine (spina angularis). Each wing presents three surfaces and a circumference.

Surfaces. Superior Surface (facies cerebralis).—The superior or cerebral surface (Fig. 53) forms part of the middle fossa of the skull; it is deeply concave, and presents eminences and depressions for the convolutions of the brain. At its anterior and internal part is seen a circular aperture, the foramen rotundum, for the transmission of the second division of the trigeminal nerve. Behind and external to this is a large, oval foramen, the foramen ovale, for the transmission of the third division of the trigeminal nerve, the small meningeal artery, and sometimes the small petrosal nerve.¹ At the inner side of the foramen ovale a small aperture may occasionally be seen opposite the root of the pterygoid process; it is the foramen Vesali, transmitting a small vein. Lastly, in the posterior angle, near to the spine of the sphenoid, is a short canal, sometimes double, the foramen spinosum; it transmits the middle meningeal artery.

External Surface.—The external surface (Fig. 54) is convex and divided by a transverse ridge, the pterygoid ridge or infratemporal crest (crista infratemporalis), into two portions. The superior or larger, convex from above downward, concave from before backward, enters into the formation of the temporal fossa, and gives attachment to part of the Temporal muscle. The inferior portion, smaller in size and concave, enters into the formation of the zygomatic fossa, and affords attachment to the External pterygoid muscle. It presents, at its posterior part, a sharp-pointed eminence of bone, the spine, to which are connected the internal lateral ligament of the lower jaw and the Tensor palati muscle. The pterygoid ridge, dividing the temporal and zygomatic portions, gives attachment to part of the External pterygoid muscle. At its inner and anterior extremity is a triangular spine of bone, which serves to increase the extent of origin of this muscle.

Anterior Surface (facies orbitalis).—The anterior or orbital surface, smooth and quadrilateral in form, assists in forming the outer wall of the orbit. It is bounded above by a serrated edge, for articulation with the frontal bone; below, by a rounded border which enters into the formation of the sphenomaxillary fissure. Internally, it presents a sharp border, which forms the lower boundary of the sphenoidal fissure, and has projecting from about its centre a little tubercle of bone, which gives origin to one head of the External rectus muscle of the eye; and at its upper part is a notch for the transmission of a recurrent branch of the lachrymal artery; externally it presents a serrated margin for articulation with the malar bone. One or two small foramina may occasionally be seen for the passage of branches of the deep temporal arteries; they are called the external orbital foramina.

Circumference (Fig. 53).—Commencing from behind, that portion of the circumference from the body of the sphenoid to the spine is serrated and articulates by its outer half with the petrous portion of the temporal bone, while the inner half forms the anterior boundary of the foramen lacerum medium, and presents

¹ The small petrosal nerve sometimes passes through a special foramea between the foramen ovale and foramen spinosum.—Ed. of 15th English Edition.
the posterior aperture of the Vidian canal (canalis pterygoideus) for the passage of the Vidian nerve and artery. In front of the spine, the circumference of the great wing presents a serrated edge, bevelled at the expense of the inner table below and of the external above, which articulates with the squamous portion of the temporal bone. At the tip of the great wing a triangular portion is seen, bevelled at the expense of the internal surface, for articulation with the anterior inferior angle of the parietal bone. Internal to this, is a triangular, serrated surface, for articulation with the frontal bone; this surface is continuous internally with the sharp inner edge of the orbital plate, which assists in the formation of the sphenoidal fissure, and externally with the serrated margin for articulation with the malar bone.

The Lesser or Orbital Wings of the Sphenoid Bone (Alae Parvae).

The lesser wings (processes of Ingrassias) are two thin, triangular plates of bone which arise from the upper and lateral parts of the body of the sphenoid, and, projecting transversely outward, terminate in a sharp point (Fig. 53). The superior surface of each is smooth, flat, broader internally than externally, and supports part of the frontal lobe of the brain. The inferior surface forms the back part of the roof of the orbit and the upper boundary of the orbital or sphenoidal fissure or foramen lacerum anterius (fissura orbitalis superior). This fissure is of a triangular form, and leads from the cavity of the cranium into the orbit; it is bounded internally by the body of the sphenoid—above, by the lesser wing; below, by the internal margin of the orbital surface of the great wing—and is converted into a foramen by the articulation of this bone with the frontal. It transmits the third, the fourth, the three branches of the ophthalmic division of the trigeminal, the abducent nerve, some filaments from the cavernous plexus of the sympathetic, the orbital branch of the middle meningeal artery, a recurrent branch from the lachrymal artery to the dura and the ophthalmic vein. The anterior border of the lesser wing is serrated for articulation with the frontal bone; the posterior border, smooth and rounded, is received into the fissure of Sylvius of the brain. Each inner extremity of this border forms an anterior clinoid process (processus clinoides anterior). The lesser wing is connected to the side of the body by two roots, the upper thin and flat, the lower thicker, obliquely directed, and presenting on its outer side, near its junction with the body, a small tubercle, for the attachment of the common tendon of origin of three of the muscles of the eye. Between the two roots is the optic foramen (foramen opticum), for the transmission of the optic nerve and ophthalmic artery.

The Pterygoid Processes of the Sphenoid Bone (Processus Pterygoidei).

The pterygoid processes (πτέρυγες, a wing; είδος, likeness), one on each side, descend perpendicularly from the point where the body and greater wing unite (Fig. 55). Each process consists of an external and an internal lamina or plate, which are joined together by their anterior borders above, but are separated below, leaving an angular cleft, the pterygoid notch or fissure (fissura pterygoidea), in which the pterygoid process or tuberosity of the palate bone is received. The two plates diverge from each other from their line of connection in front, so as to form a V-shaped fossa, the pterygoid fossa (fossa pterygoidea). The external pterygoid plate (lamina lateralis processus pterygoidei) is broad and thin, turned a little outward, and, by its outer surface, forms part of the inner wall of the zygomatic fossa, giving attachment to the External pterygoid; its inner surface forms part of the pterygoid fossa, and gives attachment to the Internal pterygoid. The internal pterygoid plate (lamina medialis processus pterygoidei) is much narrower and longer, curving outward, at its extremity, into a hook-like process of bone, the hamular process.
(hamulus pterygoideus), around which turns the tendon of the Tensor palati muscle. The outer surface of this plate forms part of the pterygoid fossa, the inner surface forming the outer boundary of the posterior aperture of the nares. On the posterior surface of the base of the process, above the pterygoid fossa, is a small, oval, shallow depression, the scaphoid fossa (fossa scaphoidea), from which arises the Tensor palati, and above which is seen the posterior orifice of the Vidian canal (canalis pterygoideus [Vidii]). Below and to the inner side of the Vidian canal, on the posterior surface of the base of the internal plate, is a little prominence, which is known by the name of the pterygoid tubercle. The Superior constrictor of the pharynx is attached to the posterior edge of the internal plate. The anterior surface of the pterygoid process is very broad at its base, and forms the posterior wall of the sphenomaxillary fossa. It supports Meckel’s ganglion. It presents, above, the anterior orifice of the Vidian canal; and below, a rough margin, which articulates with the perpendicular plate of the palate bone.

The Sphenoidal Spongy Bone.

The sphenoidal spongy, turbinal or turbinated bones (the bones of Bertin, concha sphenoidales) are two thin, curved plates of bones, which exist as separate pieces until puberty, and occasionally are not joined to the sphenoid in the adult. They are situated at the anterior and inferior part of the body of the sphenoid, an aperture (apertura sinus sphenoidalis) of variable size being left in the anterior wall of each, through which the sphenoidal sinuses open into the nasal fossae. They are irregular in form and taper to a point behind, being broader and thinner in front. Their upper surface, which looks toward the cavity of the sinus, is concave; their under surface convex. Each bone articulates in front with the ethmoid, externally with the palate; its pointed posterior extremity is placed above the vomer, and is received between the root of the pterygoid process on the outer side and the rostrum of the sphenoid on the inner.¹

Development.—Up to about the eighth month of foetal life the sphenoid bone consists of two distinct parts: a posterior or post-sphenoid part, which comprises the pituitary fossa, the greater wings, and the pterygoid processes; and an anterior or pre-sphenoid part, to which the anterior part of the body and lesser wings belong. It is developed by fourteen centres: eight for the posterior sphenoid division, and six for the anterior sphenoid. The eight centres for the posterior

¹ A small portion of the sphenoidal turbinated bone sometimes enters into the formation of the inner wall of the orbit, between the os planum of the ethmoid in front, the orbital plate of the palate below, and the frontal above. — Cland, Roy. Soc. Trans., 1862.
sphenoid are: one for each greater wing and external pterygoid plate, one for each internal pterygoid plate, two for the posterior part of the body, and one on each side for the lingula. The six for the anterior sphenoid are: one for each lesser wing, two for the anterior part of the body, and one for each sphenoidal turbinated bone.

Post-sphenoid Division.—The first nuclei to appear are those for the greater wings (ali-sphenoids). They make their appearance between the foramen rotundum and foramen ovale about the eighth week, and from them the external pterygoid plates are also formed. Soon after, the nuclei for the posterior part of the body appear, one on either side of the sella turcica, and become blended together about the middle of foetal life. About the fourth month the remaining four centres appear, those for the internal pterygoid plates being ossified in membrane and becoming joined to the external pterygoid plate about the sixth month. The centres for the lingula speedily become joined to the rest of the bone.

Pre-sphenoid Division.—The first nuclei to appear are those for the lesser wings (orbito-sphenoids). They make their appearance about the ninth week, at the outer borders of the optic foramina. A second pair of nuclei appear on the inner side of the foramina shortly after, and, becoming united, form the front part of the body of the bone. The remaining two centres for the sphenoidal turbinated bones make their appearance about the fifth month. At birth they consist of small triangular laminae, and it is not till the third year that they become hollowed out and cone-shaped. About the fourth year they become fused with the lateral masses of the ethmoid, and hence, from an embryological point of view, may be regarded as belonging to the ethmoid.

The pre-sphenoid is united to the body of the post-sphenoid about the eighth month, so that at birth the bone consists of three pieces—viz., the body in the centre, and on each side the great wings with the pterygoid processes. The lesser wings become joined to the body at about the time of birth. At the first year after birth the greater wings and body are united. From the tenth to the twelfth year the spongy bones are partially united to the sphenoid, their junction being complete by the twentieth year. Lastly, the sphenoid joins the occipital from the eighteenth to the twenty-fifth year.

Articulations.—The sphenoid articulates with all the bones of the cranium, and five of the face—the two malar, the two palate, and vomer; the exact extent of articulation with each bone is shown in the accompanying figures.1

Attachment of Muscles.—To eleven pairs: the Temporal, External pterygoid, Internal pterygoid, Superior constrictor, Tensor palati, Levator palpebræ, Oblique oculi superior, Superior rectus, Internal rectus, Inferior rectus, External rectus.

The Ethmoid Bone (Os Ethmoidale).

The ethmoid (ἐθμων, a sieve) is an exceedingly light, spongy bone, of a cubical form, situated at the anterior part of the base of the cranium, between the two orbits at the root of the nose, and contributing to form each of these cavities.

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1 It also sometimes articulates with the tuberosity of the superior maxilla.—Ed. of 15th English Edition.
It consists of three parts: a horizontal plate, which forms part of the base of the cranium; a perpendicular plate, which forms part of the septum nasi; and two lateral masses of cells.

The Horizontal Lamina or Cribriform Plate (lamina cribrosa) (Fig. 57) forms part of the anterior fossa of the base of the skull, and is received into the ethmoid notch of the frontal bone between the two orbital plates. Projecting upward from the middle line of this plate is a thick, smooth, triangular process of bone, the crista galli, so called from its fancied resemblance to a cock's comb. Its base joins the cribiform plate. Its posterior border, long, thin, and slightly curved, serves for the attachment of the falx. Its anterior border, short and thick, articulates with the frontal bone, and presents two small projecting alae (processus alares), which are received into corresponding depressions in the frontal, completing the foramen cecum behind. Its sides are smooth and sometimes bulging; in which case it is found to enclose a small sinus.1 On each side of the crista galli the cribiform plate is narrow and deeply grooved, to support the bulb of the olfactory tract, and is perforated by foramina for the passage of the olfactory nerves. These foramina are arranged in three rows: the innermost, which are the largest and least numerous, are lost in grooves on the upper part of the septum; the foramina of the outer row are continued on to the surface of the upper spongy bone. The foramina of the middle row are the smallest; they perforate the bone and transmit nerves to the roof of the nose. At the front part of the cribiform plate, on each

1 Sir George Humphry states that the crista galli is commonly inclined to one side, usually the opposite to that toward which the lower part of the perpendicular plate is bent.—The Human Skeleton, 1858, p. 277.
side of the crista galli, is a small fissure, which transmits the nasal branch of the ophthalmic nerve; and at its posterior part a triangular notch, which receives the ethmoidal spine of the sphenoid.

The **Vertical or Perpendicular Lamina or Plate** (lamina perpendicularis or mesethmoid) (Fig. 60) is a thin, flattened lamella of bone, which descends from the under surface of the cribriform plate, and assists in forming the septum of the nose. It is much thinner in the middle than at the circumference, and is generally deflected a little to one side. Its anterior border articulates with the nasal spine of the frontal bone and crest of the nasal bones. Its posterior border, divided into two parts, articulates by its upper half with the sphenoidal crest of the sphenoid, by its lower half with the vomer. The inferior border serves for the attachment of the triangular cartilage of the nose. On each side of the perpendicular plate numerous grooves and canals are seen, leading from the foramina on the cribriform plate; they lodge filaments of the olfactory nerves.

The **Lateral Mass or Labyrinth** (labyrinthus ethmoidalis) of the ethmoid consists of a number of thin-walled cellular cavities, the **ethmoidal cells** (cellulae ethmoidales) interposed between two vertical plates of bone, the outer one of which forms part of the orbit, and the inner one part of the nasal fossa of the corresponding side. There are two lateral masses, one on each side. The ethmoidal cells are not present at birth, but appear during the fifth year. In the disarticulated bone many of these cells appear to be broken; but when the bones are articulated they are closed in at every part, except where they open into the nasal fossa. The **upper surface** of each lateral mass presents a number of apparently half-broken cellular spaces; these are closed in, when articulated, by the edges of the ethmoidal notch of the frontal bone. Crossing this surface are two grooves on each side, converted into canals by articulation with the frontal; they are the **anterior** and **posterior ethmoidal canals** (canalis ethmoidale anterius and posterius), and open on the inner wall of the orbit. The **posterior surface** also presents large, irregular cellular cavities, which are closed in by articulation with the sphenoidal turbinated bones and the orbital process of the palate. The cells at the anterior surface are completed by the lachrymal bone and nasal process of the superior maxillary, and those below also by the superior maxillary. The **outer surface** of each lateral mass is formed of a thin, smooth, oblong plate of bone, called the **os planum** (lamina papyracea); it forms part of the inner wall of the orbit, and articulates, above, with the orbital plate of the frontal; below, with the superior maxillary; in front, with the lachrymal; and behind, with the sphenoid and orbital process of the palate.

From the **inferior part** of each lateral mass, immediately beneath the os planum, there projects downward and backward an irregular lamina of bone, called the **unciform process** (processus uncinatus), from its hook-like form; it serves to close in the upper part of the orifice of the antrum, and articulates with the ethmoidal
process of the inferior turbinated bone. It is often broken in disarticulating the bones.

The inner surface of each lateral mass forms part of the outer wall of the nasal fossa of the corresponding side. It is formed of a thin lamella of bone, which descends from the under surface of the cribriform plate, and terminates below in a free, convoluted margin, the middle turbinated or the inferior ethmoidal turbinate bone (concha nasalis media). The middle turbinated bone may contain a cell or cells, which are really ethmoidal cells. Howard A. Lothrop studied 1000 specimens, and found cells in 9 per cent. of them. He never found cells in children. As a rule, a turbinate cell communicates with a posterior ethmoidal cell, but may join an anterior ethmoidal cell. The cells may open into the superior meatus or into the middle meatus. The whole of this surface is rough and marked above by numerous grooves, which run nearly vertically downward from the cribriform plate; they lodge branches of the olfactory nerve, which are distributed on the mucous membrane covering the bone. The back part of this surface is subdivided by a narrow oblique fissure, the superior meatus of the nose (meatus nasi superior), bounded above by a thin, curved plate of bone, the superior turbinated bone (concha nasalis superior). By means of an orifice at the upper part of this fissure the posterior ethmoidal cells open into the superior meatus. Below, and in front of the superior meatus, is seen the convex surface of the middle turbinated bone. It extends along the whole length of the inner surface of each lateral mass; its lower margin is free and thick, and its concavity, directed outward, assists in forming the middle meatus. It is by a large orifice at the upper and front part of the middle meatus that the anterior ethmoidal cells, and through them the frontal sinuses, communicate with the nose by means of a funnel-shaped canal, the infundibulum (infundibulum ethmoidale). The cellular cavities of each lateral mass, thus walled in by the os planum on the outer side and by the other bones already mentioned, are divided by a thin transverse bony partition into two sets, which do not communicate with each other; they are termed the anterior and posterior ethmoidal cells or sinuses. The former, more numerous, communicate with the frontal sinuses above and the middle meatus below by means of a long, flexuous canal, the infundibulum; the posterior, less numerous, open into the superior meatus and communicate (occasionally) with the sphenoidal sinuses. In some cases the ethmoidal sinuses communicate with the maxillary sinus. In some cases the os planum never develops, and the ethmoidal sinuses are separated from the orbit merely by membrane.

Development.—By three centres: one for the perpendicular lamella, and one for each lateral mass. The lateral masses are first developed, ossific granules making their appearance in the os planum between the fourth and fifth months of foetal life, and extending into the spongy bones. At birth the bone consists of the two lateral masses, which are small and ill-developed. During the first year after birth the perpendicular plate and crista galli begin to ossify, from a single nucleus, and become joined to the lateral masses about the beginning of the second year. The cribriform plate is ossified partly from the perpendicular plate and partly from the lateral masses. The formation of the ethmoidal cells, which completes the bone, does not commence until the end of the fourth year.

\(^1\) Annals of Surgery, May, 1903.
Articulations.—With fifteen bones: the sphenoid, two sphenoidal turbinated, the frontal, and eleven of the face—the two nasal, two superior maxillary, two lachrymal, two palate, two inferior turbinated, and the vomer. No muscles are attached to this bone.

DEVELOPMENT OF THE CRANIUM.

The cerebral vesicles became enclosed by an envelope of membrane derived from the embryonic connective tissue about the head end of the chorda. This sac from the mesoderm is converted into fibrous tissue, and is known as the membranous cranium. In adult life the dura mater represents the membranous cranium.

In mammals the base and part of the sides of the membranous cranium become cartilaginous, but the roof and the remaining part of the sides remain membranous. Ossification commences in the roof and begins at a later period in the base. Although ossification begins in the membrane bones before it does in the cartilage bones, and the bones of the roof appear before the bones of the base and make considerable progress in their growth, at birth ossification is more advanced in the base, this portion of the skull forming a solid, immovable groundwork.

The Skull at Different Ages.—The skull at birth is relatively of large size as compared with the body. The cranial cranium is large and the face is small. The fontanelles are open (see below). There are no sutures, but the margins of adjacent bones are widely separated by fibrous tissue which runs from the periosteum to the dura mater. The bones of the vault have no diploë and digital impressions are absent on the cranial surfaces. The parietal eminences and the frontal eminences are very distinct. The orbits and parietal bones are large. If the base is examined it is noted that the mastoid processes are absent, that the lower border of the symphysis of the jaw is on a level with the condyles of the occipital bone, and that the pterygoid plates form “a large angle with the skull base, whereas in the adult the angle is almost a right one.” The lower jaw at birth is shown in Fig. 91.

The development of individual bones is considered under the appropriate headings. At puberty various pneumatich cells develop in bone and alter the form of the head and face.

After the eruption of the first set of teeth the age can be determined with reasonable certainty, and the degree of obliteration of the sutures will also give valuable information. In the vast majority of individuals the metopic suture becomes a mere trace during the fifth or sixth years. Ossification at the junction of the coronal and sagittal sutures and osseous union of the sphenoid and basilar portion of the occipital occur during maturity. The lower jaw of an adult is shown in Fig. 93.

In old age much of the diploë disappears and the bones become thinner and more porous. The alveolar surfaces of the jaws are absorbed if the teeth are lost, and the lower jaw alters its form (Fig. 94).

Sexual Differences.—It is not always possible to tell with certainty a woman’s skull from a man’s, but certain features are of value in reaching a conclusion. Virchow maintained that in non-European races it is very difficult to determine the sex from the skull, though among some savage races the differences may be great. It is always to be borne in mind that a woman’s skull may be of the masculine type and a man’s skull may be of the feminine type. There is no constant characteristic significant of the male or female skull. As a general rule, the female skull is smaller and lighter than the male; the muscular ridges and processes are less distinct, the mastoid processes are of less size, the orbital margins are thin and sharp, the forehead is more vertical and the vertex is more flattened, and the edge of the tympanic plate is “rounder and more tuberculous” (Cunningham). The frontal air sinuses are smaller in women than in men, one reason why the glabella is more prominent in men. The flattening of the vertex in women, previously referred to, causes the top of the head to be at a more relaxed angle with the forehead than in men (Ecker). This characteristic was recognized by the Greek sculptors (Havelock Ellis). The cephalic index, which shows the relation of skull breadth to skull length, is of doubtful value in determining sex.

The Fontanelles (Fonticuli).

Before birth the bones at the vertex and side of the skull are separated from each other by membranous intervals in which bone is deficient. These intervals are principally found at the four angles of the parietal bones. Hence there are six fontanelles. Their formation is due to the wave of ossification being circular and the bones quadrilateral; the ossific matter first meets at the margins of the bones, at the points nearest to their centres of ossification, and vacuities

1 J. Bland Sutton in Henry Morris’ Human Anatomy.
2 Ibid.
3 Man and Woman, by Havelock Ellis.
or spaces are left at the angles, which are called fontanelles, so named from the pulsations of the brain, which are perceptible at the anterior fontanelle, and have been likened to the rising of water in a fountain. The anterior or bregmatic fontanelle (fonticulus frontalis) (Fig. 62), is the largest; it is lozenge-shaped, and corresponds to the junction of the sagittal and coronal sutures; the posterior fontanelle (fonticulus occipitalis) (Fig. 62), of smaller size, is triangular, and is situated at the junction of the sagittal and lambdoid sutures; the remaining ones, the anterolateral and the posterolateral fontanelles (fonticulus sphenoidalis et fonticulus mastoideo) (Fig. 63), are situated at the inferior angles of each parietal bone. The antero-lateral fontanelle is closed in from one to two months after birth; the postero-lateral is not completely closed until the end of the first year. The posterior fontanelle is closed in one or two months after birth; the anterior fontanelle remains open until the middle of the first or the beginning of the second year. Sometimes the anterior fontanelle remains open beyond two years, and is occasionally persistent throughout life. Each space is gradually filled in by an extension of the ossifying process or by the development of a Wormian bone.

**Supernumerary, Wormian, Sutural or Epactal Bones (Ossa Triqueta).**

In addition to the constant centres of ossification of the skull, additional ones are occasionally found in the course of the sutures. These form irregular, isolated bones, interposed between the cranial bones, and have been termed Wormian bones or *ossa triqueta*. They are most frequently found in the course of the lambdoid suture, but occasionally also occupy the situation of the fontanelles, especially the posterior and, more rarely, the anterior. Frequently one is found between the anterior inferior angle of the parietal bone and the greater wing of the sphenoid, the epicteric bone or the pterion ossicle (Fig. 63). They have a great tendency to be symmetrical on the two sides of the skull, and they vary much in size, being in some cases not larger than a pin's head, and confined to the outer table; in other cases so large that one pair of these bones may form the whole of the occipital bone above the superior curved lines, as described

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1 Wormius, a physician of Copenhagen, is said to have given the first detailed description of these bones.
by Béclard and Ward. Their number is generally limited to two or three, but more than a hundred have been found in the skull of an adult hydrocephalic skeleton. In their development, structure, and mode of articulation they resemble the other cranial bones.

**Congenital Fissures and Gaps.**

An arrest in the ossifying process may give rise to deficiencies or gaps; or to fissures, which are of importance in a medico-legal point of view, as they are liable to be mistaken for fractures. The fissures generally extend from the margins toward the centre of the bone, but the gaps may be found in the middle as well as at the edges. In course of time they may become covered with a thin lamina of bone.

**BONES OF THE FACE (OSSA FACIEI).**

The Facial Bones are fourteen in number—viz., the

- Two Nasal.
- Two Superior Maxillæ.
- Two Lachrymal.
- Two Malar.
- Two Palate.
- Two Inferior Turbinated.
- Vomer.
- Inferior Maxilla or Mandible.

"Of these, the upper and lower jaws are the fundamental bones for mastication, and the others are accessories; for the chief function of the facial bones is to provide an apparatus for mastication, while subsidiary functions are to provide for the sense organs (eye, nose, tongue) and a vestibule to the respiratory and vocal organs. Hence the variations in the shape of the face in man and the lower animals depend chiefly on the question of the character of their food and their mode of obtaining it."  

**The Nasal Bones (Ossa Nasalia).**

The nasal (nasus, the nose) are two small oblong bones, varying in size and form in different individuals; they are placed side by side at the middle and upper

![Nasal and lachrymal bones in situ](image)

part of the face, forming, by their junction, "the bridge" of the nose (Fig. 67). Each bone presents for examination two surfaces and four borders.

1 W. W. Keen, American edition, 1887, p. 185.
Surfaces. **Outer Surface.**—The outer surface is concave from above downward, convex from side to side; it is covered by the Pyramidalis and Compressor nasi muscles, and gives attachment at its upper part to a few fibres of the Occipito-frontalis muscle (Theile). It is marked by numerous small arterial furrows, and perforated about its centre by a foramen (foramen nasale), sometimes double, for the transmission of a small vein.

**Inner Surface.**—The inner surface is concave from side to side, convex from above downward; in which direction it is traversed by a longitudinal groove (sometimes a canal), for the passage of a branch of the nasal nerve.

**Borders.** **Superior Border.**—The superior border is narrow, thick, and serrated, for articulation with the nasal notch of the frontal bone.

**Inferior Border.**—The inferior border is broad, thin, sharp, inclined obliquely downward, outward, and backward, and serves for the attachment of the lateral cartilage of the nose. This border presents, about its middle, a notch, through which passes the branch of the nasal nerve above referred to, and is prolonged at its inner extremity into a sharp spine, which, when articulated with the opposite bone, forms the nasal angle.

**External Border.**—The external border is serrated, bevelled at the expense of the internal surface above and of the external below, to articulate with the nasal process of the superior maxillary.

**Internal Border.**—The internal border, thicker above than below, articulates with its fellow of the opposite side, and is prolonged behind into a vertical crest, which forms part of the septum of the nose; this crest articulates above downward with the nasal spine of the frontal above, and the perpendicular plate of the ethmoid, and the triangular septal cartilage of the nose.

**Development.**—By one centre foreach bone, which appears about the eighth week.

**Articulations.**—With four bones: two of the cranium, the frontal and ethmoid, and two of the face, the opposite nasal and the superior maxillary.

**Attachment of Muscles.**—A few fibres of the Occipito-frontalis muscle.

The Superior Maxillary Bones (Upper Jaw Bones or Maxillæ).

The superior maxillæ (maxilla, the jaw bone) are the most important bones of the face from a surgical point of view, on account of the number of diseases to which some of their parts are liable. Their careful examination becomes, therefore, a matter of considerable interest. They are the largest bones of the face, excepting the lower jaw, and form, by their union, the whole of the upper jaw. Each maxilla assists in the formation of three cavities, the roof of the mouth, the floor and outer wall of the nasal fossae, and the floor of the orbit, and also enters into the formation of two fossae, the zygomatic and sphenoid-maxillary, and two fissures, the spheno-maxillary and pterygo-maxillary. The bone presents for examination a body and four processes—malar, nasal, alveolar, and palate.

The Body of the Superior Maxilla (Corpus Maxillæ).

The body is somewhat cuboid and is hollowed out in its interior to form a large cavity, the **antrum of Highmore** (sinus maxillaris). Its surfaces are four—
an external or facial, a posterior or zygomatic, a superior or orbital, and an internal or nasal.

**Surfaces. External Surface (facies anterior).—**The external anterior or facial surface (Fig. 70) is directed forward and outward. It presents at its lower part a series of eminences corresponding to the position of the anterior five alveoli (juga alveolaria). Just above those for the incisor teeth is a depression, the **incisive** or **myrtiform fossa**, which gives origin to the Depressor alae nasi; and below it to the alveolar border is attached a slip of the Orbicularis oris. Above and a little external to it the Compressor nasi arises. More external is another depression, the **canine fossa** (fossa canina), larger and deeper than the incisive fossa, from which it is separated by a vertical ridge, the **canine eminence**, corresponding to the socket of the canine tooth. The canine fossa gives origin to the Levator anguli oris. Above the canine fossa is the **infraorbital foramen** (foramen infraorbitale), the termination of the infraorbital canal; it transmits the infraorbital vessels and nerve. Sometimes the infraorbital canal opens by two, very rarely by three, orifices on the face. Above the infraorbital foramen is the **margin of the orbit** (margo infraorbitalis), which affords partial attachment to the Levator labii superioris proprius. To the sharp margin of bone which bounds this surface in front and separates it from the internal surface is attached the Dilator naris posterior.

**Posterior Surface (facies infratemporalis).—**The posterior or **zygomatic** or **infra-temporal** surface is convex, directed backward and outward, and forms part of the **zygomatic fossa**. It is separated from the facial surface by a strong ridge of bone, the **malar process**, which extends upward from the socket of the second molar tooth. It presents about its centre several apertures leading to canals in the substance of the bone; they are termed the **posterior dental canals** (foramina alveolaria), and transmit the posterior dental vessels and nerves. At the lower part of this surface is a rounded eminence, the **maxillary tuberosity** (tuber maxillare), especially prominent after the growth of the wisdom-tooth, rough on its inner
side for articulation with the tuberosity of the palate bone, and sometimes with the external pterygoid plate. It gives attachment to a few fibres of origin of the Internal pterygoid muscle. Immediately above this is a smooth surface, which forms the anterior boundary of the sphen-maxillary fossa; it presents a groove which, running obliquely downward, is converted into a canal by articulation with the palate bone, forming the posterior palatine or palato-maxillary canal for the descending palatine artery and great palatine nerve.

**Superior Surface (facies orbitalis).—**The superior or orbital surface is thin, smooth, triangular, and forms part of the floor of the orbit. It is bounded internally by an irregular margin which in front presents a notch, the lachrymal notch (incisura lacrimalis), which receives the lachrymal bone; in the middle articulates with the os planum of the ethmoid, and behind with the orbital process of the palate bone; bounded externally by a smooth, rounded edge which enters into the formation of the sphen-maxillary fissure, and which sometimes articulates at its anterior extremity with the orbital plate of the sphenoid; bounded in front by part of the circumference of the orbit, which is continuous on the inner side with the nasal, on the outer side with the malar process. Along the middle line of the orbital surface is a deep groove, the infraorbital groove (sulcus infraorbitalis), for the passage of the infraorbital vessels and nerve. The groove commences at the middle of the outer border of this surface, and, passing forward, terminates in a canal, which subdivides into two branches. One of the canals, the infraorbital canal (canalis infraorbitalis), opens just below the margin of the orbit; the other, which is smaller, runs downward in the substance of the anterior wall of the antrum; it is called the anterior dental canal, and transmits the anterior dental vessels and nerve to the front teeth of the upper jaw. From the back part of the infraorbital canal a second small canal is sometimes given off, which runs downward in the outer wall of the antrum, and conveys the middle dental nerve to the bicuspide teeth. Occasionally this canal is derived from the anterior dental. At the inner and fore part of the orbital surface, just external to the lachrymal groove for the nasal duct, is a depression which gives origin to the Inferior oblique muscle of the eye.

**Internal Surface.**—The internal surface (Figs. 71 and 81) is unequally divided into two parts by a horizontal projection of bone, the palate process (processus palatinus): the portion above the palate process is known as the nasal surface (facies nasalis). It forms part of the outer wall of the nasal fossa. Below the palate process is the cavity of the mouth. The superior division of the nasal surface presents a large, irregular opening, the maxillary hiatus (hiatus maxillaris), leading into the antrum of Highmore. At the upper border of this aperture are numerous broken cellular cavities, which in the articulated skull are closed in by the ethmoid and lachrymal bones. Below the aperture is a smooth concavity which forms part of the inferior meatus of the nasal fossa, and behind it is a rough surface which articulates with the perpendicular plate of the palate bone, traversed by a groove which, commencing near the middle of the posterior border, runs obliquely downward and forward, and forms, when completed by its articulation with the palate bone, the posterior palatine or palato-maxillary canal. In front of the opening of the antrum is a deep groove, converted into a canal (canalis nasolacrimalis) by the lachrymal and inferior turbinateated bones. The groove is called the lachrymal groove (sulcus lacrimalis), and lodges the nasal duct. More anteriorly is a well-marked rough ridge, the inferior turbinateated crest (crista conchalis), for articulation with the inferior turbinateated bone. The shallow concavity above this ridge forms part of the middle meatus of the nose, while that below it forms part of the inferior meatus. The portion of this surface below the palate process is concave, rough, and uneven, and perforated by numerous small foramina for the passage of nutrient vessels. It enters into the formation of the roof of the mouth.
The **Antrum of Highmore, Maxillary Antrum, or Maxillary Sinus** (sinus maxillaris), is a pyramidal cavity hollowed out of the body of the maxillary bone. It varies much in size. It is in most cases a large cavity, but in some is very small. The apex of the antrum, directed outward, is formed by the malar process; its base by the outer wall of the nose. Its walls are everywhere exceedingly thin, and correspond to the orbital, facial, and zygomatic surfaces of the body of the bone. The antral floor is, in most persons, on a level with the floor of the nasal fossa, but in some individuals it is on a lower level. Not unusually the inner wall of the antrum will be found to contain depressions or pockets. In rare instances an antral cavity is made into two by a bony septum. Its inner wall or base presents, in the disarticulated bone, a large, irregular aperture (hiatus maxillaris), which communicates with the nasal fossa. The margins of this aperture are thin and ragged, and the aperture itself is much contracted by its articulation with the ethmoid above, the inferior turbinate below, and the palate bone behind.\(^1\) In the articulated skull this cavity communicates with the middle meatus of the nasal cavity, generally by two small apertures left between the above-mentioned bones. In the recent state usually only one small opening exists, near the upper part of the cavity, sufficiently large to admit the end of a probe, the other being closed by the lining membrane of the sinus. That the opening into the nasal fossa does not afford the best drainage is demonstrated, when we note that it is at the highest and not at the lowest point of the antrum. "In rare instances the antrum communicates with the anterior ethmoidal cells, or the orbital and posterior ethmoidal cells and sphenoidal sinuses."\(^2\)

At birth the antrum exists, though in a rudimentary state. It attains its full size from the twelfth to the fourteenth year.

Crossing the cavity of the antrum are often seen several projecting laminae of bone, similar to those seen in the sinuses of the cranium; and on its posterior wall

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1. In some cases, at any rate, the lachrymal bone encroaches slightly on the anterior superior portion of the opening, and assists in forming the inner wall of the antrum.—Ed. of 15th English Edition.

are the posterior dental canals, transmitting the posterior dental vessels and nerves to the teeth. Projecting into the floor are several conical processes, corresponding to the roots of the first and second molar teeth; in some cases the floor is perforated by the teeth in this situation.

It is from the extreme thinness of the walls of this cavity that we are enabled to explain how a tumor growing from the antrum encroaches upon the adjacent parts, pushing up the floor of the orbit, and displacing the eyeball, projecting inward into the nose, protruding forward on to the cheek, and making its way backward into the zygomatic fossa and downward into the mouth.

The Processes of the Superior Maxillæ.

Malar Process (processus zygomaticus).—The malar process is a rough, triangular eminence, situated at the angle of separation of the facial from the zygomatic surface. In front it is concave, forming part of the facial surface; behind it is also concave, and forms part of the zygomatic fossa; above it is rough and serrated for articulation with the malar bone; whilst below a prominent ridge marks the division between the facial and zygomatic surfaces. A small part of the Masseter muscle arises from this process.

Nasal Process (processus frontalis).—The nasal process is a strong, triangular plate of bone, which projects upward, inward, and backward by the side of the nose, forming part of its lateral boundary. Its external surface is concave, smooth, perforated by numerous foramina, and gives attachment to the Levator labii superioris alaeque nasi, the Orbicularis palpebrarum, and Tendo oculi. Its internal surface forms part of the outer wall of the nasal fossae; at its upper part it presents a rough, uneven surface, which articulates with the ethmoid bone, closing in the anterior ethmoidal cells; below this is a transverse ridge, the superior turbinated crest (crista ethmoidalis), for articulation with the middle turbinated bone of the ethmoid, bounded below by a shallow, smooth concavity which forms part of the middle meatus; below this again is the inferior turbinated crest (already described), where the process joins the body of the bone. Its upper border articulates with the frontal bone. The anterior border of the nasal process is thin, directed obliquely downward and forward, and presents a serrated edge for articulation with the nasal bone; its posterior border is thick, and hollowed into a groove, the lachrymal groove (sulcus lacrimalis), for the naso-lachrymal duct: of the two margins of this groove, the inner one articulates with the lachrymal bone; the outer one forms part of the circumference of the orbit. Just where the latter joins the orbital surface is a small tubercle, the lachrymal tubercle; this serves as a guide to the position of the lachrymal sac in the operation for fistula lachrymalis. The lachrymal groove in the articulated skull is converted into a canal (canalis lacrimalis) by the lachrymal; bone and lachrymal process of the inferior turbinated; it is directed downward, and a little backward and outward, is about the diameter of a goose-quill, slightly narrower in the middle than at either extremity, and terminates below in the inferior meatus. It lodges the nasal duct.

Alveolar Process (processus alveolaris).—The alveolar process is the thickest and most spongy part of the bone, broader behind than in front, and excavated into deep cavities for the reception of the teeth (alveoli dentales). These cavities are eight in number, and vary in size and depth according to the teeth they contain. That for the canine tooth is the deepest; those for the molars are the widest, and subdivided into minor cavities by septa; those for the incisors are single, but deep and narrow. The limbus alveolaris is the broad inferior margin of the alveolar process. On the anterior surface are five projections correspond
ing to the five anterior alveoli. They are called *juga alveolaria*. The cavities for the teeth are separated by *septa interalveolaria*. The Buccinator muscle arises from the outer surface of this process as far forward as the first molar tooth.

**Palate Process (processus palatinus).—**The palate process, thick and strong, projects horizontally inward from the inner surface of the bone. It is much thicker in front than behind, and forms a considerable part of the floor of the nostril and the roof of the mouth. Its **inferior surface** (Fig. 72) is concave, rough and uneven, contains numerous little cavities for the glands of the mucous membrane, and forms part of the roof of the mouth. This surface is perforated by numerous foramina for the passage of the nutrient vessels, channelled at the back part of its alveolar border by a longitudinal groove, sometimes a canal, for the transmission of the posterior palatine vessels, and the great posterior palatine nerve from Meckel's ganglion, and presents little depressions for the lodgement of the palatine glands. When the two superior maxillary bones are articulated together, a large orifice may be seen in the middle line, immediately behind the incisor teeth. This is the **anterior palatine fossa** (*foramen incisivum*). On examining the bottom of this fossa four canals are seen: two branch off laterally to the right and left nasal fossae, and two, one in front and one behind, lie in the middle line. The former pair of these openings are named the **incisor foramina** or **foramina of Stenson**; they are the openings of the forking **incisor canal** (*canalis incisivus*), through which pass the anterior or terminal branches of the descending or posterior palatine arteries, which ascend from the mouth to the nasal fossae, and they contain the remains of Jacobson's organ. The canals in the middle line are termed the **foramina of Scarpa**, and transmit the naso-palatine nerves, the left passing through the anterior, and the right through the posterior, canal. Occasionally in adults' skulls, often in children’s skulls, on the palatal surface of the process a delicate linear suture may sometimes be seen extending from the anterior palatine fossa to the interval between the lateral incisor and the canine tooth. This marks out the **inter-maxillary** or **pre-maxillary bones** or the **incisive bone** (*os incisivum*) on each side. It is the portion of the upper jaw which is in front of the anterior palatine foramen, and which in some animals exists permanently as a separate piece. It includes the whole thickness of the alveolus, the corresponding part of the floor of the nose, and the anterior nasal spine, and contains the sockets of the incisor teeth. The pre-maxillary bone has a separate centre of ossification and develops in association with the vertical plate of the ethmoid and the vomer. The incisive bones, which are always present in the foetus, usually join the rest of the bone
early in development, more or less well-marked sutures (sutura incisiva) indicating the lines of union. In double hare-lip the incisive bones covered by the median part of the lip are frequently not joined to the palate processes of the superior maxillary bones, but are fixed to the nasal septum. Albrecht maintains that instead of two intermaxillary segments or incisive bones, each carrying two incisor teeth, there are originally four, each carrying the rudiment of one tooth and each of a triangular shape, the apices approaching at the anterior palatine canal. The segments are separated by five sutures. The maxilla is called the exo-gnathion, each mesial segment is called an endo-gnathion, and each lateral segment a meso-gnathion. In hare-lip the cleft may be purely in the soft parts, but may pass into the nostril, the alveolar portion of the maxilla, or through the palate bone (cleft palate). In hare-lip with cleft palate (alveolar hare-lip) Kölliker believes that the cleft is between the maxilla and the intermaxillary bone; that is, between the exo-gnathion and the meso-gnathion. Albrecht is of the opinion that the cleft is between the endo-gnathion and the meso-gnathion. In some cases of double hare-lip the pre-maxillary segment contains the germs of four incisors, and in such a case the cleft must be between the exo-gnathion and the meso-gnathion. In other cases it contains but two, and in such a case the cleft must be as indicated by Albrecht, as Fergusson’s explanation is not in accordance with our knowledge of development. Fergusson believed that if the germs of four incisors are not present the missing ones were lost in the gap. The upper surface of the palate process is concave from side to side, smooth, and forms part of the floor of the nose. It presents the upper orifices of the foramina of Stenson and Scarpa, the former being on each side of the middle line, the latter being situated in the intermaxillary suture, and therefore not visible unless the two bones are placed in apposition. The outer border of the palate process is incorporated with the rest of the bone. The inner border is thicker in front than behind, and is raised above into a ridge, the nasal crest (crista nasalis), which, with the corresponding ridge in the opposite bone, forms a groove for the reception of the vomer. In front this crest rises to a considerable height, and this portion is named the incisor crest. The anterior margin is bounded by the thin, concave border of the opening of the nose, prolonged forward internally into a sharp process, forming, with a similar process of the opposite bone, the anterior nasal spine (spina nasalis anterior). The posterior border is serrated for articulation with the horizontal plate of the palate bone.
Development.—This bone commences to ossify at a very early period, and ossification proceeds in it with great rapidity, so that it is difficult to ascertain with certainty its precise number of centres. It appears, however, probable that it is ossified from four centres, which are deposited in membrane. 1. One which forms that portion of the body of the bone which lies internal to the infraorbital canal, including the floor of the orbit, the outer wall of the nasal fossa, and the nasal process. 2. A second which gives origin to that portion of the bone which lies external to the infraorbital canal and the malar process. 3. A third from which is developed the palatine process posterior to Stenson’s canal and the adjoining part of the nasal wall. 4. And a fourth for the front part of the alveolus which carries the incisor teeth and corresponds to the pre-maxillary bone of the lower animals. These centres appear about the eighth week, and by the tenth week the three first-named centres have become fused together and the bone consists of two portions, one the maxilla proper, and the other the pre-maxillary portion. The suture between these two portions on the palate persists till middle life, but is not to be seen on the facial surface. This is believed by Callender to be due to the fact that the front wall of the sockets of the incisive teeth is not formed by the pre-maxillary bone, but by an outgrowth from the facial part of the superior maxilla. The antrum appears as a shallow groove on the inner surface of the bone at an earlier period than any of the other nasal sinuses, its development commencing about the fourth month of fetal life. The sockets for the teeth are formed by the growing downward of two plates from the dental groove, which subsequently becomes divided by partitions jetting across from the one to the other. If the two palatal processes fail to unite partially or completely, a partial or complete cleft palate results.

Articulations.—With three bones: two of the cranial, the frontal and ethmoid, and seven of the face—viz., the nasal, malar, lachrymal, inferior turbinate, palate, vomer, and its fellow of the opposite side. Sometimes it articulates with the orbital plate of the sphenoid, and sometimes with its external pterygoid plate.

Attachment of Muscles.—To twelve: the Orbicularis palpebrarum, Obliquus oculi inferior, Levator labii superioris alaeque nasi, Levator labii superioris proprius, Levator anguli oris, Compressor nasi, Depressor alae nasi, Dilator naris posterior, Masseter, Buccinator, Internal pterygoid, and Orbicularis oris.

Changes Produced in the Upper Jaw by Age.

At birth and during infancy the diameter of the bone is greater in an antero-posterior than in a vertical direction. Its nasal process is long, its orbital surface large, and its tuberosity well marked. In the adult the vertical diameter is the greater, owing to the development of the alveolar process and the increase in size of the antrum. In old age the bone approaches again in character to the infantile condition: its height is diminished, and after the loss of the teeth the alveolar process is absorbed, and the lower part of the bone contracted and diminished in thickness.

The Lachrymal Bone (Os Lacrimale).

The lachrymal (lachryma, a tear) is the smallest and most fragile bone of the face. There are two lachrymal bones. They are situated at the front part of the inner wall of the orbit (Fig. 67), and resemble somewhat in form, thinness,
and size a finger-nail; hence they are termed the ossa unguis. Each bone presents for examination two surfaces and four borders.

**Surfaces. External Surface.**—The external or orbital surface (Fig. 77) is divided by a vertical ridge, the lacrimal crest (crista lacrimalis posterior), into two parts. The portion of bone in front of this ridge, the lacrimal sulcus (sulcus lacrimalis), presents a smooth, concave, longitudinal groove, the free margin of which unite with the nasal process of the superior maxillary bone, completing the lacrimal groove. The upper part of this groove (fossa sacci lacrimalis) lodges the lacrimal sac; the lower part (sulcus lacrimalis) lodges the nasal duct. The portion of bone behind the ridge is smooth, slightly concave, and forms part of the inner wall of the orbit. The ridge, with a part of the orbital surface immediately behind it, affords attachment to the Tensor tarsi muscle: it terminates below in a small, hook-like projection, the hamular process (hamulus lacrimalis), which articulates with the lacrimal tubercle of the superior maxillary bone, and completes the upper orifice of the lacrimal groove. It sometimes exists as a separate piece, which is then called the lesser lacrimal bone.

**Internal Surface.**—The internal or nasal surface presents a depressed furrow, corresponding to the ridge on its outer surface. The surface of bone in front of this forms part of the middle meatus, and that behind it articulates with the ethmoid bone, filling in the anterior ethmoidal cells.

**Borders.**—Of the four borders, the anterior is the longest, and articulates with the nasal process of the superior maxillary bone. The posterior, thin and uneven, articulates with the os planum of the ethmoid. The superior, the shortest and thickest, articulates with the internal angular process of the frontal bone. The inferior is divided by the lower edge of the vertical crest into two parts; the posterior part articulates with the orbital plate of the superior maxillary bone; the anterior portion is prolonged downward into a pointed process, which articulates with the lacrimal process of the inferior turbinated bone and assists in the formation of the lacrimal groove.

**Development.**—By a single centre, which makes its appearance soon after ossification of the vertebral has commenced.

**Articulations.**—With four bones: two of the cranium, the frontal and ethmoid, and two of the face, the superior maxillary and the inferior turbinated.

**Attachment of Muscles.**—To one muscle, the Tensor tarsi.

**The Malar Bone (Os Zygomaticum).**

The name malar is derived from mala, the cheek. The malar or yoke bone is also called the cheek bone. There are two malar bones. Each is a small, quadrangular bone, situated at the upper and outer part of the face. They form the prominence of the cheek, part of the outer wall and floor of the orbit, and part of the temporal and zygomatic fossae (Fig. 78). Each bone presents for examination an external and an internal surface; four processes, the frontal, orbital, maxillary, and zygomatic processes; and four borders.

**Surfaces. External or Malar Surface (facies malaris).**—The external surface (Fig. 79) is smooth, convex, perforated near its centre by a small aperture, the malar foramen (foramen zygomaticofaciale), for the passage of nerves and vessels from the orbit. The malar surface is covered by the Orbicularis palpebrarum muscle, and affords attachment to the Zygomaticus major and minor muscles.
Internal or Temporal Surface (*facies temporalis*).—The internal surface (Fig. 80), directed backward and inward, is concave, presenting internally a rough, triangular surface, for articulation with the superior maxillary bone; and externally, a smooth concave surface, which above forms the anterior boundary of the temporal fossa, and below, where it is wider, forms part of the zygomatic fossa. This surface presents, a little above its centre, the aperture of a malar canal (*foramen zygomaticotemporale*), and affords attachment to a portion of the Masseter muscle at its lower part.

Processes. Frontal Process (*processus frontosphenoidalis*).—Of the four processes, the frontal is thick and serrated, and articulates with the external angular process of the frontal bone. To its orbital margin is attached the external tarsal ligament.

Orbital Process.—The orbital process is a thick and strong plate, which projects backward from the orbital margin of the bone. Its supero-internal surface (*facies
and forming superior antero-inferior arched, and articulates articular anterior inner edge to ridge; with there are the maxillary and nasal borders.

Attachment. The maxillary bone consists of two parts, an orbital and a malar, which are ossified by separate centres.

Articulations. With four bones: three of the cranium, frontal, sphenoid, and temporal; and one of the face, the superior maxillary.

Attachment of Muscles. To four: the Levator labii superioris proprius, Zygomaticus major and minor, and Masseter.

The Palate Bone (Os Palatinum).

The palate bones (palatum, the palate) are situated at the back part of the nasal fossae: they are wedged in between the superior maxillary bones and the pterygoid processes of the sphenoid (Fig. 81). Each bone assists in the formation of three cavities: the floor and outer wall of the nose, the roof of the mouth, and the floor of the orbit, and enters into the formation of two fossae, the spheno-maxillary (fossa pterygo-palatina) and pterygoid fossae (fossa pterygoidea); and one fissure, the spheno-maxillary fissure (fissura orbitalis inferior). In form the palate
bone somewhat resembles the letter L, and may be divided into an inferior or horizontal plate and a superior or vertical plate.

**The Horizontal Plate of the Palate Bone (Pars Horizontalis)** (Figs. 72, 82, 83).

The horizontal plate is of a quadrilateral form, and presents two surfaces and four borders.

**Surfaces.** Superior Surface (*facies nasalis*).—The superior or nasal surface, concave from side to side, forms the back part of the floor of the nasal cavity.

Inferior Surface (*facies palatina*).—The inferior or palatine surface, slightly concave and rough, forms the back part of the hard palate. At its posterior part may be seen a transverse ridge, more or less marked, for the attachment of part of the aponeurosis of the Tensor palati muscle. At the outer extremity of this ridge is a deep groove, the pterygopalatine groove (*sulcus pterygopalatinus*), converted into a canal by its articulation with the tuberosity of the superior maxillary bone, and forming the lower end of the posterior palatine canal (*canalis pterygopalatinus*), the opening of which is called the great palatine foramen (*foramen palatinum majus*). Near this groove the orifices (*foramina palatina minora*) of one or two small canals, accessory posterior palatine canals (*canales palatini*) may be seen. Through the posterior palatine canal emerge the descending palatine artery and the great posterior palatine nerve.

**Borders.**—The anterior border is serrated, bevelled at the expense of its inferior surface, and articulates with the palate process of the superior maxillary bone. The posterior border is concave, free, and serves for the attachment of the soft palate. Its inner extremity is sharp and pointed, and, when united with the opposite bone, forms a projecting process, the posterior nasal or palatine spine (*spina nasalis posterior*), for the attachment of the Azygos uvulae muscle. The external border is united with the lower part of the perpendicular plate almost at right angles. The internal border, the thickest, is serrated for articulation with its fellow of the opposite side; its superior edge is raised into a ridge, which, united with the opposite bone, forms a crest (*crista nasalis*) into which the vomer is received.
The Vertical or Perpendicular Plate of the Palate Bone (Pars Perpendicularis).

The vertical or perpendicular plate (Figs. 82 and 83) is thin, of an oblong form, and directed upward and a little inward. It presents two surfaces, an external and an internal, and four borders.

Surfaces. Internal, Medial, or Nasal Surface (facies nasalis).—The internal surface presents at its lower part a broad, shallow depression, which forms part of the inferior meatus of the nose. Immediately above this is a well-marked horizontal ridge, the inferior turbinated crest (crista conchalis), for articulation with the inferior turbinated bone; above this, a second broad, shallow depression, which forms part of the middle meatus, surmounted above by a horizontal ridge less prominent than the inferior, the superior turbinated crest (crista ethmoidalis), for articulation with the middle turbinated bone. Above the superior turbinated crest is a narrow, horizontal groove, which forms part of the superior meatus.

External, Lateral, or Maxillary Surface (facies maxillaris).—The external surface is rough and irregular throughout the greater part of its extent, for articulation with the inner surface of the superior maxillary bone, its upper and back part being smooth where it enters into the formation of the spheno-maxillary fossa; it is also smooth in front, where it covers the orifice of the antrum. Toward the back part of this surface is a deep groove, the pterygo-palatine groove, converted into a canal, the posterior palatine canal (canalis pterygopalatinus), by its articulation with the superior maxillary bone. It transmits the posterior or descending palatine vessels and the great or anterior palatine nerve from Meckel's ganglion.

Borders. Anterior Border (Fig. 82).—The anterior border is thin, irregular, and presents opposite the inferior turbinated crest a pointed, projecting lamina, the maxillary process (processus maxillaris), which is directed forward, and closes in the lower and back part of the opening of the antrum.

Posterior Border.—The posterior border (Fig. 83) presents a deep groove, the edges of which are serrated for articulation with the pterygoid process of the sphenoid. At the lower part of this border is seen a pyramidal process of bone, the pterygoid process or tuberosity of the palate (processus pyramidalis), which is received into the angular interval between the two pterygoid
plates of the sphenoid at their inferior extremity. This process presents at its back part a median groove and two lateral surfaces. The groove is smooth, and forms part of the pterygoid fossa, affording attachment to the Internal pterygoid muscle; whilst the lateral surfaces are rough and uneven, for articulation with the anterior border of each pterygoid plate. A few fibres of the Superior constrictor arise from the tuberosity of the palate bone. The base of this process, continuous with the horizontal portion of the bone, presents the aperture of the accessory descending palatine canals, through which pass the two smaller descending branches of Meckel’s ganglion; whilst its outer surface is rough for articulation with the inner surface of the body of the superior maxillary bone.

**Superior Border.**—The superior border of the vertical plate presents two well-marked processes separated by an intervening notch or foramen. The anterior, or larger, is called the **orbital process**; the posterior, the **sphenoidal process**.

**Processes. Orbital Process** *(processus orbitalis).*—The orbital process, directed upward and outward, is placed on a higher level than the sphenoidal. It presents five surfaces, which enclose a hollow cellular cavity, and is connected with the perpendicular plate by a narrow, constricted neck. Of these five surfaces, three are articular, two non-articular or free surfaces. The three articular are the anterior or **maxillary surface**, which is directed forward, outward, and downward, is of an oblong form, and rough for articulation with the superior maxillary bone. The posterior or sphenoidal surface is directed backward, upward, and inward. It ordinarily presents a small, open cell, the **orbital sinus** *(sinus orbitalis)*, which communicates with the sphenoidal cells, and the margins of which are serrated for articulation with the vertical part of the sphenoidal turbinated bone. “The orbital may communicate not only with the sphenoidal sinus and the ethmoidal cells, but, in rare instances, with the maxillary antrum.” The **internal or ethmoidal surface** is directed inward, upward, and forward, and articulates with the lateral mass of the ethmoid bone. In some cases the cellular cavity opens on the internal surface of the bone; it then communicates with the posterior ethmoidal cells. More rarely it opens on both surfaces, and then communicates with both the posterior ethmoidal and the sphenoidal cells. The non-articular or free surfaces are the superior or **orbital surface**, directed upward and outward, of triangular form, concave, smooth, and forming the back part of the floor of the orbit; and the **external or zygomatic surface**, directed outward, backward, and downward, of an oblong form, smooth, lying in the sphenomaxillary fossa, and looking into the zygomatic fossa. The latter surface is separated from the orbital by a smooth, rounded border, which enters into the formation of the sphenomaxillary fissure.

**Sphenoidal Process** *(processus sphenoidalis).*—The sphenoidal process of the palate bone is a thin, compressed plate, much smaller than the orbital, and directed upward and inward. It presents three surfaces and two borders. The **superior surface**, the smallest of the three, articulates with the under surface of the sphenoidal turbinated bone; it presents a groove, which contributes to the formation of the pterygo-palatine canal. The **internal surface** is concave, and forms part of the outer wall of the nasal fossa. The **external surface** is divided into an articular and a non-articular portion: the former is rough, for articulation with the inner surface of the internal pterygoid plate of the sphenoid; the latter is smooth, and forms part of the sphenomaxillary fossa. The **anterior border** forms the posterior boundary of the sphenopalatine notch. The **posterior border**, serrated at the expense of the outer table, articulates with the inner surface of the internal pterygoid plate.

The orbital and sphenoidal processes are separated from one another by a deep notch, the **sphenopalatine notch** *(incisura sphenopalatinum)*, which is converted

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1 Dr. D. Kerfoot Shute, in the Reference Handbook of the Medical Sciences.
into a foramen, the spheno-palatine foramen (foramen sphenopalatinum), by articulation with the under surface of the body of the sphenoid bone. Sometimes the two processes are united above, and form between them a complete foramen (Figs. S2 and S3), or the notch is crossed by one or more spicule of bone, so as to form two or more foramina. In the articulated skull this foramen is seen to pass from the spheno-maxillary fossa into the back part of the superior meatus. It transmits the spheno-palatine vessels and the superior nasal and naso-palatine nerves.

**Development.**—From a single centre, which makes its appearance about the second month at the angle of junction of the two plates of the bone. From this point ossification spreads inward to the horizontal plate, downward into the tuberosity, and upward into the vertical plate. In the fetus the horizontal plate is much larger than the vertical, and even after it is fully ossified the whole bone is at first remarkable for its shortness.

**Articulations.**—With six bones: the sphenoid, ethmoid, superior maxillary, inferior turbinated, vomer, and opposite palate.

**Attachment of Muscles.**—To four: the Tensor palati, Azygos uvulae, Internal pterygoid, and Superior constrictor of the pharynx.

**The Inferior Turbinated Bone (Concha Nasalis Inferior).**

The inferior turbinal or turbinated bones (*turbo*, a whirl) are situated one on each side of the outer wall of the nasal fossa. Each inferior turbinated bone (*concha nasalis inferior*) consists of a layer of thin, spongy bone, curled upon itself like a scroll—hence its name “turbinated”—and extends horizontally along the outer wall of the nasal fossa, immediately below the orifice of the antrum (Fig. 84). Each bone presents two surfaces, two borders, and two extremities.
Surfaces.—The internasal surface (Fig. 85) is convex, perforated by numerous apertures, and traversed by longitudinal grooves and canals for the lodgement of arteries and veins. In the recent state it is covered by the lining membrane of the nose. The external surface is concave (Fig. 86), and forms part of the inferior meatus.

Borders.—Its upper border is thin, irregular, and connected to various bones along the outer wall of the nose. It may be divided into three portions: of these, the anterior articulates with the inferior turbinated crest of the superior maxillary bone; the posterior with the inferior turbinated crest of the palate bone; the middle portion of the superior border presents three well-marked processes, which vary much in their size and form. Of these, the anterior and smallest is situated at the junction of the anterior fourth with the posterior three-fourths of the bone: it is small and pointed, and is called the lachrymal process (processus lacrimalis); it articulates by its apex with the anterior inferior angle of the lachrymal bone, and by its margins with the groove on the back of the nasal process of the superior maxillary, and thus assists in forming the canal for the nasal duct. At the junction of the two middle fourths of the bone, but encroaching on its posterior fourth, a broad, thin plate, the ethmoidal process (processus ethmoidalis), ascends to join the unciform process of the ethmoid; from the lower border of this process a thin lamina of bone curves downward and outward, hooking over the lower edge of the orifice of the antrum, which it narrows below: it is called the maxillary process (processus maxillaris), and fixes the bone firmly to the outer wall of the nasal fossa. The inferior border is free and thick, more especially in the middle of the bone. Bone extremities are more or less narrow and pointed, the posterior being the more tapering. If the bone is held so that its outer concave surface is directed backward (i. e., toward the holder), and its superior border, from which the lachrymal and ethmoidal processes project, upward, the lachrymal process will be directed to the side to which the bone belongs. In a study of 1000 specimens, Howard A. Lothrop did not discover cells in the inferior turbinate bone. Development.—By a single centre, which makes its appearance about the middle of foetal life.

Articulations.—With four bones: one of the cranium, the ethmoid, and three of the face, the superior maxillary, lachrymal, and palate.

No muscles are attached to this bone.

The Vomer (Ploughshare Bone).

The vomer (vomer, a ploughshare) is a single bone, situated vertically at the back part of the nasal fossae, forming part of the septum of the nose (Fig. 87). It is thin, somewhat like a ploughshare in form; but it varies in different individuals, being frequently bent to one or the other side; it presents for examination two surfaces and four borders.

1 If the lachrymal process is broken off, as is often the case, the side to which the bone belongs may be known by recollecting that the maxillary process is nearer the back than the front of the bone.—Ed. of 15th English Edition.

2 Annals of Surgery, May, 1903.
Surfaces.—The lateral surfaces are smooth, marked by small furrows for the lodgement of blood-vessels, and by a groove on each side, sometimes a canal, the naso-palatine groove or canal, which runs obliquely downward and forward to the intermaxillary suture; it transmits the naso-palatine nerve.

Borders.—The superior border, the thickest, presents a deep groove, bounded on each side by a horizontal projecting leaf of bone; these leaves are the alæ (alæ vomeris). The groove formed by the alæ receives the rostrum of the sphenoid, while the alæ are overlapped and retained by the vaginal processes, which project from the under surface of the body of the sphenoid at the base of the pterygoid processes. At the front of the groove a fissure is left for the transmission of blood-vessels to the substance of the bone. The inferior border, the longest, is broad and uneven in front, where it articulates with the two superior maxillary bones; thin and sharp behind, where it joins with the palate bones. The upper half of the anterior border usually consists of two laminae of bone, in the groove between which is received the perpendicular plate of the ethmoid; the lower half, also separated into two lamellae, receives between them the lower margin of the septal cartilage of the nose. The posterior border is free, concave, and separates the nasal fossae behind. It is thick and bifid above, thin below.

The surfaces of the vomer are covered by mucous membrane, which is intimately connected with the periosteum, with the intervention of very little, if any,
submucous connective tissue. Hence polypi are rarely found growing from this surface, though they frequently grow from the outer wall of the nasal fossae, where the submucous tissue is abundant.

Development.—The vomer at an early period consists of two laminae, separated by a very considerable interval, and enclosing between them a plate of cartilage, the vomerine cartilage, which is prolonged forward to form the remainder of the septum. Ossification commences in the membrane at the postero-inferior part of this cartilage by two centres, one on each side of the middle line, which extend to form the two laminae. They begin to coalesce at the lower part, but their union is not complete until after puberty.

Articulations.—With six bones: two of the cranium, the sphenoid and ethmoid; and four of the face, the superior maxillary and the two palate bones; and with the cartilage of the septum.

The vomer has no muscles attached to it.

The Maxillary Bone, Inferior Maxilla, Mandible or Lower Jaw (Mandibula).

The mandible, the largest and strongest bone of the face, serves for the reception of the lower teeth. It consists of a curved, horizontal portion, the body, and two perpendicular portions, the rami, which join the back part of the body nearly at right angles.

The Horizontal Portion or Body of the Mandible (Corpus Mandibulae).

The horizontal portion or body (Fig. 89) is convex in its general outline, and curved somewhat like a horseshoe. It presents for examination two surfaces and two borders.

Surfaces. External Surface.—The external surface is convex from side to side, concave from above downward. In the median line is a vertical ridge, the symphysis, which extends from the upper to the lower border of the bone, and indicates the point of junction of the two pieces of which the bone is composed at an early period of life. The lower part of the ridge terminates in a prominent triangular eminence, the mental process or protuberance (protuberantia mentalis). This eminence is rounded below, and often presents a median depression separating two processes, the mental tubercles (tubera mentalia). It forms the chin, a feature peculiar to the human skull. On either side of the symphysis, just below the
cavities for the incisor teeth, is a depression, the **incisive or incisor fossa**, for the attachment of the Levator menti (or Levator labii inferioris); more externally is attached a portion of the Orbicularis oris (accessorii orbicularis inferioris), and, still more externally, a foramen, the **mental foramen** (foramen mentale), for the passage of the mental vessels and nerve. This foramen is placed just below the interval between the two bicuspids teeth. Running outward from the base of the mental process on each side is a ridge, the **external oblique line** (linea obliqua). The ridge is at first nearly horizontal, but afterward inclines upward and backward, and is continuous with the anterior border of the ramus: it affords attachment to the Depressor labii inferioris and Depressor anguli oris; below it the Platysma myoides is attached.

**Internal Surface.**—The internal surface (Fig. 90) is concave from side to side, convex from above downward. In the middle line is an indistinct linear depres-

![Fig. 90.—The mandible. Inner surface. Side view.](image-url)

Fig. 90.—The mandible. Inner surface. Side view.
gland. The external oblique line and the internal or mylo-hyoidean line divide the body of the bone into a superior or alveolar and an inferior or basilar portion.

**Borders.**—The **superior or alveolar portion** of the body (**pars alveolaris**) has above a narrow border which is wider and the margins of which are thicker behind than in front. Its narrow margin is called the **limbus alveolaris**. It is hollowed into numerous cavities (**alveoli dentales**), for the reception of the teeth; these cavities are sixteen in number, and vary in depth and size according to the teeth which they contain. The cavities are separated from one another by **septa interalveolaria**. The **juga alveolaria** are prominences on the outer surface over the three front alveoli. To the outer side of the alveolar border the Buccinator muscle is attached upon the **buccinator crest** (**crista buccinatoria**) as far forward as the first molar tooth. The **inferior or basilar portion** (**basis mandibulae**) is rounded, longer than the superior, and thicker in front than behind; it presents a shallow groove, just where the body joins the ramus, over which the facial artery turns.

**The Perpendicular Portions or Rami of the Mandible (Rami Mandibulæ).**

The perpendicular portions or rami are of a quadrilateral form. Each presents for examination two surfaces, four borders, and two processes.

**Surfaces. External Surface.**—The external surface is flat, marked with ridges, and gives attachment throughout nearly the whole of its extent to the Masseter muscle.

**Internal Surface.**—The internal surface presents about its centre an oblique foramen (**foramen mandibulare**) of the inferior dental canal (**canalis mandibulae**), for the passage of the inferior dental vessels and nerve. The margin of this opening is irregular; it presents in front a prominent ridge, surmounted by a sharp spine, the **lingula** (**lingula mandibulae**), which gives attachment to the internal lateral ligament of the lower jaw, and at its lower and back part a notch leading to a groove, the **mylo-hyoidean groove** (**sulcus mylohyoideus**), which runs obliquely downward to the back part of the submaxillary fossa, and lodges the mylo-hyoid vessels and nerve. Behind the groove is a rough surface, for the insertion of the Internal pterygoid muscle. The **inferior dental canal** runs obliquely downward and forward in the substance of the ramus, and then horizontally forward in the body; it is here placed under the alveoli, with which it communicates by small openings. On arriving at the incisor teeth, it turns back to communicate with the mental foramen, giving off two small canals, which run forward, to be lost in the cancellous tissue of the bone beneath the incisor teeth. This canal, in the posterior two-thirds of the bone, is situated nearer the internal surface of the jaw; and in the anterior third, nearer its external surface. Its walls are composed of compact tissue at either extremity, and of cancellous in the centre. It contains the inferior dental vessels and nerve, from which branches are distributed to the teeth through small apertures at the bases of the alveoli.

**Borders.**—The **lower border** of the ramus is thick, straight, and continuous with the body of the bone. At its junction with the posterior border is the **angle of the jaw** (**angulus mandibulae**). The outer portion of the angle is called the **gonion**. The angle is either inverted or everted, and marked by rough, oblique ridges on each side, for the attachment of the Masseter externally, and the Internal pterygoid internally; the stylo-maxillary ligament is attached to the angle between these muscles. The **anterior border** is thin above, thicker below, and continuous with the external oblique line. The **posterior border** is thick, smooth, rounded, and covered by the parotid gland. The **upper border** of the ramus is thin, and presents two processes, separated by a deep concavity, the **sigmoid notch** (**incisura mandibulae**). Of these processes, the anterior is the **coronoid**, the posterior the **condyloid**.
Coronoid Process (processus coronoides).—The coronoid process is a thin, flattened, triangular eminence of bone, which varies in shape and size in different subjects, and serves chiefly for the attachment of the Temporal muscle. Its external surface is smooth, and affords attachment to the Temporal and Masseter muscles. Its internal surface gives attachment to the Temporal muscle and presents the commencement of a longitudinal ridge, which is continued to the posterior part of the alveolar process. On the outer side of this ridge is a deep groove, continued below on the outer side of the alveolar process; this ridge and part of the groove afford attachment, above, to the Temporal; below, to the Buccinator muscle.

Condyloid Process (processus condyloideus).—The condyloid process, shorter but thicker than the coronoid, consists of two portions: the condyle (capitulum mandibulae), and the constricted portion which supports the condyle, the neck (collum mandibulae). The condyle is of an oblong form, its long axis being transverse, and set obliquely on the neck in such a manner that its outer end is a little more forward and a little higher than its inner. It is convex from before backward and from side to side, the articular surface extending farther on the posterior than on the anterior aspect. At its outer extremity is a small tubercle for the attachment of the external lateral ligament of the temporo-mandibular joint. The neck of the condyle is flattened from before backward, and strengthened by ridges which descend from the fore part and sides of the condyle. Its lateral margins are narrow, the external one giving attachment to part of the external lateral ligament. Its posterior surface is convex; its anterior is hollowed out on its inner side by a depression, the pterygoid depression (fovea pterygoidea), for the attachment of the External pterygoid muscle.

The Sigmoid Notch (incisura mandibulae), separating the two processes, is a deep semilunar depression, crossed by the masseteric vessels and nerve.

Development.—The lower jaw is developed principally from membrane, but partly from cartilage. The process of ossification commences early—earlier than in any other bone except the clavicle. The greater part of the bone is formed from a centre of ossification (dentary), which appears between the fifth and sixth week in the membrane on the outer surface of Meckel's cartilage. A second centre (splenial) appears in the membrane on the inner surface of the cartilage, and from this centre the inner wall of the sockets of the teeth is formed; this terminates above in the lingula. The anterior extremity of Meckel's cartilage becomes ossified, forming the body of the bone on each side of the symphysis. Two supplemental patches of cartilage appear at the condyle and at the angle, in each of which a centre of ossification for these parts appears; the coronoid process is also ossified from a separate centre. At birth the bone consists of two halves, united by a fibrous symphysis, in which ossification takes place during the first year.

Articulation.—With the glenoid (mandibular) fossae of the two temporal bones.

Attachment of Muscles.—To fifteen pairs: to its external surface, commencing at the symphysis, and proceeding backward: Levator menti, Depressor labii inferioris, Depressor anguli oris, Platysma myoides, Buccinator, Masseter; a portion of the Orbicularis oris (Accessori orbicularis inferioris) is also attached to this surface. To its internal surface, commencing at the same point: Genio-hyoglossus, Genio-hyoides, Mylo-hyoides, Digastric, Superior constrictor, Temporal, Internal pterygoid, External pterygoid.

CHANGES PRODUCED IN THE LOWER JAW BY AGE.

The changes which the lower jaw undergoes after birth relate (1) to the alterations effected in the body of the bone by the first and second dentitions, the loss of the teeth in the aged, and the subsequent absorption of the alveoli; (2) to the size and situation of the dental canal; and (3) to the angle at which the ramus joins with the body.
SIDE VIEW OF THE LOWER JAW AT DIFFERENT PERIODS OF LIFE.

At birth (Fig. 91) the bone consists of lateral halves, united by fibrous tissue. The body is a mere shell of bone, containing the sockets of the two incisor, the canine, and the two temporary molar teeth, imperfectly partitioned from one another. The dental canal is of large size, and runs near the lower border of the bone, the mental foramen opening beneath the socket of the first molar. The angle is obtuse (175 degrees), and the condyloid portion nearly in the same horizontal line with the body; the neck of the condyle is short, and bent backward. The coronoid process is of comparatively large size, and situated at right angles with the rest of the bone.

After birth (Fig. 92) the two segments of the bone become joined at the symphysis, from below upward, in the first year; but a trace of separation may be visible in the beginning of the second year near the alveolar margin. The body becomes elongated in its whole length, but more especially behind the mental foramen, to provide space for the three additional teeth developed in this part. The depth of the body becomes greater, owing to increased growth of the alveolar part, to afford room for the fangs of the teeth, and by thickening of the subdental portion, which enables the jaw to withstand the powerful action of the masticatory muscles; but the alveolar portion is the deeper of the two, and, consequently, the chief part of the body lies above the oblique line. The dental canal after the second dentition is situated just above the level of the mylo-hyoid ridge, and the mental foramen occupies the position usual to it in the adult. The angle becomes less obtuse, owing to the separation of the jaws by the teeth. (About the fourth year it is 140 degrees.)

In the adult (Fig. 93) the alveolar and basilar portions of the body are usually of equal depth. The mental foramen opens midway between the upper and lower border of the bone,
and the dental canal runs nearly parallel with the mylo-hyoid line. The ramus is almost vertical in direction, and joins the body nearly at right angles.

In old age (Fig. 94) the bone becomes greatly reduced in size; for with the loss of the teeth the alveolar process is absorbed, and the basilar part of the bone alone remains, consequently, the chief part of the bone is below the oblique line. The dental canal, with the mental foramen opening from it, is close to the alveolar border. The rami are oblique in direction, the angle obtuse, and the neck of the condyle more or less bent backward.

The Sutures.

The bones of the cranium and face are connected to each other by means of sutures. That is, the articulating surfaces or edges of the bones are more or less roughened or uneven, and are closely adapted to each other, a small amount of intervening fibrous tissue, the sutural ligament, fastening them together. The cranial sutures may be divided into three sets: 1. Those at the vertex of the skull. 2. Those at the side of the skull. 3. Those at the base.

The sutures at the vertex of the skull are four: the metopic, the sagittal, the coronal, and the lambdoid.

The Metopic or Frontal Suture (sutura frontalis) is usually noted in adults as a trivial fissure, just above the glabella. At birth the two halves of the frontal bone are separated by the suture. This suture is, as a rule, almost completely or completely closed during the fifth or sixth year, but occasionally it remains intact.

The Interparietal or Sagittal Suture (sutura sagittalis) is formed by the junction of the two parietal bones, and extends from the middle of the frontal bone backward to the superior angle of the occipital. This suture is sometimes perforated, near its posterior extremity, by the parietal foramen; and in front, where it joins the coronal suture, a space is occasionally left which encloses a large Wormian bone.

The Fronto-parietal or Coronal Suture (sutura coronalis) extends transversely across the vertex of the skull, and connects the frontal with the parietal bones. It commences at the extremity of the greater wing of the sphenoid on one side, and terminates at the same point on the opposite side. The dentations of the suture are more marked at the sides than at the summit, and are so constructed that the frontal rests on the parietal above, whilst laterally the frontal supports the parietal.
The Occipito-parietal or Lambdoid Suture (sutura lambdaidea), so called from its resemblance to the Greek letter λ, connects the occipital with the parietal bones. It commences on each side at the mastoid portion of the temporal bone, and inclines upward to the end of the sagittal suture. The dentations of this suture are very deep and distinct, and are often interrupted by several small Wornian bones.

The sutures at the side of the skull extend from the external angular process of the frontal bone to the lower end of the lambdoid suture behind. The anterior portion is formed between the lateral part of the frontal bone above and the malar and great wing of the sphenoid below, forming the fronto-malar suture (sutura zygomaticofrontalis) and fronto-sphenoidal suture (sutura sphenofrontalis). These sutures can also be seen in the orbit, and form part of the so-called transverse facial suture. The posterior portion is formed between the parietal bone above and the great wing of the sphenoid, the squamous and mastoid portions of the temporal bone below, forming the sphenoparietal, squamo-parietal, and masto-parietal sutures.

The sphenoparietal (sutura sphenoparietalis) is very short; it is formed by the tip of the great wing of the sphenoid, which overlaps the anterior inferior angle of the parietal bone.

The squamo-parietal or squamous suture (sutura squamosa) is arched. It is formed by the squamous portion of the temporal bone overlapping the middle division of the lower border of the parietal.

The masto-parietal (sutura parietomastoidea) is a short suture, deeply dentated, formed by the posterior inferior angle of the parietal and the superior border of the mastoid portion of the temporal.

The sutures at the base of the skull are the basilar in the centre, and on each side the petro-occipital, the masto-occipital, the petro-sphenoidal, and the squamosphenoidal.

The Basilar Suture (fissura sphenoopticollis) is formed by the junction of the basilar surface of the occipital bone with the posterior surface of the body of the sphenoid. At an early period of life a thin plate of cartilage exists between these bones, but in the adult they become fused into one (synchondrosis sphenoopticollis). Between the outer extremity of the basilar suture and the termination of the lambdoid an irregular suture exists, which is subdivided into two portions. The inner portion, formed by the union of the petrous part of the temporal with the occipital bone, is termed the petro-occipital fissure (fissura petrooccipitalis). The outer portion, formed by the junction of the mastoid part of the temporal with the occipital, is called the masto-occipital suture (sutura occipitomastoidea). Between the bones forming the petro-occipital suture a thin plate of cartilage exists; in the masto-occipital is occasionally found the opening of the mastoid foramen. Between the outer extremity of the basilar suture and the sphenoparietal an irregular suture may be seen, formed by the union of the sphenoid with the temporal bone. The inner and smaller portion of this suture is termed the petro-sphenoidal fissure (fissura sphenopetrosa); it is formed between the petrous portion of the temporal and the great wing of the sphenoid; the outer portion, of greater length and arched, is formed between the squamous portion of the temporal and the great wing of the sphenoid; it is called the squamosphenoidal suture (sutura sphenosquamosa).

The cranial bones are connected with those of the face, and the facial bones with each other, by numerous sutures, which, though distinctly marked, have received no special names. The only remaining suture deserving especial consideration is the transverse suture. This extends across the upper part of the face, and is formed by the junction of the frontal with the facial bones: it extends from the external angular process of one side to the same point on the opposite side, and connects the frontal with the malar, the sphenoid, the ethmoid, the lachrymal,
the superior maxillary, and the nasal bones on each side (sutura zygomatico-frontalis; the orbital portion of the sutura sphenofrontalis, sutura fronto-ethmoidalis, sutura frontolacrimalis, sutura frontomaxillaris, sutura nasofrontalis).

The sutures remain separate for a considerable period after the complete formation of the skull. It is probable that they serve the purpose of permitting the growth of the bones at their margins, while their peculiar formation, together with the interposition of the sutural ligament between the bones forming them, prevents the dispersion of blows or jars received upon the skull. Humphry remarks, "that, as a general rule, the sutures are first obliterated at the parts in which the ossification of the skull was last completed—viz., in the neighborhood of the fontanelles; and the cranial bones seem in this respect to observe a similar law to that which regulates the union of the epiphyses to the shafts of the long bones." The same author remarks that the time of their disappearance is extremely variable: they are sometimes found well marked in skulls edentulous with age, while in others which have only just reached maturity they can hardly be traced. The obliteration of the sutures takes place sooner on the inner than on the outer surface of the skull. The sagittal and coronal sutures are as a rule the first to become ossified—the process starting near the posterior extremity of the former and the lower ends of the latter.

THE SKULL AS A WHOLE.

The skull, formed by the union of the several cranial and facial bones already described, when considered as a whole is divisible into five regions: a superior region or vertex, an inferior region or base, two lateral regions, and an anterior region, the face.

The Vertex of the Skull.

The superior region, or vertex, presents two surfaces, an external and an internal.

Surfaces. External Surface. (This surface as seen from above is called the norma verticalis.)—The external surface is bounded, in front, by the glabella and supraorbital ridges; behind, by the occipital protuberance and superior curved lines of the occipital bone; laterally, by an imaginary line extending from the outer end of the superior curved line, along the temporal ridge, to the external angular process of the frontal bone. This surface includes the greater part of the vertical portion of the frontal, the greater part of the parietal, and the superior third of the occipital bone; it is smooth, convex, of an elongated oval form, crossed transversely by the coronal suture, and from before backward by the sagittal, which terminates behind in the lambdoid. The point of junction of the coronal and sagittal sutures is named the bregma, and is represented by a line drawn vertically upward from the external auditory meatus, the head being in its normal position. The point of junction of the sagittal and lambdoid sutures is called the lambda, and is about 2½ inches above the external occipital protuberance. From before backward may be seen the frontal eminences and remains of the suture connecting the two lateral halves of the frontal bone; on each side of the sagittal suture are the parietal foramen and parietal eminence, and still more posteriorly the convex surface of the occipital bone. In the neighborhood of the parietal foramen the skull is often flattened, and the name of obelion is sometimes given to that point of the sagittal suture which lies exactly opposite to the parietal foramen.

Internal or Cerebral Surface.—The internal surface is concave, presents depressions for the convolutions of the cerebrum, and numerous furrows for the lodgment of branches of the meningeal arteries. Along the middle line of this
surface is a longitudinal groove, narrow in front, where it commences at the frontal crest, but broader behind, where it lodges the superior longitudinal sinus, and by its margin affords attachment to the falx. On either side of it are several depressions for the arachnoid villi, and at its back part the internal openings of the parietal foramina. This surface is crossed, in front, by the coronal suture; from before backward by the sagittal; behind, by the lambdoid.

**The Base of the Skull (the Skull being without the Mandible).**

The inferior region, or base of the skull, presents two surfaces—an internal or cerebral, and an external or basilar.

**Surfaces. Internal Upper or Cerebral Surface.**—The internal or cerebral surface (Fig. 95) presents three fossae, called the anterior, middle, and posterior fossae of the cranium.

**Anterior Fossa (fossa cranii anterior).**—The anterior fossa is formed by the orbital plates of the frontal, the cribriform plate of the ethmoid, the anterior third of the superior surface of the body, and the upper surface of the lesser wings of the sphenoid bone. It is the most elevated of the three fossae, convex externally where it corresponds to the roof of the orbit, concave in the median line in the situation of the cribriform plate of the ethmoid. It is traversed by three sutures, the ethmo-frontal, ethmo-sphenoidal, and fronto-sphenoidal, and lodges the frontal lobes of the cerebrum. It presents, in the median line, from before backward, the commencement of the groove for the superior longitudinal sinus and the frontal crest for the attachment of the falx; the foramen caecum, an aperture formed between the frontal bone and the crista galli of the ethmoid, which, if pervious, transmits a small vein from the nose to the superior longitudinal sinus; behind the foramen caecum, the crista galli, the posterior margin of which affords attachment to the falx; on either side of the crista galli, the cribriform plate, which supports the olfactory bulb, and presents three rows of foramina for the transmission of its nervous filaments, and in front a slit-like opening for the nasal branch of the ophthalmic division of the trigeminal nerve. On the outer side of each olfactory groove, transmits the anterior ethmoidal vessels and the nasal nerve, which latter runs in a depression along the surface of the ethmoid to the slit-like opening above mentioned; while the posterior ethmoidal foramen opens at the back part of this margin under cover of the projecting lamina of the sphenoid, and transmits the posterior ethmoidal vessels. Farther back in the middle line is the ethmoidal spine, bounded behind by a slight elevation, separating two shallow longitudinal grooves which support the olfactory lobes. Behind this is a transverse sharp ridge, running outward on either side to the anterior margin of the optic foramen, and separating the anterior from the middle fossa of the base of the skull. The anterior fossa presents, laterally, depressions for the convolutions of the brain and grooves for the lodgement of the anterior meningeal arteries.

**Middle Fossa (fossa cranii media).**—The middle fossa, deeper than the preceding, is narrow in the middle line, but becomes wider at the side of the skull. It is bounded in front by the posterior margin of the lesser wing of the sphenoid, the anterior clinoid process, and the ridge forming the anterior margin of the optic groove; behind, by the superior border of the petrous portion of the temporal and the dorsum sellae; externally by the squamous portion of the temporal and the anterior inferior angle of the parietal bone, and greater wing of the sphenoid. It is traversed by four sutures, the squamo-parietal, spheno-parietal, squamo-sphenoidal, and petro-sphenoidal. In the middle line, from before backward, is the optic groove,
behind which lies the **chiasma** (optic commissure); the groove terminates on each side in the **optic foramen**, for the passage of the optic nerve and ophthalmic artery;

behind the optic groove is the **olivary process** and laterally the **anterior clinoid processes**, to which are attached processes of the tentorium. Farther back is the **sella turcica**, a deep depression which lodges the pituitary gland, bounded in front by a
small eminence on either side, the **middle clinoid process**, and behind by a broad, square plate of bone, the *dorsum sellae* or *dorsum ephippii*, surmounted at each superior angle by a tubercle, the **posterior clinoid process**; beneath the latter process is a notch, for the abducent nerve. On each side of the sella turcica is the **cavernous groove**: it is broad, shallow, and curved somewhat like the italic letter *j*; it commences behind at the foramen lacerum medium, and terminates on the inner side of the anterior clinoid process, and presents along its outer margin a ridge of bone. This groove lodges the cavernous sinus, the internal carotid artery, and the nerves of the orbit. The sides of the middle fossa are of considerable depth; they present depressions for the convolutions of the brain and grooves for the branches of the middle meningeal artery; the latter commence on the outer side of the foramen spinosum, and consist of two large branches, an anterior and a posterior; the former passing upward and forward to the anterior inferior angle of the parietal bone, the latter passing upward and backward. The following foramina may also be seen from before backward: Most anteriorly is the **foramen lacerum anterius**, or *sphenoidal fissure* (*fissura orbitalis superior*), formed above by the lesser wing of the sphenoid; below, by the greater wing; internally, by the body of the sphenoid; and sometimes completed externally by the orbital plate of the frontal bone. It transmits the third, the fourth, the three branches of the ophthalmic division of the trigeminal, the abducent nerve, some filaments from the cavernous plexus of the sympathetic, the orbital branch of the middle meningeal artery, a recurrent branch from the lachrymal artery to the dura, and the ophthalmic vein. Behind the inner extremity of the sphenoidal fissure is the **foramen rotundum**, for the passage of the second division of the trigeminal or the superior maxillary nerve; still more posteriorly is seen a small orifice, the **foramen Vesalii**, an opening situated between the foramen rotundum and ovale, a little internal to both; it varies in size in different individuals, and is often absent; when present it transmits a small vein. It opens below into the pterygoid fossa, just at the outer side of the sphenoidal depression. Behind and external to the latter opening is the **foramen ovale**, which transmits the third division of the trigeminal or the inferior maxillary nerve, the small meningeal artery, and the small petrosal nerve. On the outer side of the foramen ovale is the **foramen spinosum**, for the passage of the middle meningeal artery; and on the inner side of the foramen ovale is the **foramen lacerum medium**. The lower part of this aperture is filled with cartilage in the recent state. The Vidian nerve and a meningeal branch from the ascending pharyngeal artery pierce this cartilage. On the anterior surface of the petrous portion of the temporal bone is seen, from without inward, the eminence caused by the projection of the superior semicircular canal; in front of and a little outside this is a depression corresponding to the roof of the tympanum; the groove leading to the hiatus Fallopii, for the transmission of the petrosal branch of the Vidian nerve and the petrosal branch of the middle meningeal artery; beneath it, the smaller groove, for the passage of the lesser petrosal nerve; and, near the apex of the bone, the depression for the Gasserian ganglion; and the internal orifice of the carotid canal (*foramen caroticum internum*), for the passage of the internal carotid artery and carotid plexus of nerves.

**Posterior Fossa** (*fossa cranii posterior*).—The posterior fossa, deeply concave, is the largest of the three, and situated on a lower level than either of the preceding. It is formed by the posterior third of the superior surface of the body of the sphenoid, by the occipital, the petrous and mastoid portions of the temporal, and the posterior inferior angle of the parietal bone; it is crossed by four sutures, the petro-occipital, the masto-occipital, the masto-parietal, and the basilar; and lodges the cerebellum, pons, and oblongata. It is separated from the middle fossa in

1 See footnote, p. 95.
the median line by the dorsum sellae, and on each side by the superior border of the petrous portion of the temporal bone. This border serves for the attachment of the tentorium, is grooved for the superior petrosal sinus, and at its inner extremity presents a notch, upon which rests the trigeminal nerve. The circumference of the fossa is bounded posteriorly by the grooves for the lateral sinuses. In the centre of this fossa is the \textit{foramen magnum}, bounded on either side by a rough tubercle, which gives attachment to the odontoid or check ligaments; and a little above these are seen the internal openings of the \textit{anterior condyloid foramina}, through which pass the hypoglossal nerves and meningeal branches from the ascending pharyngeal arteries. In front of the foramen magnum is a grooved surface, formed by the basilar process of the occipital bone and by the posterior third of the superior surface of the body of the sphenoid, which supports the oblongata and pons, and articulates on each side with the petrous portion of the temporal bone, forming the \textit{petro-occipital suture}, the anterior half of which is grooved for the inferior petrosal sinus, the posterior half being encroached upon by the \textit{foramen lacerum posterius} or \textit{jugular foramen} (\textit{foramen jugulare}). This foramen presents three compartments: through the anterior passes the inferior petrosal sinus; through the posterior, the lateral sinus and some meningeal branches from the occipital and ascending pharyngeal arteries; and through the middle, the glosso-pharyngeal, vagus, and accessory nerves. Above the jugular foramen is the \textit{internal auditory meatus}, for the facial and auditory nerves and auditory artery; behind and external to this is the slit-like opening leading into the \textit{aqueductus vestibuli}, which lodges the ductus endolymphaticus; while between the two latter, and near the superior border of the petrous portion, is a small, triangular depression, the remains of the \textit{foccular fossa}, which lodges a process of the dura and occasionally transmits a small vein into the substance of the bone. Behind the foramen magnum are the \textit{inferior occipital fossae}, which lodge the hemispheres of the cerebellum, separated from one another by the \textit{internal occipital crest}, which serves for the attachment of the falcula (\textit{falx cerebelli}) and lodges the occipital sinus. The posterior fossae are surmounted above by the deep transverse grooves for the lodgement of the lateral sinuses. These channels, in their passage outward, groove the occipital bone, the posterior inferior angle of the parietal, the mastoid portion of the temporal, and the jugular process of the occipital, and terminate at the back part of the jugular foramen. Where the lateral sinus grooves the mastoid portion of the temporal bone the orifice of the \textit{mastoid foramen} may be seen. Just previous to the termination of the groove the \textit{posterior condyloid foramen} opens into it. Neither foramen is constant.

\textbf{External Under or Basilar Surface} (the view from below is called the \textit{norma basalis}).—The external surface of the base of the skull (Fig. 96) is extremely irregular. It is bounded in front by the incisor teeth in the upper jaw; behind by the superior curved lines of the occipital bone; and laterally by the alveolar arch, the lower border of the malar bone, the zygoma, and an imaginary line extending from the zygoma to the mastoid process and extremity of the superior curved line of the occiput. It is formed by the palate processes of the superior maxillary and palate bones, the vomer, the pterygoid processes, under surface of the great wing, spinous processes and part of the body of the sphenoid, the under surface of the squamous, mastoid, and petrous portions of the temporal, and the under surface of the occipital bone. The anterior part of the base of the skull is raised above the level of the rest of this surface (when the skull is turned over for the purpose of examination), surrounded by the alveolar process, which is thicker behind than in front, and excavated by sixteen depressions for lodging the teeth of the upper jaw, the cavities varying in depth and size according to the teeth they contain. Immediately behind the incisor teeth is the \textit{anterior palatine fossa} (\textit{foramen incisivum}). At the bottom of this fossa may usually be seen four apertures:
two placed laterally, the foramina of Stenson, which open above, one in the floor of each nostril, and transmit the anterior branch of the posterior palatine vessels, and

\[\text{Foramina of Stenson}\]

\[\text{Anterior palatine foramina}\]

\[\text{Posterior nasal spine}\]

\[\text{Hamular process}\]

\[\text{Sphenoid process of palate}\]

\[\text{Pterygo-palatine canal}\]

\[\text{Tensor palatini}\]

\[\text{Canal for Jacobson's nerve}\]

\[\text{Aquseductus cochleae}\]

\[\text{Foramen lacerum posterior}\]

\[\text{Canal for Arnold's nerve}\]

\[\text{Auricular fissure}\]

\[\text{Fig. 96.—Base of the skull. External surface.}\]
two in the median line in the intermaxillary suture, the foramina of Scarpa, one in front of the other, the anterior transmitting the left, and the posterior (the larger) the right, naso-palatine nerve. These two lateral canals are sometimes wanting, or they may join to form a single one, or one of them may open into one of the lateral canals above referred to. The palatine vault is concave, uneven, perforated by numerous foramina, marked by depressions for the palatine glands, and crossed by a crucial suture, formed by the junction of the four bones of which it is composed. At the front part of this surface a delicate linear suture may frequently be seen, passing outward and forward from the anterior palatine fossa to the interval between the lateral incisor and canine teeth, and marking off the pre-maxillary portion of the bone: At each posterior angle of the hard palate is the posterior palatine foramen, for the transmission of the posterior palatine vessels and great descending palatine nerve; and running forward and inward from it a groove, for the same vessels and nerve. Behind the posterior palatine foramen is the tuberosity of the palate bone, perforated by one or more accessory posterior palatine canals, and marked by the commencement of a ridge which runs transversely inward, and serves for the attachment of the tendinous expansion of the Tensor palatii muscle. Projecting backward from the centre of the posterior border of the hard palate is the posterior nasal spine, for the attachment of the Azygos uvulae muscle. Behind and above the hard palate is the posterior aperture of the nares, divided into two parts by the vomer, bounded above by the body of the sphenoid, below by the horizontal plate of the palate bone, and laterally by the internal pterygoid plate of the sphenoid. Each aperture measures about an inch in the vertical and about half an inch in the transverse direction. At the base of the vomer may be seen the expanded ale of this bone, receiving between them, on each side, the rostrum of the sphenoid. Near the lateral margins of the vomer, at the root of the pterygoid processes, are the pterygo-palatine canals. The pterygoid process, which bounds the posterior nares on each side, presents near its base the pterygoid or Vidian canal (canalis pterygoideus), for the Vidian nerve and artery. Each process consists of two plates, which bifurcate at the extremity to receive the tuberosity of the palate bone, and are separated behind by the pterygoid fossa, which lodges the Internal pterygoid muscle. The internal plate is long and narrow, presenting on the outer side of its base the scaphoid fossa, for the origin of the Tensor palatii muscle, and at its extremity the hamular process, around which the tendon of this muscle turns. The external pterygoid plate is broad, forms the inner boundary of the zygomatic fossa, and affords attachment by its outer surface to the External pterygoid muscle.

Behind the nasal fossae in the middle line is the basilar surface of the occipital bone, presenting in its centre the pharyngeal spine, for the attachment of the Superior constrictor muscle of the pharynx, with depressions on each side for the insertion of the Rectus capitis anticus major and minor. At the base of the external pterygoid plate is the foramen ovale, for the transmission of the third division of the trigeminal nerve, the small meningeal artery, and sometimes the small petrosal nerve; behind this, the foramen spinosum, which transmits the middle meningeal artery, and the prominent sinus process of the sphenoid, which gives attachment to the internal lateral ligament of the lower jaw and the Tensor palatii muscle. External to the sinus process is the glenoid fossa, divided into two parts by the Glaserian fissure (page 84), the anterior portion concave, smooth, bounded in front by the eminentia articularis, and serving for the articulation of the condyle of the lower jaw; the posterior portion rough, bounded behind by the tympanic plate, and serving for the reception of part of the parotid gland. Emerging from between the laminae of the vaginal process of the tympanic plate is the styloid process, and at the base of this process is the stylo-mastoid foramen, for the exit of the facial nerve and entrance of the stylo-mastoid artery. External to the stylo-
mastoid foramen is the **auricular fissure**, for the exit of the auricular branch of the vagus, bounded behind by the mastoid process. Upon the inner side of the mastoid process is a deep groove, the **digastric fossa**; and a little more internally the **occipital groove**, for the occipital artery. At the base of the internal pterygoid plate is a large and somewhat triangular aperture, the **foramen lacerum medium**, bounded in front by the great wing of the sphenoid, behind by the apex of the petrous portion of the temporal bone, and internally by the body of the sphenoid and basilar process of the occipital bone: it presents in front the posterior orifice of the Vidian canal; behind, the aperture of the carotid canal. The basilar surface of this opening is filled in the recent state by fibro-cartilaginous substance; across its upper or cerebral aspect passes the internal carotid artery. External to this aperture the **petro-sphenoidal suture** is observed, at the outer termination of which is seen the orifice of the canal for the Eustachian tube and that for the Tensor tympani muscle. Behind this suture is seen the under surface of the **petrous portion of the temporal bone**, presenting, from within outward, the quadrilateral, rough surface, part of which affords attachment to the Levator palati and Tensor tympani muscles; posterior to this surface is the orifice of the **carotid canal** (*foramen caroticum externum*) and the orifice of the **aquaeductus cochleae**, the former transmitting the internal carotid artery and the ascending branches of the superior cervical ganglion of the sympathetic, the latter serving for the passage of a small artery to and a small vein from the cochlea. Behind the carotid canal is a large aperture, the **jugular foramen**, formed in front by the petrous portion of the temporal, and behind by the occipital; it is generally larger on the right than on the left side, and is divided into three compartments by processes of dura. The anterior is for the passage of the inferior petrosal sinus; the posterior, for the lateral sinus and some meningeal branches from the occipital and ascending pharyngeal arteries; the central one, for the glosso-pharyngeal, vagus, and accessory nerves. On the ridge of bone dividing the carotid canal from the jugular foramen is the small foramen for the transmission of Jacobson’s nerve; and on the wall of the jugular foramen, near the root of the styloid process, is the small aperture for the transmission of the vagus nerve. Behind the basilar surface of the occipital bone is the **foramen magnum**, bounded on each side by the condyles, rough internally for the attachment of the check or odontoid ligaments, and presenting externally a rough surface, the **jugular process**, which serves for the attachment of the Rectus capitis lateralis muscle and the lateral occipito-atlantal ligament. On either side of each condyle anteriorly is the **anterior condyloid fossa**, perforated by the **anterior condyloid foramen**, for the passage of the hypoglossal nerve and often a meningeal branch of the ascending pharyngeal artery. Behind each condyle is the **posterior condyloid fossa**, perforated by the **posterior condyloid foramen**, for the transmission of a vein to the lateral sinus. Behind the foramen magnum is the **external occipital crest**, terminating above at the **external occipital protuberance**, whilst on each side are seen the **superior and inferior curved lines**; these, as well as the surfaces of bone between them, are rough for the attachment of the muscles, which are enumerated on page 76.

**The Lateral Region of the Skull.**

The view of the lateral region of the skull from the side is known as the **norma lateralis**. The lateral region is of a somewhat triangular form, the base of the triangle being formed by a line extending from the external angular process of the frontal bone along the temporal ridge backward to the outer extremity of the superior curved line of the occiput; and the sides by two lines, the one drawn downward and backward from the external angular process of the frontal bone to the angle of the lower jaw, the other from the angle of the jaw upward and back-
ward to the outer extremity of the superior curved line. This region is divisible into three portions—temporal fossa, mastoid portion, and zygomatic or infratemporal fossa.

**The Temporal Fossa (fossa temporalis).**—The temporal fossa is bounded above and behind by the temporal ridges, which extend from the external angular process of the frontal upward and backward across the frontal and parietal bones, curving downward behind to terminate in the posterior root of the zygomatic process, supra-

**mastoid crest.** In front it is bounded by the frontal, malar, and great wing of the sphenoid; externally by the zygomatic arch formed conjointly by the malar and temporal bones; below, it is separated from the zygomatic fossa by the pterygoid ridge, seen on the outer surface of the great wing of the sphenoid. This fossa is formed by five bones, part of the frontal, great wing of the sphenoid, parietal, squamous portion of the temporal and malar bones, and is traversed by six sutures, part of the transverse facial, spheno-malar, coronal, spheno-parietal, squamo-parietal, and squamo-sphenoidal. The point where the coronal suture crosses the superior temporal ridge is sometimes named the stephanion; and the region where the four bones, the parietal, the frontal, the squamous, and the greater wing of the sphenoid, meet, at the anterior inferior angle of the parietal bone, is named the pterion. This point is about on a level with the external angular process of the frontal bone and about one and a half inches behind it. This fossa is deeply concave in front, convex behind, traversed by grooves which lodge branches of the deep temporal arteries, and filled by the Temporal muscles.
The Mastoid Portion.—The mastoid portion of the side of the skull is bounded in front by the tubercle of the zygoma; above, by a line which runs from the posterior root of the zygoma to the end of the mastoid-parietal suture; behind and below by the masto-occipital suture. It is formed by the mastoid and part of the squamous and petrous portions of the temporal bone; its surface is convex and rough for the attachment of muscles, and presents, from behind forward, the mastoid foramen, the mastoid process, the external auditory meatus surrounded by the tympanic plate, and, most anteriorly, the temporo-maxillary articulation. The point where the posterior inferior angle of the parietal meets the occipital bone and mastoid portion of the temporal is named the asterion.

The Zygomatic or Infratemporal Fossa (fossa infratemporalis).—The zygomatic fossa is an irregularly shaped cavity, situated below and on the inner side of the zygoma; bounded in front by the zygomatic surface of the superior maxillary bone and the ridge which descends from its malar process; behind, by the posterior border of the external pterygoid plate and the eminentia articularis; above, by the pterygoid ridge on the outer surface of the great wing of the sphenoid and the under part of the squamous portion of the temporal; below, by the alveolar border of the superior maxilla; internally, by the external pterygoid plate; and externally, by the zygomatic arch and ramus of the lower jaw (Fig. 98).

It contains the lower part of the Temporal, the External and Internal pterygoid muscles, the internal maxillary artery and vein, and inferior maxillary nerve and their branches. At its upper and inner part may be observed two fissures, the spheno-maxillary and pterygo-maxillary fissures.

The Spheno-maxillary Fissure (fissura orbitalis inferior), horizontal in direction, opens into the outer and back part of the orbit. It is formed above by the lower border of the orbital surface of the great wing of the sphenoid; below, by the external border of the orbital surface of the superior maxilla and a small part of the palate bone; externally, by a small part of the malar bone:1 internally, it joins at

1 Occasionally the superior maxillary bone and the sphenoid articulate with each other at the anterior extremity of this fissure; the malar is then excluded from entering into its formation.—Ed. of 15th English Edition.
right angles with the pterygo-maxillary fissure. This fissure opens a communication from the orbit into three fossae—the **temporal, zygomatic, and spheno-maxillary fossa**; it transmits the superior maxillary nerve and its orbital branch, the infraorbital vessels, and ascending branches from the sphenopalatine or Meckel’s ganglion.

The **pterygo-maxillary fissure** is vertical, and descends at right angles from the inner extremity of the preceding; it is a V-shaped interval, formed by the divergence of the superior maxillary bone from the pterygoid process of the sphenoid. It serves to connect the sphenomaxillary fossa with the zygomatic fossa, and transmits the internal maxillary artery.

The **sphenomaxillary or pterygo-palatine fossa** (fossa pterygopalatina).—The sphenomaxillary fossa is a small, triangular space situated at the angle of junction of the sphenomaxillary and pterygo-maxillary fissures, and placed beneath the apex of the orbit. It is formed above by the under surface of the body of the sphenoid and by the orbital process of the palate bone; in front, by the superior maxillary bone; behind, by the anterior surface of the base of the pterygoid process and lower part of the anterior surface of the great wing of the sphenoid; internally, by the vertical plate of the palate. This fossa has three fissures terminating in it—the **sphenoidal, sphenomaxillary, and pterygomaxillary**; it communicates with the orbit by the sphenomaxillary fissure; with the nasal fossae by the spheno-palatine foramen, and with the zygomatic fossa by the pterygo-maxillary fissure. It also communicates with the cavity of the cranium, and has opening into it five foramina. Of these, there are three on the posterior wall: the **foramen rotundum** above; below and internal to this, the **Vidian canal**; and still more inferiorly and internally, the **pterygo-palatine canal**. On the inner wall is the **spheno-palatine foramen**, by which the sphenomaxillary communicates with the nasal fossa; and below is the superior orifice of the **posterior palatine canal**, besides occasionally the orifices of the accessory posterior palatine canals. The fossa contains the superior maxillary nerve and Meckel’s ganglion, and the termination of the internal maxillary artery.

The Anterior Region of the Skull.

The view of the anterior region of the skull from the front is known as the **norma frontalis**. It forms the face, is of an oval form, presents an irregular surface, and is excavated for the reception of two of the organs of sense, the eye and the nose. It is bounded above by the glabella and margins of the orbit; below, by the prominence of the chin; on each side by the malar bone and anterior margin of the ramus of the jaw. In the median line are seen from above downward the **glabella**, and diverging from it are the **superciliary ridges**, which indicate the situation of the frontal sinuses and supports the eyebrow. Beneath the glabella is the fronto-nasal suture, the mid-point of which is termed the **nasion**, and below this is the arch of the nose, formed by the nasal bones, and the nasal processes of the superior maxillary. The nasal arch is convex from side to side, concave from above downward, presenting in the median line the **internal nasal suture** (sutura internasalis), formed between the nasal bones, laterally the **nasomaxillary suture** (sutura nasomaxillaris), formed between the nasal bone and the nasal process of the superior maxillary bone. Below the nose is seen the opening of the **anterior nares**, which is heart-shaped, with the narrow end upward, and presents laterally the thin, sharp margins serving for the attachment of the lateral cartilages of the nose, and in the middle line below a prominent process, the **anterior nasal spine**, bounded by two deep notches. Below this is the **intermaxillary suture** (sutura intermaxillaris), and on each side of it the **incisive fossa**. Beneath this fossa are the alveolar processes of the upper and lower jaws, containing the incisor teeth, and at the lower part of the
median line the symphysis of the chin, the mental process, with its two mental tubercles, separated by a median groove, and the incisive fossa of the lower jaw.

On each side, proceeding from above downward, is the supraorbital ridge, terminating externally in the external angular process at its junction with the malar, and internally in the internal angular process; toward the inner third of this ridge is the supraorbital notch or foramen, for the passage of the supraorbital vessels and nerve. Beneath the supraorbital ridge is the opening of the orbit, bounded externally by the orbital ridge of the malar bone; below, by the orbital ridge formed by the malar and superior maxillary bones; internally, by the nasal process of the superior maxillary and the internal angular process of the frontal bone. On the outer side of the orbit is the quadrilateral anterior surface of the malar bone, perforated by one or two small malar foramina. Below the inferior margin of the orbit is the infraorbital foramen, the termination of the infraorbital canal, and beneath this the canine fossa, which gives attachment to the Levator anguli oris; still lower are the alveolar processes, containing the teeth of the upper and lower jaws. Beneath the alveolar arch of the lower jaw is the mental foramen, for the passage of the mental vessels and nerve, the external oblique line, and at the lower border of the bone, at the point of junction of the body with the ramus, a shallow groove for the passage of the facial artery.

Orbits, Orbital Cavities, or Orbital Fossae.—The orbits (from orbis, a circle) (Fig.99) are two quadrilateral pyramidal cavities, situated at the upper and anterior

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**Fig. 99.**—Antero-lateral region of the skull. (Cryer.)
part of the face, their bases being directed forward and outward, and their apices backward and inward, so that the axes of the two, if continued backward, would meet over the body of the sphenoid bone. The wide orbital opening or mouth is called the aditus orbitae. The orbit is lined with periosteum, the periorbita. Each orbit (orbita) is formed of seven bones, the frontal, sphenoid, ethmoid, superior maxillary, malar, lachrymal, and palate; but three of these, the frontal, ethmoid, and sphenoid, enter into the formation of both orbits, so that the two cavities are formed of eleven bones only. Each cavity presents for examination a roof, a floor, an inner and an outer wall, four angles, a circumference or base, and an apex.

The Roof (paries superior).—The roof is concave, directed downward and slightly forward, and formed in front by the orbital plate of the frontal; behind, by the lesser wing of the sphenoid. This surface presents internally the depression for the cartilaginous pulley of the Superior oblique muscle; externally, the depression for the lachrymal gland; and posteriorly, the suture connecting the frontal and lesser wing of the sphenoid.

The Floor (paries inferior).—The floor is directed upward and outward, and is of less extent than the roof; it is formed chiefly by the orbital process of the superior maxillary; in front, to a small extent, by the orbital process of the malar, and behind, by the superior surface of the orbital process of the palate. This surface presents at its anterior and internal part, just external to the lachrymal groove, a depression for the attachment of the Inferior oblique muscle; externally, the suture between the malar and superior maxillary bones; near its middle, the infra-orbital groove; and posteriorly, the suture between the maxillary and palate bones.

Inner or Medial Wall (paries medialis).—The inner wall is flattened, nearly vertical, and formed from before backward by the nasal process of the superior maxillary, the lachrymal, os planum of the ethmoid, and a small part of the body of the sphenoid. This surface presents the lachrymal groove and crests of the lachrymal bone, and the sutures connecting the lachrymal with the superior maxillary, the ethmoid with the lachrymal in-front, and the ethmoid with the sphenoid behind.

Outer or Lateral Wall (paries lateralis).—The outer wall is directed forward and inward, and is formed in front by the orbital process of the malar bone; behind, by the orbital surface of the greater wing of the sphenoid. On it are seen the orifices of one or two malar canals, and the suture connecting the sphenoid and malar bones.

Angles.—The superior external angle is formed by the junction of the upper and outer walls; it presents from before backward, the suture connecting the frontal with the malar in front and with the great wing of the sphenoid behind; quite posteriorly is the foramen lacerum anterius, or sphenoidal fissure, which transmits the third, the fourth, the three branches of the ophthalmic division of the trigeminal, the abducent nerve, some filaments from the cavernous plexus of the sympathetic, the orbital branch of the middle meningeal artery, a recurrent branch from the lachrymal artery to the dura, and the ophthalmic vein. The superior internal angle is formed by the junction of the upper and inner wall, and presents the suture connecting the frontal bone with the lachrymal in front and with the ethmoid behind. The point of junction of the anterior border of the lachrymal with the frontal has been named the dacyron. This angle presents two foramina, the anterior and posterior ethmoidal foramina, the former transmitting the anterior ethmoidal vessels and nasal nerve, the latter the posterior ethmoidal vessels. The inferior external angle, formed by the junction of the outer wall and floor, presents the spheno-maxillary fissure, which transmits the superior maxillary nerve and its orbital branches, the infraorbital vessels, and the ascending branches from the sphenopalatine or Meckel's ganglion. The inferior internal angle is formed by the union of the lachrymal bone and the os planum of the ethmoid with the superior maxillary and palate bones.
Circumference.—The circumference or base of the orbit, quadrilateral in form, is bounded above (margo supraorbitalis) by the supraorbital ridge; below (margo infraorbitalis), by the anterior border of the orbital plate of the malar and superior maxillary bones; externally, by the external angular process of the frontal and malar bones; internally, by the internal angular process of the frontal and the nasal process of the superior maxillary. The circumference is marked by three sutures, the fronto-maxillary internally, the fronto-malar externally, and the malo-maxillary below; it contributes to the formation of the lachrymal groove, and presents, above, the supraorbital notch (or foramen), for the passage of the supraorbital vessels and nerve.

Apex.—The apex, situated at the back of the orbit, corresponds to the optic foramen, a short circular canal which transmits the optic nerve and ophthalmic artery. It will thus be seen that there are nine openings communicating with each orbit—viz., the optic foramen, sphenoidal fissure, spheno-maxillary fissure, supraorbital foramen, infraorbital canal, anterior and posterior ethmoidal foramina, malar foramina, and the canal for the nasal duct.

The Nasal Cavity (cavum nasi).—The nasal cavities or nasal fossae (Figs. 84 and 100) are two large, irregular cavities situated on either side of the middle line of the face, extending from the base of the cranium to the roof of the mouth, and separated from each other by a thin vertical septum, the septum of the nose (septum nasi osseum), formed by the perpendicular plate of the ethmoid and by the vomer. Each cavity communicates by a large aperture, the anterior nasal aperture (apertura pyriformis), with the front of the face, and by the two posterior nares (choanae) with the naso-pharynx behind. These fossae are much

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1 Quain, Testut, and others give the apex of the orbit as corresponding with the inner end of the sphenoidal fissure. It seems better, however, to adopt the statement in the text, since the muscles of the eyeball take origin around the optic foramen, and diverge from it to the globe of the eye.—Ed. of 15th English Edition.

2 In the skull freed of soft parts, the anterior nasal cavities open in front by the aperture pyriformis. In the skull with the soft parts in place they open by the anterior nares.
THE ANTERIOR REGION OF THE SKULL

narrower above than below, and in the middle than at the anterior or posterior openings; their depth, which is considerable, is much greater in the middle than at either extremity. "The nasal fossae are surrounded by four other fossae—above is the cranial fossa; laterally, the orbital fossa; and below, the cavity of the mouth." Each nasal fossa communicates with four sinuses, the frontal above, the sphenoidal behind, and the maxillary and ethmoidal on the outer wall. Each fossa also communicates with four cavities: with the orbit by the lachrymal groove, with the mouth by the anterior palatine canal, with the cranium by the olfactory foramina, and with the sphen-maxillary fossa by the spheno-palatine foramen; and they occasionally communicate with each other by an aperture in the septum. The bones entering into their formation are fourteen in number: three of the cranium, the frontal, sphenoid, and ethmoid, and all the bones of the face, excepting the malar and lower jaw. Each cavity is bounded by a roof, a floor, an inner and an outer wall.

Upper Wall.—The upper wall, or roof (Fig. 101), is long, narrow, and horizontal in its centre, but slopes downward at its anterior and posterior extremities; it is formed in front by the nasal bones and nasal spine of the frontal, which are directed downward and forward; in the middle, by the cribiform plate of the ethmoid, which is horizontal; and behind, by the under surface of the body of the sphenoid and sphenoidal turbinated bones, the ala of the vomer and the sphenoidal process of the palate bone, which are directed downward and backward. This surface presents, from before backward, the internal aspect of the nasal bones; on their outer side, the suture formed between the nasal bone and the nasal process of the superior maxillary; on their inner side, the elevated crest which receives the nasal spine of the frontal and the perpendicular plate of the ethmoid, and articulates with its fellow of the opposite side; whilst the surface of the bones is perforated by a few small vascular apertures, and presents the longitudinal groove for the nasal nerve; farther back is the transverse suture, connecting the frontal with the nasal in front, and the ethmoid behind, the olfactory foramina and nasal slit on the under surface of the cribiform plate, and the suture between it and the sphenoid behind; quite posteriorly are seen the sphenoidal turbinated bones, the orifices of the sphenoidal sinuses, and the articulation of the alae of the vomer with the under surface of the body of the sphenoid.

Floor (Figs. 84, 100, and 101).—The floor is flattened from before backward, concave from side to side, and wider in the middle than at either extremity. It is formed in front by the palate process of the superior maxillary; behind, by the palate process of the palate bone. This surface presents, from before backward, the anterior nasal spine; behind this, the upper orifices of the anterior palatine canal; internally, the elevated crest which articulates with the vomer; and behind, the suture between the palate and superior maxillary bones, and the posterior nasal spine.

Inner or Medial Wall.—The inner wall, or septum (Figs. 101 and 103), is a thin vertical partition which separates the nasal fossae from each other; it is occasionally perforated, so that the fossae communicate, and it is frequently deflected considerably to one side. It is formed, in front, by the crest of the nasal bones and nasal spine of the frontal; in the middle, by the perpendicular plate of the ethmoid; behind, by the vomer and rostrum of the sphenoid; below, by the crests of the superior maxillary and palate bones. It presents, in front, a large, triangular notch, which receives the septal cartilage of the nose; and behind, the grooved edge of the vomer. Its surface is marked by numerous vascular and nervous canals and the groove for the naso-palatine nerve, and is traversed by sutures connecting the bones of which it is formed.

Outer or Lateral Wall.—The outer wall (Figs. 84 and 101) is formed, in front, by the nasal process of the superior maxillary and lachrymal bones; in the middle,

1 Howard A. Lothrop, in Annals of Surgery, May, 1903.
2 See footnote, p. 99.
by the ethmoid and inner surface of the body of the superior maxillary and inferior turbinated bones; behind, by the vertical plate of the palate bone and the internal pterygoid plate of the sphenoid. Upon this outer wall are two marked projections of bone (Figs. 84 and 101). One is known as the inferior turbinated bone and the other as the middle turbinated bone. The superior turbinated bones or bodies appear as less distinct bony projections. This surface presents three irregular longitudinal passages, or meatuses, termed the superior, middle, and inferior meatuses of the nose (Figs. 84, 101, and 102). The superior meatus (meatus nasi superior), the
smallest of the three, is situated at the upper and back part of each nasal fossa, occupying the posterior third of the outer wall. It is situated between the superior and middle turbinated bones, and has opening into it two foramina, the sphenopalatine foramina at the back of its outer wall, and the posterior ethmoidal cells at the front part of the outer wall. The sphenoidal sinus opens into a recess, the sphenethmoidal recess (recessus sphenoethmoidalis), which is situated above and behind the superior turbinated bone. The middle meatus (meatus nasi medius) is situated external to the middle turbinated bone, and above the inferior turbinated bone, and extends from the anterior end of the inferior turbinated bone to the sphenopalatine foramen of the outer wall of the nasal fossa. Anteriorly it terminates in a depression, the atrium of the nasal meatus. The bulla ethmoidalis, an elevated area disclosed by removing the middle turbinated bone. Below and in front of the bulla is a groove, the semilunar hiatus (hiatus semilunaris), into which open the antrum and the anterior ethmoidal cells. The middle meatus presents in front the orifice of the infundibulum (infundibulum ethmoidale), by which the middle meatus communicates with the anterior ethmoidal cells, and through these with the frontal sinuses. The middle ethmoidal cells also open into this meatus, while at the centre of the outer wall is the orifice of the maxillary antrum (hiatus maxillaris), which varies somewhat as to its exact position in different skulls. The inferior meatus (meatus nasi inferior), the largest of the three, is the space between the inferior turbinated bone and the floor of the nasal fossa. It extends along the entire length of the outer wall of the nose, is broader in front than behind, and presents anteriorly the lower orifice of the canal for the nasal duct (canalis nasolacrimalis). The anterior nares present a heart-shaped or pyriform opening (apertura piriformis) whose long axis is vertical and narrow extremity upward. This opening in the recent state is much contracted by the cartilages of the nose. It is bounded above by the inferior border of the nasal bone; laterally by the thin, sharp margin which separates the facial from the nasal surface of the superior

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**Fig. 103.** Inner wall of nasal fossa, or septum of nose.
maxillary bone; and below by the same border, where it slopes inward to join its fellow of the opposite side at the anterior nasal spine. The posterior nares, or choanae, are the two posterior oval openings of the nasal fossa, by which they communicate with the upper part of the naso-pharynx. They are situated immediately in front of the basilar process, and are bounded above by the under surface of the body of the sphenoid and ake of the vomer; below, by the posterior border of the horizontal plate of the palate bone; externally, by the inner surface of the internal pterygoid plate; and internally, in the middle line, they are separated from each other by the posterior border of the vomer.

**Shape of the Skull.**—Great variations in shape occur. There is a notable contrast between the oval or elliptical skull of a Caucasian, the pyramidal skull of an Esquimaux, and the prognathous skull of a Negro. There are also wide differences in skulls of persons of the same race. The skull may be dolichocephalic, that is, long and narrow (Figs. 105 and 107); it may be brachycephalic, that is, short and round (Figs. 104 and 106); it may be acrocephalic, that is, shaped like a sugar loaf. There may be great bulging of the occiput or forehead, the forehead may be vertical or sloped backward, and may be high or low. In many dolichocephalic skulls there is a distinct elevation over the sagittal suture. A skull possessed of such a longitudinal ridge is called scaphoid. The shape of a dolichocephalic skull is due to early closure of the sagittal and metopic sutures. A skull becomes short and round because of early closure of the coronal and lambdoidal sutures. The sugar loaf skull results from early obliteration of the transverse and longitudinal sutures. An individual

**FIG. 104.**—Brachycephalic cranium. (Poirier and Charpy.)

**FIG. 105.**—Dolichocephalic cranium. (Poirier and Charpy.)

**FIG. 106.**—Brachycephalic cranium. (Poirier and Charpy.)

**FIG. 107.**—Dolichocephalic cranium. (Poirier and Charpy.)
with a long and narrow skull usually has a long, narrow face; an individual with a short and round skull usually has a short and broad face. The head is practically always asymmetrical, the left side, especially the frontal region of the left side, being the larger, and the right side being the higher in a large majority of persons. The right orbit is usually higher, and the right side of the jaw is stronger, than the left. This asymmetry results from the habitual assumption of some one position.

**Dimensions of the Skull.**—The diameters of different skulls, even of those of the same race, vary greatly. Broca estimated the mean diameters of the skull as follows:

<table>
<thead>
<tr>
<th>MEAN.</th>
<th>MALES. Millimetres.</th>
<th>FEMALES. Millimetres.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>182</td>
<td>174</td>
</tr>
<tr>
<td>Breadth</td>
<td>145</td>
<td>135</td>
</tr>
<tr>
<td>Height</td>
<td>132</td>
<td>125</td>
</tr>
</tbody>
</table>

**Cranial Capacity.**—Capacity is in direct ratio to dimensions. According to Welcker the average capacity in males is 1450 c.c., and in females is 1300 c.c. A *microcephalic* skull has a capacity of less than 1350 c.c.; a *mesocephalic* skull has a capacity of from 1350 to 1450 c.c.; a *megacephalic* skull has a capacity of over 1450 c.c.

**Indices and Angles.**—The length of a diameter is of slight importance; the relation which this length bears to other measurements may be of considerable importance.

**The Cephalic Index.**—The cephalic index is the proportion borne by the greatest breadth of the skull to the greatest length. It is used to determine the form of the skull. The formula is as follows:

\[
\text{Maximum breadth} \times 100 \div \text{maximum length} = \text{Cephalic index.}
\]

The greatest length is obtained by measuring from the glabella to the occipital point; the greatest breadth, by measuring the widest distance just above the supramastoid ridge. A dolichocephalic skull (long antero-posterior diameter and short transverse diameter) has a cephalic index of under 75. The mesaticephalic skull (median head) has a cephalic index from 75 to 80. The brachycephalic skull (short antero-posterior diameter) has a cephalic index over 80.

**Index of Height.**—This is the ratio of height to length. The line of height is from the basion to the bregma. The formula for this index is as follows:

\[
\text{Height} \times 100 \div \text{length} = \text{Index of height.}
\]

**The Facial Index.**—This is the ratio between the length and the breadth of the face. The length is measured from the nasion to the mental point; the breadth between the zygomatic arches. The formula is as follows:

\[
\text{Length} \times 100 \div \text{breadth} = \text{Facial index.}
\]

We have also the *nasal index*, the *orbital index*, and the *palatal index*. Camper's facial angle has been abandoned because of inaccuracy. This angle was obtained by drawing one line from the middle of the external auditory meatus to the inferior margin of the nasal septum (from the auricular point to the nasal spine), the other from the most prominent point in the midline of the forehead to the nasal spine. The angle formed by the meeting of these two lines varies between 62 degrees and 85 degrees (Cunningham). The more the lower part of the face projects the less the angle. This projection is marked in the negro races. Such a projecting face is called *prognathous*.

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1 Quoted by Prof. Dwight in Piersol's *Human Anatomy*. 
Flower's Gnathic Index.—This is now employed instead of Camper's facial angle. A line is drawn from the basion to the alveolar point, and another line is drawn between the basion and nasion. We estimate the ratio which the measurement of the first line bears to the second. The formula is as follows:

\[ \frac{\text{Basi-alveolar line} \times 100}{\text{basi-nasal line}} = \text{Gnathic index.} \]

Dwight\(^1\) tells us that an orthognathous skull has an index below 98; a mesognathous skull has an index from 90 to 103; a prognathous skull has an index above 103.

For the Skull at Different Ages, see p. 102; Sexual Differences in the Skull, p. 102; the Fontanelles, p. 102.

Surface Form.—The various bony prominences or landmarks which are to be easily felt and recognized in the head and face, and which afford the means of mapping out the important structures comprised in this region, are as follows:

1. Supraorbital arch.
2. Internal angular process.
3. External angular process.
4. Zygomatic arch.
5. Mastoid process.
7. Superior curved line of occipital bone.
8. Parietal eminences.
10. Frontal eminences.
11. Superciliary ridges.
13. Lower margin of orbit.
14. Lower jaw.

1. The supraorbital arches are to be felt throughout their entire extent, covered by the eyebrows. They form the upper boundary of the circumference or base of the orbit, and separate the face from the forehead. They are strong and arched, and terminate internally on each side of the root of the nose in the internal angular process, which articulates with the lachrymal bone. Externally they terminate in the external angular process, which articulates with the malar bone. This arched ridge is sharper and more defined in its outer than in its inner half, and forms an overhanging process which protects and shields the lachrymal gland. It thus protects the eye in its most exposed situation and in the direction from which blows are most likely to descend. The supraorbital arch varies in prominence in different individuals. It is more marked in the male than in the female, and in some races of mankind than others. In the less civilized races, as the forehead recedes backward, the supraorbital arch becomes more prominent, and approaches more to the characters of the monkey tribe, in which the supraorbital arches are very largely developed, and acquire additional prominence from the oblique direction of the frontal bone. 2. The internal angular process is scarcely to be felt. Its position is indicated by the angle formed by the supraorbital arch with the nasal process of the superior maxillary bone and the lachrymal bone at the inner side of the orbit. Between the internal angular processes of the two sides is a broad surface which assists in forming the root of the nose, and immediately above this a broad, smooth, somewhat triangular surface, the glabella, situated between the superciliary ridges. 3. The external angular process is much more strongly marked than the internal, and is plainly to be felt. It is formed by the junction or confluence of the supraorbital and temporal ridges, and, articulating with the malar bone, it serves to a very considerable extent to support the bones of the face. In carnivorous animals the external angular process does not articulate with the malar, and therefore this lateral support to the bones of the face is not present. 4. The zygomatic arch is plainly to be felt throughout its entire length, being situated almost immediately under the skin. It is formed by the malar bone and the zygomatic process of the temporal bone. At its anterior extremity, where it is formed by the malar bone, it is broad and forms the prominence of the cheek; the posterior part is narrower, and terminates just in front and a little above the tragus of the external ear. The lower border is more plainly to be felt than the upper, in consequence of the dense temporal fascia being attached to the latter, which somewhat obscures its outline. Its shape differs very much in individuals and in different races of mankind. In the most degraded type of skull—as, for instance, in the skull of the negro of the Guinean Coast—the malar bones project forward and not outward, and the zygoma at its posterior extremity extends farther outward before it is twisted on itself to be prolonged forward. This makes the zygomatic arch stand out in bold relief, and affords greater space for the Temporal muscle. In skulls which have a more pyramidal shape, as in the Esquimaux or Greenlander, the malar bones do not project forward and downward under the eyes, as in the preceding form, but take a direction outward, forming with the zygoma a large, rounded sweep or segment of a circle. Thus it happens that if two lines are drawn from the zygomatic arches, touching the temporal ridges, they meet above the top of the head, instead of being parallel, or nearly so, as in the European skull, in which the zygomatic arches are not

\(^{1}\) Piersol's Human Anatomy.
THE ANTERIOR REGION OF THE SKULL

149

nearly so prominent. This gives to the face a more or less oval type. 5. Behind the ear is the mastoid portion of the temporal bone, plainly to be felt, and terminating below in a nipple-shaped process. Its anterior border can be traced immediately behind the concha, and its apex is on about a level with the lobule of the ear. It is rudimentary in infancy, but gradually develops in childhood, and is more marked in the negro than in the European. 6. The external occipital protuberance is always plainly to be felt just at the level where the skin of the neck joins that of the head. At this point the skull is thick for the purposes of safety, while radiating from it are numerous curved arches or buttresses of bone which give to this portion of the skull further security. 7. Running outward on either side from the external occipital protuberance is an arched ridge of bone, which can be more or less plainly perceived. This is the superior curved line of the occipital bone, and gives attachment to some of the muscles which keep the head erect on the spine; accordingly, we find it more developed in the negro tribes, in whom the jaws are much more massive, and therefore require stronger muscles to prevent their extra weight carrying the head forward. Below this line the surface of bone at the back of the head is obscured by the overlying muscles. Above it, the vault of the cranium is thinly covered with soft structures, so that the form of this part of the head is almost exactly that of the upper portion of the occipital, the parietal, and the frontal bones themselves; and in bald persons, even the lines of junction of the bones, especially the junction of the occipital and parietal at the lambdoid suture, may be defined as a slight depression, caused by the thickening of the borders of the bones in this situation. 8. In the line of the greatest transverse diameter of the head, on each side of the middle line, are generally to be found the parietal eminences, one on each side of the middle line, though sometimes these eminences are not situated at the point of the greatest transverse diameter, which is at some other prominent part of the parietal region. They denote the point where ossification of the parietal bone began. They are much more prominent and well-marked in early life, in consequence of the sharper curve of the bone at this period, so that it describes the segment of a smaller circle. Later in life, as the bone grows, the curve spreads out and forms the segment of a larger circle, so that the eminence becomes less distinguishable. In consequence of this sharp curve of the bone in early life, the whole of the vault of the skull has a squarer shape than it has in later life, and this appearance may persist in some rickety skulls. The eminence is more apparent in the negro’s skull than in that of the European. This is due to greater flattening of the temporal fossa in the former skull to accommodate the larger Temporal muscle which exists in these races. The parietal eminence is particularly exposed to injury from blows or falls on the head, but fracture is to a certain extent prevented by the shape of the bone, which forms an arch, so that the force of the blow is diffused over the bone in every direction. 9. At the side of the head may be felt the temporal ridge. Commencing at the external angular process, it may be felt as a curved ridge, passing upward and then curving backward, on the frontal bone, separating the forehead from the temporal fossa. It may then be traced passing backward in a curved direction, over the parietal bone, and, though less marked, still generally to be recognized. Finally, the ridge curves downward, and terminates in the posterior root of the zygoma, which separates the squamous from the subcutaneous mastoid portion of the temporal bone. Sir Victor Horsley has recently shown in an article on the “Topography of the Cerebral Cortex,” that the second temporal ridge (see page 76) can be made out on the living body. 10. The frontal eminences vary a good deal in different individuals, being considerably more prominent in some than in others, and they are often not symmetrical on the two sides of the body, the one being much more pronounced than the other. This is often especially noticeable in the skull of the young child or infant, and becomes less marked as age advances. The prominence of the frontal eminences depends more upon the general shape of the whole bone than upon the size of the protuberances themselves. As the skull is more highly developed in consequence of increased intellectual capacity, so the frontal bone becomes more upright and the frontal eminences stand out in bolder relief. Thus they may be considered as affording, to a certain extent, an indication of the development of the hemispheres of the brain beneath, and of the mental powers of the individual. They are not so much exposed to injury as the parietal eminences. In falls forward the upper extremities are involuntarily thrown out, and break the force of the fall, and thus shield the frontal bone from injury. 11. Below the frontal eminences on the forehead are the superciliary ridges, which denote the position of the frontal sinuses, and vary according to the size of the sinuses in different individuals, being, as a rule, small in the female, absent in children, and sometimes unusually prominent in the male, when the frontal sinuses are largely developed. They commence on either side of the glabella, and at first present a rounded form, which gradually fades away at their outer ends. 12. The nasal bones form the prominence of the nose. They vary much in size and shape, and to them is due the varieties in the contour of this organ and much of the character of the face. Thus, in the Mongolian or Ethiopian they are flat, broad, and thick at their base, giving to these races the flattened nose by which they are characterized, and differing very decidedly from the Caucasian, in whom the nose, owing to the shape of the nasal bones, is narrow, elevated at the bridge, and elongated downward. Below, the nasal bones are thin and connected with the cartilages of the nose, and the angle or arch formed by
their union serves to throw out the bridge of the nose, and is much more marked in some individuals than others. 13. The lower margin of the orbit, formed by the superior maxillary bone and the malar bone, is plainly to be felt throughout its entire length. It is continuous internally with the nasal process of the superior maxillary bone, which forms the inner boundary of the orbit. At the point of junction of the lower margin of the orbit with the nasal process is to be felt a little tubercle of bone, which can be plainly perceived by running the finger along the bone in this situation. This tubercle serves as a guide to the position of the lachrymal sac, which is situated above and behind it. 14. The outline of the lower jaw is to be felt throughout its entire length. Just in front of the tragus of the external ear, and below the zygomatic arch, the condyle can be made out. When the mouth is opened this prominence of bone can be perceived advancing out of the glenoid fossa on to the eminentia articularis, and receding again when the mouth is closed. From the condyle the posterior border of the ramus can be felt extending down to the angle. A line drawn from the condyle to the angle would indicate the exact position of this border. From the angle to the synphysis of the chin the lower, rounded border of the body of the bone is plainly to be felt. At the point of junction of the two halves of the bone is a well-marked triangular eminence, the mental process, which forms the prominence of the chin.

Fixed Points for Measurement.—In order to determine the location of regions of surgical importance within the skull (bony spaces, vessels, fissures, centres, and convolutions of the brain) and in order to estimate cranial capacity, measurements are made and these measurements are taken from fixed points. The following are the chief fixed points:

The Alveolar Point. The lowest mid-point of the alveolar process of the upper jaw.

The Asterion. The region of the postero-lateral fontanelle, at the posterior inferior margin of the parietal bone.

The Auricular Point. The centre of the external auditory meatus.

The Basin. The middle of the anterior edge of the foramen magnum.

The Bregma. The site of the anterior fontanelle, where the sagittal and coronal sutures meet.

The Dacyron. The point where the frontal, the lachrymal, and the superior maxillary bones come in contact.

The Glabella. Midway between the two superciliary ridges.

The Glenoid Point. The centre of the glenoid cavity.

The Gonion. The outer surface of the angle of the mandible.

The Inion. The external occipital protuberance.

The Lambda. The point of junction of the sagittal and lambdoid sutures.

The Malar Point. The most prominent portion of the malar bone.

The Mental Point. The point on the synphysis menti which projects most forward.

The Nasion. The middle of the naso-frontal suture.

The Orielion. A point in the sagittal suture between the parietal foramina.

The Occipital Point. The most prominent mid-point posterior. It is situated above the inion.

The Opisthion. The point where a line joining the summits of the orbits touches the median line. It is the middle of the narrowest transverse diameter of the forehead.

The Opisthion. The mid-point of the posterior margin of the foramen magnum.

The Pterion. The site of the antero-lateral fontanelle, where the frontal, parietal, squamous portion of the temporal and greater wing of the sphenoid are in relation.

The Inferior Stephanion. The point where the inferior temporal ridge meets the coronal suture.

The Superior Stephanion. The point where the superior temporal ridge meets the coronal suture.

The Subnasal Point. At the root of the anterior nasal spine in the mid-line.

The Vertex. The highest point of the vault of the skull.

Besides these points we use the mastoid process, the nasal spine, the zygomatic arch, the frontal eminences, the parietal eminences, the supraorbital ridges, the superciliary ridges, the mental process, supraneatal spine, the external and internal angular processes, and the canine fossa.

Surgical Anatomy.—The thickness of the skull varies greatly in different regions of the same skull and in different individuals. The average thickness of the skull-cap is about one-fifth of an inch. The thickest portions are the occipital protuberance, the inferior portion of the frontal bone, and the mastoid process. The thinnest portions are the occipital fossae, the squamous portion of the temporal bone, and over certain sinuses and arteries. An arrest in the ossifying process may give rise to deficiencies or gaps, or to fissures, which are of importance in a medico-legal point of view, as they are liable to be mistaken for fractures. The fissures generally extend from the margin toward the centre of the bone, but gaps may be found in the middle as well as at the edges. In course of time they may become covered with a thin lamina of bone.

Occasionally a protrusion of the brain or its membranes may take place through one of these
THE ANTERIOR REGION OF THE SKULL

gaps in an imperfectly developed skull. When the protrusion consists of membranes only, and is filled with cerebro-spinal fluid, it is called a meningocele; when the protrusion consists of brain as well as membranes, it is termed an encephalocele and when the protruded brain is a prolongation from one of the ventricles, and is distended by a collection of fluid from an accumulation in the ventricle, it is termed an hydrencephalocele. This latter condition is sometimes found at the root of the nose, where a protrusion of the anterior horn of the lateral ventricle takes place through a deficiency of the fronto-nasal suture. These malformations are usually found in the middle line, and most frequently at the back of the head, the protrusion taking place through the fissures which separate the four centres of ossification from which the tabular portion of the occipital bone is originally developed (see page 75). They most frequently occur through the upper part of the vertical fissure, which is the last to ossify, but not uncommonly through the lower part, when the foramen magnum may be incomplete. More rarely these protrusions have been met with in other situations than those above mentioned, both through normal fissures, as the sagittal, lambdoid, and other sutures, and also through abnormal gaps and deficiencies at the sides, and even at the base of the skull. Force may be responsible in a young person for separating a suture. This accident, seldom met with even in the young, is only occasionally encountered in older persons.

Fractures of the skull may be divided into those of the vault and those of the base. Fractures of the vault are usually produced by direct violence. This portion of the skull varies in thickness and strength in different individuals, but, as a rule, is sufficiently strong to resist a very considerable amount of violence without being fractured. This is due to several causes: the rounded shape of the head and its construction of a number of secondary elastic arches, each made up of a single bone; the fact that it consists of a number of bones, united, at all events in early life, by a sutural ligament, which acts as a sort of buffer and interrupts the continuity of any violence applied to the skull; the presence of arches or ridges, both on the inside and outside of the skull, which materially strengthen it; and the mobility of the head upon the spine, which further enables it to withstand violence. The elasticity of the bones of the head is especially marked in the skull of the child, and this fact, together with the wide separation of the individual bones from each other, and the interposition between them of other and softer structures render fracture of the bones of the head a very uncommon event in infants and quite young children; as age advances and the bones become joined, fracture is more common, though still less liable to occur than in the adult. Fractures of the vault may, and generally do, involve the whole thickness of the bone; but sometimes one table may be fractured without any corresponding injury to the other. Thus, the outer table of the skull may be splintered and driven into the diploe, or in the frontal or mastoid regions into the frontal or mastoid cells, without any injury to the internal table. And on the other hand, the internal table has been fractured, and portions of it depressed and driven inward, without any fracture of the outer table. As a rule, in fractures of the skull the inner table is more splintered and comminuted than the outer, and this is due to several causes. It is thinner and more brittle; the force of the violence as it passes inward becomes broken up, and is more diffused by the time it reaches the inner table; the bone, being in the form of an arch, bends as a whole and spreads out, and thus presses the particles together on the convex surface of the arch—i.e., the outer table—and forces them asunder on the concave surface or inner table; and, lastly, there is nothing firm under the inner table to support it and oppose the force. Fractures of the vault may be simple fissures or starred and comminuted fractures, and these may be compressed or elevated. These latter cases of fracture with elevation of the fractured portion are uncommon, and can only be produced by direct wound. In comminuted fracture a portion of the skull is broken into several pieces, the lines of fracture radiating from a centre where the chief impact of the blow was felt; if depressed, a fissure circumscribes the radiating line, enclosing a portion of skull. If this area is circular, it is termed a pond fracture, and would in all probability have been caused by a round instrument, as a life-preserver or hammer; if elliptical in shape, it is termed a gutter fracture, and would owe its shape to the instrument which had produced it, as a poker. A fracture may take place along the line of an ossified or partly ossified suture. When a surgeon explores the vault of the skull through a wound he must not mistake a Wormian bone for a fragment produced by a fracture. A Wormian bone which may lead to mistake is encountered at the anterior inferior angle of the parietal bone. Wormian bones are most frequently found along the lambdoid suture.

Fractures of the base are most frequently produced by the extension of a fissure from the vault, as in falls on the head, where the fissure starts from the part of the vault which first struck the ground. Sometimes, however, they are caused by direct violence, when foreign bodies have been forced through the thin roof of the orbit, through the cribriform plate of the ethmoid from being thrust up the nose, or through the roof of the pharynx. Other cases of fracture of the base occur from indirect violence, as in fracture of the occipital bone from impaction of the spinal column against its condyles in falls on the buttocks, knees, or feet, or in cases where the glenoid cavity has been fractured by the violent impact of the condyle of the lower jaw against it from blows on the chin.
The most common place for fracture of the base to occur is through the middle fossa, and here the fissure usually takes a fairly definite course. Starting from the point struck, which is generally somewhere in the neighborhood of the parietal eminence, it runs downward through the parietal bone and the squamous portion of the temporal bone and across the petrous portion of this bone, frequently traversing and implicating the internal auditory meatus, to the middle lacerated foramen. From this it may pass across the body of the sphenoid, through the pituitary fossa to the middle lacerated foramen of the other side, and may indeed travel round the whole cranium, so as to completely separate the anterior from the posterior part. The course of the fracture should be borne in mind, as it explains the symptoms to which fracture in this region may give rise; thus, if the fissure pass across the internal auditory meatus, injury to the facial and auditory nerves may result, with consequent facial paralysis and deafness; or the tubular prolongation of the arachnoid around these nerves in the meatus may be torn, and thus permit of the escape of the cerebro-spinal fluid. There should be communication between the internal ear and the tympanum and the membrana tympani be ruptured, as is frequently the case; again, if the fissure passes across the pituitary fossa and the muco-periosteum covering the under surface of the body of the sphenoid is torn, blood will find its way into the pharynx and be swallowed, and after a time vomiting of blood will result. Fractures of the anterior fossa, involving the bones forming the roof of the orbit and nasal fossa, are generally the results of blows on the forehead; but fracture of the cribiform plate of the ethmoid may be a complication of fracture of the nasal bone. When the fracture implicates the roof of the orbit, the blood finds its way into this cavity, and, travelling forward, appears as a subconjunctival ecchymosis. Subconjunctival ecchymosis can also be caused by fracture of the malar bone. If the roof of the nasal fossa be fractured, the blood escapes from the nose. In rare cases there may be also escape of cerebro-spinal fluid from the nose where the dura and arachnoid have been torn. In fractures of the posterior fossa extravasation of blood takes place beneath the deep fascia and discoloration of the skin is soon observed in the course of the posterior auricular artery, the discoloration first appearing in the skin over the tip of the mastoid process of the temporal bone (Battle's sign). Some of the blood which was extravasated beneath the deep fascia approaches the surface through the openings in the deep fascia for the passage of vessels and nerves.

The bones of the skull are frequently the seat of nodes, and not uncommonly necrosis results from this cause, also from injury. Necrosis may involve the entire thickness of the skull, but is usually confined to the external table. Necrosis of the internal table alone is rarely met with. The bones of the skull are also sometimes the seat of sarcomatous tumor.

The skull in rickets is peculiar: the forehead is high, square, and projecting, and the antero-posterior diameter of the skull is long in relation to the transverse diameter. The bones of the face are small and ill-developed, and this gives the appearance of a larger head than actually exists. The bones of the head are often thick, especially in the neighborhood of the sutures, and the anterior fontanelle is late in closing, sometimes remaining unclosed till the fourth year. The condition of craniotabes has by some been also believed to be the result of rickets, by others is believed to be due to inherited syphilis. In all probability it is due to both. In these cases the bone undergoes atrophic changes in patches, so that it becomes greatly thinned in places, generally where there is pressure, as from the pillow or nurse's arm. It is, therefore, usually met with in the parietal bone and vertical plate of the occipital bone.

In congenital syphilis deposits of porous bone are often found at the angles of the parietal bones and two halves of the frontal bone which bound the anterior fontanelle. These deposits are separated by the coronal and sagittal sutures, and give to the skull an appearance like a hot cross bun. They are known as Parrot's nodes, and such a skull has received the name of natiform, from its fancied resemblance to the buttocks. When the surgeon wishes to effect an entrance into the interior of the mastoid antrum (Fig. 108) he applies his bar or gouge in the supraneal triangle 1 cm. posterior to the supraneal spine, being careful to keep below the posterior root of the zygoma and the level of the superior wall of the bony meatus. If the instrument is entered at a higher level it will open the cerebral cavity; the instrument should be carried inward, forward, and a little upward, that is, in the direction of the auditory canal. The antrum is usually reached after the penetration of from 1 to 1 1/2 cm. of bone. The depth at which the antrum is situated is not constant. "It is safe to say that if the instrument penetrates deeper than 1 1/2 cm. and be directed too far forward or downward, the horizontal semicircular canal or the aqueductus Fallopian will be encountered. If the former were opened in a purulent otitis media there would travel along it to the vestibule and from there into the internal auditory meatus, producing a pachymeningitis or extradural (epidural) abscess of the posterior fossa of the skull; or from the vestibule through the perpendicular semicircular canal, which if accompanied by erosion of its bony covering would lead to involvement of the meninges of the middle fossa; the same would hold good for the posterior semicircular canal, affecting the posterior fossa. If the latter (the aqueductus Fallopian) were opened an inflammation of the facial nerve which is contained therein would result, producing paralysis of that side of the face. The inflammatory process might also find its way through the entire canal to the internal auditory meatus, causing a pachymeningitis or extradural abscess as mentioned above; or, travelling along the nerve
THE ANTERIOR REGION OF THE SKULL

to its cerebral attachment, would produce a meningitis or subdural (intradural) abscess. The direction of the penetrating instrument must also be forward, in order to avoid injuring the lateral sinus" ("Anatomy and Surgery of the Temporal Bone," by A. E. Schmitt, M.D., American Journal of the Medical Sciences, April, 1903). In the operation for infective thrombosis of the lateral sinus the sinus is deliberately exposed and opened (Fig. 108).

Hartley divides the mastoid process into four parts as follows: The upper margin is the posterior root of the zygoma. The anterior margin is the anterior border of the mastoid. The posterior margin is a vertical line dropped from the masto-occipital junction. The lower margin is an imaginary line backward from the mastoid tip. This space is divided into four equal parts. Points upon it may be designated as on a map. Take the left side for demonstration.

An opening in the N. W. quadrant enters the antrum, one into the N. E. quadrant exposes the lateral sinus, one into the S. W. quadrant enters mastoid cells, and a superficial one into the S. E. quadrant enters mastoid cells, but a deep one exposes the descending portion of the lateral sinus. When pus breaks through the mastoid process it may enter the sheath of the Digastric or Sterno-cleido-mastoid muscle and point a considerable distance away from the bone, Bezold's abscess.

In connection with the bones of the face a common malformation is cleft palate, owing to the non-union of the palatal processes of the maxillary or pre-oral arch. This cleft may involve the whole or only a portion of the hard palate, and usually involves the soft palate also. The cleft is in the middle line, except it involves the alveolus in front, when it follows the suture between the main portion of the bone and the pre-maxillary bone. Sometimes the cleft runs on either side of the pre-maxillary bone, so that this bone is quite isolated from the maxillary bones and hangs from the end of the vomer. In such a case the pre-maxillary bone usually contains the germs of the central incisors only. In some cases there is no pre-maxillary bone and the great gap in the lip is in the median line. Cleft palate (Fig. 92) is usually associated with hare-lip, which, when single, is almost always on one side, corresponding to the position of the suture between the lateral incisor and canine tooth. Some few cases of median hare-lip have been described. In double hare-lip there is a cleft on each side of the middle line (see page 111).

The outlines and the height of the arch of the palate vary greatly in different persons. A narrow palate with a high arch is common in idiots and certain degenerates.

The bones of the face are sometimes fractured as the result of direct violence. The two most commonly broken are the nasal bone and the mandible, and of these the latter is by far the most frequently fractured of all the bones of the face. Fracture of the nasal bone is for the most part transverse, and takes place about half an inch from the free margin. The broken portion may be displaced backward or more generally to one side by the force which produced the lesion, as there are no muscles here which can cause displacement. The malar bone is probably never broken alone; that is to say, unconnected with a fracture of the other bones of the face. The zygomatic arch is occasionally fractured, and when this occurs from direct violence, as is usually the case, the fragments may be displaced inward. This lesion is often attended with great difficulty or even inability to open and shut the mouth, and this has been stated to be due to the depressed fragments perforating the temporal muscle, but would appear rather to be caused by the injury done to the bony origin of the Masseter muscle. Fractures of the superior maxilla may vary much in degree, from the chipping off of a portion of the alveolar arch, a frequent accident when the "old key" instrument was used for the extraction of teeth, to an extensive comminution of the whole bone from severe violence, as the kick of a horse. The most common situation for a fracture of the mandible bone is in the neighborhood of the canine tooth, as at this spot the jaw is weakened by the deep socket for the fang of this tooth; it is next most frequently fractured at the angle; then at the symphysis, and finally the neck of the condyle or the coronoid process may be broken. Occasionally a double fracture may occur, one in either half of the bone. The fractures are usually compound,
from laceration of the mucous membrane covering the gums. The displacement is mainly the result of the same violence as produced the injury, but may be further increased by the action of the muscles passing from the neighborhood of the symphysis to the hyoid bone.

The superior and inferior maxillary bones are both of them frequently the seat of neerosis, though the disease affects the lower much more frequently than the upper jaw. It may be the result of periostitis, from tooth irritation, injury, or the action of some specific poison, as sulphur, or from salivation by mercury; it not infrequently occurs in children after attacks of the exanthematous fevers, and a special form occurs from the action of the fumes of phosphorus in persons engaged in the manufacture of matches.

Tumors attack the jaw bones not infrequently, and these may be either innocent or malignant: in the upper jaw cysts may occur in the antrum, constituting the so-called dropsy of the antrum; or, again, cysts may form in either jaw in connection with the teeth; either cysts connected with the roots of fully developed teeth, the "dental cyst;" or cysts connected with imperfectly developed teeth, the "dentigerous cyst." Solid innocent tumors include the fibroma, the chondroma, and the osteoma. Of malignant tumors there are the endotheliomata, the sarcomata, and the epitheliomata. The sarcomata are of various kinds, the spindle-celled, the round-celled, which are of a very malignant character, and the myeloid sarcomata, principally affecting the alveolar margin of the bone. Of the epitheliomata we find the squamous variety spreading to the bone from the palate or gum, and the cylindrical epithelioma originating in the antrum or nasal fossae.

Both superior and inferior maxillary bones occasionally require excision for tumors and in some other conditions. The upper jaw is removed by an incision from the inner canthus of the eye, along the side of the nose, round the ala, and down the middle line of the upper lip. A second incision is carried outward from the inner canthus of the line along the lower margin of the orbit as far as the prominence of the malar bone. The flap thus formed is reflected outward and the surface of the bone exposed, and the central incisor of the diseased side is removed. The connections of the bone to the other bones of the face are then divided with a narrow saw and bone-cutting forceps. They are (1) the junction with the malar bone, passing into the sphenomaxillary fissure; (2) the nasal process; a small portion of its upper extremity, connected with the nasal bone in front, the lachrymal bone behind, and the frontal bone above, being left; (3) the connection with the bone on the opposite side and the palate in the roof of the mouth. The bone is now firmly grasped with lion-jaw forceps, and by means of a rocking movement upward and downward the remaining attachments of the orbital plate with the ethmoid and the back of the bone with the palate, broken through. The soft palate is first separated from the hard with a scalpel, and is not removed. Occasionally in removing the upper jaw it will be found that the orbital plate can be spared, and this should always be done if possible. A horizontal saw-cut is to be made just below the infraorbital foramen and the bone cut through with a chisel and mallet. Lockwood has pointed out that in removing the upper jaw the surgeon must be careful in dividing the nasal process of the superior maxilla to preserve the internal orbital or palpebral ligament (Tendo oculi), because this ligament arises from the palpebral ligament, and if it is interfered with the eye will inevitably drop downward. Removal of one-half of the lower jaw is sometimes required. If possible, the section of the bone should be made to one side of the symphysis, so as to save the genial tubercles and the origin of the genio-hyoglossus muscle, as otherwise the tongue tends to fall backward and may produce suffocation. Having extracted the central or preferably the lateral incisor tooth, a vertical incision is made down to the bone, commencing at the free margin of the lip, and carried to the lower border of the bone; it is then carried along its lower border to the angle and up the posterior margin of the ramus to a level with the lobule of the ear. The flap thus formed is raised by separating all the structures attached to the outer surface of the bone. The jaw is now sawn through at the point where the tooth has been extracted, and the knife passed along the inner side of the jaw, separating the structures attached to this surface. The jaw is then grasped by the surgeon and strongly depressed, so as to bring down the coronoid process and enable the operator to sever the tendon of the Temporal muscle. The jaw can be now further depressed, care being taken not to evert it nor rotate it outward, which would endanger the internal maxillary artery, and the External pterygoid muscle is torn through or divided. The capsular ligament is now opened in front and the lateral ligaments divided, and the jaw removed with a few final touches of the knife.

The antrum of Highmore occasionally requires tapping for suppuration. This may be done through the socket of a tooth, preferably the first molar, the fangs of which are most intimately connected with the antrum, or through the facial aspect of the bone above the alveolar process. This latter method does not perhaps afford such efficient drainage, but there is less chance of food finding its way into the cavity. The operation may be performed by incising the mucous membrane above the second molar tooth, and driving a trocar or any sharp-pointed instrument into the cavity.
THE HYOID OR LINGUAL BONE (OS HYOIDEM).

The hyoid bone (Fig. 109) is named from its resemblance to the Greek upsilon; it is also called the lingual bone, because it supports the tongue and gives attachment to its numerous muscles. It is a bony arch, shaped like a horseshoe, and consisting of five segments: a body, two greater cornua, and two lesser cornua. It is suspended from the tip of the styloid processes of the temporal bone by ligamentous bands, the stylo-hyoid ligaments.

Body (corpus ossei hyoidei).—The body, or basi-hyal, forms the central part of the bone, and is of a quadrilateral form.

Surfaces.—Its anterior surface (Fig. 109), convex, directed forward and upward, is divided into two parts by a vertical ridge which descends along the median line and is crossed at right angles by a horizontal ridge, so that this surface is divided into four spaces or depressions. At the point of meeting of these two lines is a prominent elevation, the tubercle. The portion above the horizontal ridge is directed upward, and is sometimes described as the superior border. The anterior surface gives attachment to the Genio-hyoid in the greater part of its extent; above, to the Genio-hyo-glossus; below, to the Mylo-hyoid, Stylo-hyoid, and aponeurosis of the Digastric (suprahyoid aponeurosis); and between these to part of the Hyoglossus. The posterior surface is smooth, concave, directed backward and downward, and separated from the epiglottis by the thyro-hyoid membrane and by a quantity of loose areolar tissue. The lateral surfaces after middle life are joined to the greater cornua. In early life they are connected to the cornua by cartilaginous surfaces, and held together by ligaments, and occasionally a synovial membrane is found between them.

Borders.—The superior border is rounded, and gives attachment to the thyro-hyoid membrane, part of the Genio-hyo-glossi and Chondro-glossi muscles. The inferior border gives attachment, in front, to the Sterno-hyoid; behind, to the Omo-hyoid and to the part of the Thyro-hyoid at its junction with the great cornu. It also gives attachment to the Levator glandulae thyroideae when this muscle is present.

Greater Cornua (cornua majora).—The greater cornua or thyro-hyals project backward from the lateral surfaces of the body; they are flattened from above downward, diminish in size from before backward, and terminate posteriorly in a tubercle for the attachment of the lateral thyro-hyoid ligament. The outer surface gives attachment to the Hyoglossus, their upper border to the Middle constrictor of the pharynx, their lower border to part of the Thyro-hyoid muscle.

Lesser Cornua (cornua minora).—The lesser cornua, or cerato-hyals, are two small, conical-shaped prominences attached by their bases to the angles of junction between the body and greater cornua, and giving attachment by their apices to the stylo-hyoid ligaments. The smaller cornua are connected to the body of the bone by a distinct diarthrodial joint, which usually persists throughout life, but occasionally becomes ankylosed.

These ligaments in many animals are distinct bones, and in man are occasionally ossified to a certain extent.—Ed. of 15th English Edition.
Development.—By five centres: one for the body, and one for each cornu. Ossification commences in the body about the eighth month, and in the greater cornua toward the end of fetal life. Ossification of the lesser cornua commences some years after birth. Sometimes there are two centres for the body.

Attachment of Muscles.—Sterno-hyoid, Thyro-hyoid, Omo-hyoid, aponeurosis of the Digastric, Stylo-hyoid, Mylo-hyoid, Genio-hyoid, Genio-hyo-glossus, Chondro-glossus, Hyo-glossus, Middle constrictor of the pharynx, and occasionally a few fibres of the Inferior lingualis. It also gives attachment to the thyro-hyoidean membrane and the stylo-hyoid, thyro-hyoid, and hyo-epiglottic ligaments.

Surface Form.—The hyoid bone can be felt in the receding angle below the chin, and the finger can be carried along the whole length of the bone to the greater cornu, which is situated just below the angle of the jaw. This process of bone is best perceived by making pressure on one cornu, and so pushing the bone over to the opposite side, when the cornu of this side will be distinctly felt immediately beneath the skin. This process of bone is an important landmark in ligature of the lingual artery.

Surgical Anatomy.—The hyoid bone is occasionally fractured, generally from direct violence, as in the act of garroting or throttling. It is frequently found broken in those who have been hung. The great cornu is the part of the bone most frequently broken, but sometimes the fracture takes place through the body of the bone. In consequence of the muscles of the tongue having important connections with this bone, there is great pain upon any attempt being made to move the tongue, as in speaking or swallowing.

THE THORAX.

The thorax, or chest, is an osseo-cartilaginous cage the cavity of which (cavum thoracis) contains and protects the principal organs of respiration and circulation. It is conical in shape, being narrow above and broad below, flattened from before backward, and longer behind than in front. It is somewhat reniform on transverse section.

Boundaries.—The posterior surface is formed by the twelve thoracic vertebrae and the posterior part of the ribs. It is concave from above downward, and presents on each side of the middle line a deep groove, the vertebral groove, in consequence of the direction backward and outward which the ribs take from their vertebral extremities to their angles. The anterior surface is flattened or slightly convex, and inclined forward from above downward. It is formed by the sternum and costal cartilages. The lateral surfaces are convex; they are formed by the ribs, separated from each other by spaces. Each space is called an intercostal space (spatium intercostale). These are eleven in number, and are occupied by the intercostal muscles.

The superior or upper opening or aperture of the thorax, the inlet (apertura thoracis superior), is reniform in shape, being broader from side to side than from before backward. It is formed by the first thoracic vertebra behind, the upper margin of the sternum in front, and the first rib on each side. It slopes downward and forward, so that the anterior part of the ring is on a lower level than the posterior. The antero-posterior diameter is about two inches, and the transverse about four. The inferior or lower opening (apertura thoracis inferior) is formed by the twelfth thoracic vertebra behind, by the twelfth ribs at the sides, and in front by the cartilages of the eleventh, tenth, ninth, eighth, and seventh ribs, which ascend on either side and form an angle, the subcostal angle (angulus infrasternalis), from the apex of which the ensiform cartilage projects. It is wider transversely than from before backward. It slopes obliquely downward and backward, so that the cavity of the thorax is much deeper behind than in front. The Diaphragm closes in the opening forming the floor of the thorax.

In the female the thorax differs as follows from the male: 1. Its general capacity is less. 2. The sternum is shorter. 3. The upper margin of the sternum
is on a level with the lower part of the body of the third thoracic vertebra, whereas in the male it is on a level with the lower part of the body of the second thoracic vertebra. 4. The upper ribs are more movable, and so allow a greater enlargement of the upper part of the thorax than in the male.

The Sternum or Breast Bone.

The sternum (στέρνον, the chest), or breast bone (Figs. 110, 111), is a flat, narrow bone, situated in the median line of the front of the chest, and consisting, in the adult, of three portions. It has been likened to an ancient sword; the upper piece, representing the handle, is termed the manubrium sterni (presternum); the middle and largest piece, which represents the chief part of the blade, is termed the gladiolus (mesosternum or corpus sterni); and the inferior piece, which is likened to the point of the sword, is termed the ensiform or xiphoi$d process or appendix (processus xiphoideus or metasternum). In early youth the sternum is composed of six pieces or sternebre. In adult life the upper piece remains as the manubrium; the inferior piece remains as the xiphoi$d; and the other four pieces fuse together to form the gladiolus. In its natural position its inclination is oblique from above downward and forward. It is slightly convex in front, concave behind, broad above, becoming narrowed at the point where the first and second pieces are connected, after which it again widens a little, and is pointed at its extremity. Its average length in the adult is about seven inches, being rather longer in the male than in the female. At the junction of the manubrium and gladiolus is a distinct angle, the angulus sterni (angle of Ludovic or angle of Louis), the manubrium looking forward, the gladiolus also looking forward, but to a less degree. This angle is on a level with the second rib, and is produced by retraction of the upper portion of the thorax.

First Piece.—The first piece of the sternum, or the manubrium sterni (presternum), is of a somewhat triangular form, broad and thick above, narrow below at its junction with the middle piece.

Surfaces.—Its anterior surface, convex from side to side, concave from above downward, is smooth, and affords attachment on each side to the Pectoralis major and sternal origin of the Sterno-cleido-mastoid muscle. In well-marked bones the ridges limiting the attachment of these muscles are very distinct. Its posterior surface, concave and smooth, affords attachment on each side to the Sterno-hyoid and Sterno-thyroid muscles.

Borders.—The superior border, the thickest, presents at its centre the pre-sternal notch (incisura jugularis), and on each side an oval articular surface, the clavicular facet (incisura clavicularis), directed upward, backward, and outward, for articulation with the sternal end of the clavicle. The inferior border presents an oval, rough surface, covered in the recent state with a thin layer of cartilage, for articulation with the second portion of the bone (synchondrosis sternalis). The junction of the manubrium with the gladiolus is marked by a transverse ridge, which corresponds to the attachment on each side of the cartilage of the second rib. The lateral borders are marked above by a depression (incisura costalis I) for the first costal cartilage, and below by a small facet, which, with a similar facet on the upper angle of the middle portion of the bone, forms a notch (incisura costalis II) for the reception of the costal cartilage of the second rib. These articular surfaces are separated by a narrow, curved edge, which slopes from above downward and inward.

Second Piece.—The second piece of the sternum, the corpus sterni or gladiolus (mesosternum), considerably longer, narrower, and thinner than the first piece, is broader below than above.
THE SKELETON

Sternum and costal cartilages.

Fig. 110.—Sternum and costal cartilages.

Fig. 111.—Posterior surface of sternum.
Surfaces.—Its anterior surface (planum sternale) is nearly flat, directed upward and forward, and marked by three transverse lines which cross the bone opposite the third, fourth, and fifth articular depressions. These lines are produced by the union of the four separate pieces of which this part of the bone consists at an early period of life. At the junction of the third and fourth pieces is occasionally seen an orifice, the sternal foramen; it varies in size and form in different individuals, and pierces the bone from before backward. This surface affords attachment on each side to the sternal origin of the Pectoralis major. The posterior surface, slightly concave, is also marked by three transverse lines, but they are less distinct than those in front: this surface affords attachment below, on each side, to the Triangularis sterni muscle, and occasionally presents the posterior opening of the sternal foramen.

Borders.—The superior border presents an oval surface for articulation with the manubrium. The inferior border is narrow, and articulates with the ensiform appendix. Each lateral border presents, at each superior angle, a small facet, which, with a similar facet on the manubrium, forms a cavity for the cartilage of the second rib; the four succeeding angular depressions receive the cartilages of the third, fourth, fifth, and sixth ribs; whilst each inferior angle presents a small facet, which, with a corresponding one on the ensiform appendix, forms a notch for the cartilage of the seventh rib. These articular depressions are known as incisurae costales. They are separated by a series of curved interarticular intervals, which diminish in length from above downward, and correspond to the intercostal spaces. Most of the cartilages belonging to the true ribs, as will be seen from the foregoing description, articulate with the sternum at the line of junction of two of its primitive component segments. This is well seen in many of the lower animals, where the separate parts of the bone remain ununited longer than in man. In this respect a striking analogy exists between the mode of connection of the ribs with the vertebral column and the connection of the costal cartilages with the sternum.

Third Piece.—The third piece of the sternum, the ensiform or xiphoid appendix (processus xiphoideus or metasternum), is the smallest of the three; it is thin and elongated in form, cartilaginous in structure in youth, but more or less ossified at its upper part in the adult.

Surfaces.—Its anterior surface affords attachment to the chondro-xiphoid ligament; its posterior surface, to some of the fibres of the Diaphragm and Triangularis sterni muscles; its lateral borders, to the aponeurosis of the abdominal muscles. Above it articulates with the lower end of the gladiolus, and at each superior angle presents a facet (incisura costalis VII), for the lower half of the cartilage of the seventh rib; below, by its pointed extremity, it gives attachment to the linea alba. This portion of the sternum is very various in appearance, being sometimes pointed, broad, and thin, sometimes bifid or perforated by a round hole, occasionally curved or deflected considerably to one or the other side.

Structure.—The bone is composed of delicate cancellous structure, covered by a thin layer of compact tissue, which is thickest in the manubrium between the articular facets for the clavicles.

Development.—The cartilaginous sternum originally consists of two bars, situated one on either side of the mesial plane and connected with the rib cartilages of its own side. These two bars fuse with each other along the middle line, and the bone, including the ensiform appendix, is developed by six centres: one for the first piece or manubrium, four for the second piece or gladiolus, and one for the ensiform appendix. Up to the middle of foetal life the sternum is entirely cartilaginous, and when ossification takes place the ossific granules are deposited in the middle of the intervals between the articular depressions for the costal cartilages, in the following order (Fig. 112): In the first piece, between the fifth and sixth months; in the second and third, between the sixth and seventh months; in
the fourth piece, at the ninth month; in the fifth, within the first year or between the first and second years after birth; and in the ensiform appendix, between the second and the seventeenth or eighteenth years, by a single centre which makes its appearance at the upper part and proceeds gradually downward. To these may be added the occasional existence, as described by Breschet, of two small episternal centres, which make their appearance one on each side of the pre-sternal notch. They are probably vestiges of the episternal bone of the monotremata and lizards. It occasionally happens that some of the segments are formed from more than one centre, the number and position of which vary (Fig. 114). Thus, the first piece may have two, three, or even six centres. When two are present, they are generally situated one above the other, the upper one being the larger; the second piece has seldom more than one; the third, fourth, and fifth pieces are often formed from two centres placed laterally, the irregular union of which will serve to explain the occasional occurrence of the sternal foramen (Fig. 113),

![Image 1](image1)

![Image 2](image2)

![Image 3](image3)

![Image 4](image4)

or of the vertical fissure which occasionally intersects this part of the bone (Fig. 113), and which is further explained by the manner in which the cartilaginous matrix, in which ossification takes place, is formed. Union of the various centres of the gladiolus commences about puberty, from below, and proceeds upward, so that by the age of twenty-five they are all united, and this portion of bone consists of one piece. The ensiform cartilage becomes joined to the gladiolus about forty. The manubrium is occasionally but seldom joined to the gladiolus in advanced life

1 Sir George Humphry states that this is "probably the more complete condition."—Ed. of 15th English Edition.
by bone. When this union takes place, however, it is generally only superficial, a portion of the centre of the sutureal cartilage remaining unossified.

**Articulations.**—With the clavicles and seven costal cartilages on each side.

**Attachment of Muscles.**—To nine pairs and one single muscle: the Pectoralis major, Sterno-cleido-mastoid, Sterno-hyoid, Sterno-thyroid, Triangularis sterni, aponeuroses of the Obliquus externus, Obliquus internus, Transversalis, Rectus muscles, and Diaphragm.

**The Ribs (Costae).**

The ribs are elastic arches of bone, which form the chief part of the thoracic walls. They are twelve in number on each side; but this number may be increased by the development of a cervical or lumbar rib, or may be diminished to eleven. The first seven are connected behind with the spine and in front with the sternum, through the intervention of the costal cartilages; they are called **true, sternal, or vertebro-sternal ribs** (*costae verae*). The remaining five are **false ribs** (*costae spuriae*); of these, the first three have their cartilages attached to the cartilage of the rib above, and are called the **vertebro-chondral ribs**; the last two are free at their anterior extremities; they are termed **floating** or **vertebral ribs**. The ribs vary in their direction, the upper ones being less oblique than the lower. The extent of obliquity reaches its maximum at the ninth rib, and gradually decreases from that rib to the twelfth. The ribs are situated one below the other in such a manner that spaces are left between them. Each space is called an **intercostal space** (*spatium intercostale*). The length of these spaces corresponds to the length of the ribs and their cartilages; their breadth is greater in front than behind, and between the upper than between the lower ribs. The ribs increase in length from the first to the seventh, when they again diminish to the twelfth. In breadth they decrease from above downward; in the upper ten the greatest breadth is at the sternal extremity.

**Common Characters of the Ribs.**

A rib from the middle of the series should be taken in order to study the common characters of the ribs (Figs. 116, 117, and 118). Each rib presents two extremities, a **posterior** or **vertebral**, an **anterior** or **sternal**, and an intervening portion—the **body** or **shaft**.

**Posterior Extremity.**—The posterior or vertebral extremity presents for examination a **head**, **neck**, and **tuberosity**.

**The Head** (**capitulum costae**).—The head (Fig. 118) is marked by a kidney shaped articular surface, divided by a horizontal ridge (**crista capituli**) into two facets for articulation with the costal cavity formed by the junction of the bodies of two contiguous thoracic vertebrae; the upper facet is small, the inferior one of larger size; the ridge separating them serves for the attachment of the inter-articular ligament.

**The Neck** (**collum costae**).—The neck is that flattened portion of the rib which extends outward from the head; it is about an inch long, and is placed in front of the transverse process of the lower of the two vertebrae with which the head articulates. Its **anterior surface** is flat and smooth, its **posterior surface** is rough for the attachment of the middle costo-transverse ligament, and is perforated by numerous foramina, the direction of which is less constant than those found on the inner surface of the shaft. Of its two borders the **superior border** presents a rough crest (**crista colli costae**) for the attachment of the anterior costo-transverse ligament; its **inferior border** is rounded. On the posterior surface of the

1 Sometimes the eighth rib cartilage articulates with the sternum; this condition occurs more frequently on the right than on the left side.—En. of 15th English Edition.
neck, just where it joins the shaft, and nearer the lower than the upper border, is an eminence—the tuberosity, or tubercle.

**Tuberosity (tuberculum costae).**—The tuberosity, or tubercle, consists of an articular and a non-articular portion. The **articular portion** (facies articularis tuberculi costae), the more internal and inferior of the two, presents a small, oval surface for articulation with the extremity of the transverse process of the lower of the two vertebrae to which the head is connected. The **non-articular portion** is a rough elevation, which affords attachment to the posterior costo-transverse ligament. The tubercle is much more prominent in the upper than in the lower ribs.

**Anterior Extremity.**—The anterior or sternal extremity is flattened, and presents a porous, oval, concave depression, into which the costal cartilage is received.

**The Shaft (corpus costae).**—The shaft is thin and flat, so as to present two surfaces, an external and an internal, and two borders, a superior and an inferior.

**Surfaces.**—The **external surface** is convex, smooth and marked at its back part, a little in front of the tuberosity, by a prominent line, directed obliquely from above

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*Fig. 116.—A central rib of right side.*

*Fig. 117.—Ribs and articulations of the vertebrae. (Sappey.)*
downward and outward; this gives attachment to a tendon of the Ilio-costalis muscle or of one of its accessory portions, and is called the angle (angulus costae). At this point the rib is bent in two directions. If the rib is laid upon its lower border, it will be seen that the portion of the shaft in front of the angle rests upon this border, while the portion of the shaft behind the angle is bent inward and at the same time tilted upward. The interval between the angle and the tuberosity increases gradually from the second to the tenth rib. The portion of bone between these two parts is rounded, rough, and irregular, and serves for the attachment of the Longissimus dorsi muscle. The portion of bone between the tubercle and sternal extremity is also slightly twisted upon its own axis, the external surface looking downward behind the angle, a little upward in front of it. This surface presents, toward its sternal extremity, an oblique line, the anterior angle. The internal surface is concave, smooth, directed a little upward behind the angle, a little downward in front of it. This surface is marked by a ridge which com-

Fig. 118.—Vertebral extremity of a rib. External surface.

mences at the lower extremity of the head; it is strongly marked as far as the inner side of the angle, and gradually becomes lost at the junction of the anterior with the middle third of the bone. The interval between it and the inferior border presents a groove, subcostal groove (sulcus costae), for the intercostal vessels and nerve. At the back part of the bone this groove belongs to the inferior border, but just in front of the angle, where it is deepest and broadest, it corresponds to the internal surface. The superior edge of the groove is rounded; it serves for the attachment of the Internal intercostal muscle. The inferior edge corresponds to the lower margin of the rib and gives attachment to the External intercostal muscle. Within the groove are seen the orifices of numerous small foramina which traverse the wall of the shaft obliquely from before backward.

Borders.—The superior border, thick and rounded, is marked by an external and an internal lip, more distinct behind than in front; they serve for the attachment of the External and Internal intercostal muscles. The inferior border, thin and sharp, has attached to it the External intercostal muscle.

Peculiar Ribs.

The ribs which require especial consideration are five in number—viz., the first, second, tenth, eleventh, and twelfth.

First Rib.—The first rib (Fig. 119) is the shortest and the most curved of all the ribs; it is broad and flat, its surface looking upward and downward, and its borders inward and outward. The head is of small size, rounded, and presents only a single articular facet for articulation with the body of the first thoracic vertebra. The neck is narrow and rounded. The tuberosity, thick and prominent, rests on the outer border. There is no angle, but in this situation the rib is slightly bent, with the convexity of the bend upward, so that the head of the bone is directed downward. The upper surface of the shaft is marked by two shallow
depressions, separated by a small rough surface (tuberculum scaleni) for the attachment of the Scalenus anticus muscle—the shallow groove in front of it transmitting the subclavian vein, the deeper groove behind it (sulcus subclavia) the subclavian artery. Between the groove for the subclavian artery and the tuberosity is a rough surface, for the attachment of the Scalenus medius muscle. The under surface is smooth, and destitute of the groove observed on the other ribs. The outer border is convex, thick, and rounded, and at its posterior

part gives attachment to the first serration of the Serratus magnus; the inner is concave, thin, and sharp, and marked about its centre by the commencement of the rough surface for the Scalenus anticus. The anterior extremity is larger and thicker than any of the other ribs.

Second Rib.—The second rib (Fig. 120) is much longer than the first, but bears a very considerable resemblance to it in the direction of its curvature. The non-articular portion of the tuberosity is occasionally only slightly marked. The angle
is slight and situated close to the tuberosity, and the shaft is not twisted, so that both ends touch any plane surface upon which it may be laid; but there is a similar though slighter bend, with its convexity upward, to that found in the first rib. The shaft is not horizontal, like that of the first rib, its outer surface, which is convex, looking upward and a little outward. It presents, near the middle, a rough eminence, tuberositas costae II, for the attachment of the second and third digitations of the Serratus magnus; behind and above which is attached the Scalenus posterior. The inner surface, smooth and concave, is directed downward and a little inward; it presents a short groove toward its posterior part.

Tenth Rib.—The tenth rib (Fig. 121) has only a single articular facet on its head.

Eleventh and Twelfth Ribs.—The eleventh and twelfth ribs (Figs. 122 and 123) have each a single articular facet on the head, which is of rather large size; they have no neck or tuberosity, and are pointed at the extremity. The eleventh has a slight angle and a shallow groove on the lower border. The twelfth has neither, and is much shorter than the eleventh, and the head has a slight inclination downward. Sometimes the twelfth rib is even shorter than the first.

Structure.—The ribs consist of cancellous tissue enclosed in a thin, compact layer.

Development.—Each rib, with the exception of the last two, is developed by three centres: one for the shaft, one for the head, and one for the tubercle. The last two have only two centres, that for the tubercle being wanting. Ossification commences in the shaft of the ribs at a very early period, before its appearance in the vertebrae. The epiphysis of the head, which is of slightly angular shape, and that for the tubercle, of a lenticular form, make their appearance between the sixteenth and twentieth years, and are not united to the rest of the bone until about the twenty-fifth year.

Attachment of Muscles.—To nineteen: The Internal and External intercostals, Scalenus anticus, Scalenus medius, Scalenus posterior, Pectoralis minor, Serratus magnus, Obliquis externus, Quadratus lumborum, Diaphragm, Latissimus dorsi, Serratus posterior superior, Serratus posterior inferior, Ilio-costalis, Musculus accessorius ad ilio-costalem, Longissimus dorsi, Cervicalis ascendens, Levatores costarum, and Infracostales.

The Costal Cartilages.

The costal cartilage (cartilago costalis) (Fig. 110) is white, hyaline cartilage. The cartilages serve to prolong the ribs forward to the front of the chest, and they contribute very materially to the elasticity of its walls. The first seven are connected with the sternum, the next three with the lower border of the cartilage of the preceding rib. The cartilages of the last two ribs have pointed extremities, which terminate in free ends in the walls of the abdomen. Like the ribs, the costal cartilages vary in their length, breadth, and direction. They increase in length from the first to the seventh, then gradually diminish to the last. They diminish in breadth, as well as the intervals between them, from the first to the last. They are broad at their attachment to the ribs, and taper toward their sternal extremities, excepting the first two, which are of the same breadth throughout, and the sixth, seventh, and eighth, which are enlarged where their margins are in contact. In direction they also vary: the first descends a little, the second is horizontal, the third ascends slightly, while all the rest follow the course of the ribs for a short extent, and then ascend to the sternum or preceding cartilage. Each costal cartilage presents two surfaces, two borders, and two extremities.

Surfaces.—The anterior surface is convex, and looks forward and upward: that of the first gives attachment to the costo-clavicular ligament and the Subclaviius muscle; that of the second, third, fourth, fifth, and sixth, at their sternal ends,
to the Pectoralis major. The others are covered by, and give partial attachment to, some of the great flat muscles of the abdomen. The posterior surface is concave, and directed backward and downward, the first giving attachment to the Sterno-thyroid, the third to the sixth inclusive to the Triangularis sterni, and the six or seven inferior ones to the Transversalis muscle and the Diaphragm.

Borders.—Of the two borders, the superior border is concave, the inferior convex; they afford attachment to the internal Intercostal muscles, the upper border of the sixth giving attachment to the Pectoralis major muscle. The contiguous borders of the sixth, seventh, and eighth, and sometimes the ninth and tenth, costal cartilages present small, smooth, oblong-shaped facets at the points where they articulate.

Extremities.—Of the two extremities, the outer extremity is continuous with the osseous tissue of the rib to which it belongs. The inner extremity of the first is continuous with the sternum; the six succeeding ones have rounded extremities, which are received into shallow concavities on the lateral margins of the sternum. The inner extremities of the eighth, ninth, and tenth costal cartilages are pointed, and are connected with the cartilage above. Those of the eleventh and twelfth are free and pointed.

The costal cartilages are most elastic in youth, those of the false ribs being more so than the true. In old age they become of a deep yellow color, and are prone to calcify.

Attachment of Muscles.—To nine: the Subclavius, Sterno-thyroid, Pectoralis major, Internal oblique, Transversalis, Rectus, Diaphragm, Triangularis sterni, and Internal intercostals.

Surface Form.—The bones of the chest are to a very considerable extent covered by muscles, so that in the strongly developed muscular subject they are for the most part concealed. In the emaciated subject, on the other hand, the ribs, especially in the lower and lateral region, stand out as prominent ridges with the sunken, intercostal spaces between them.

In the middle line, in front, the superficial surface of the sternum is to be felt throughout its entire length, at the bottom of a deep median furrow situated between the two great pectoral muscles and called the sternal furrow. These muscles overlap the anterior surface somewhat, so that the whole of the sternum in its entire width is not subcutaneous; and this overlapping is greater opposite the centre of the bone than above and below, so that the furrow is wider at its upper and lower parts, but narrower in the middle. The centre of the upper border of the sternum is visible, constituting the pre-sternal notch, but the lateral parts of this border are obscured by the tendinous origins of the Sterno-mastoid muscles, which present themselves as oblique tendinous cords, which narrow and deepen the notch. Lower down on the subcutaneous surface a well-defined transverse ridge, the angle of Ludwig, is always to be felt. This denotes the line of junction of the manubrium and body of the bone, and is a useful guide to the second costal cartilage, and thus to the identity of any given rib. The second rib being found through its costal cartilage, it is easy to count downward and find any other. From the middle of the sternum the furrow spreads out, and, exposing more of the surface of the body of the bone, terminates below in a sudden depression, the infrasternal depression or pit of the stomach (scrobiulus cordis), which corresponds to the ensiform cartilage. This depression lies between the cartilages of the seventh ribs, and in it the ensiform cartilage may be felt. The sternum in its vertical diameter presents a general convexity forward, the most prominent point of which is at the joint between the manubrium and gladiolus.

On each side of the sternum the costal cartilages and ribs on the front of the chest are partially obscured by the great pectoral muscles; through which, however, they are to be felt as ridges, with yielding intervals between them, corresponding to the intercostal spaces. Of these spaces, the one between the second and third ribs is the widest, the next two somewhat narrower, and the remainder, with the exception of the last two, comparatively narrow.

The lower border of the Pectoralis major muscle corresponds to the fifth rib, and below this, on the front of the chest, the broad, flat outline of the ribs, as they begin to ascend, and the more rounded outline of the costal cartilages, are often visible. The lower boundary of the front of the thorax, the abdomino-thoracic arch, which is most plainly seen by arching the body backward, is formed by the ensiform cartilage and the cartilages of the seventh, eighth, ninth, and tenth ribs, and the extremites of the eleventh and twelfth ribs or their cartilages.

1 The first and seventh also, occasionally, give origin to the same muscle.—Ed. of 15th English Edition.
On each side of the chest, from the axilla downward, the flattened external surfaces of the ribs may be defined in the form of oblique ridges, separated by depressions corresponding to the intercostal spaces. They are, however, covered by muscles, which obscure their outline to a certain extent in the strongly developed. Nevertheless, the ribs, with the exception of the first, can generally be followed over the front and sides of the chest without difficulty. The first rib, being almost completely covered by the clavicle and scapula, can only be distinguished in a small portion of its extent. At the back the angles of the ribs form a slightly-marked oblique line on each side of and some distance from the vertebral spines. This line diverges somewhat as it descends, and external to it is a broad, convex surface caused by the projection of the ribs beyond their angles. Over this surface, except where covered by the scapula, the individual ribs can be distinguished.

Surgical Anatomy.—Malformations of the sternum present nothing of surgical importance beyond the fact that abscesses of the mediastinum may sometimes escape through the sternal foramen. Fractures of the sternum are by no means common, owing, no doubt, to the elasticity of the ribs and their cartilages, which support it like so many springs. When broken it is frequently associated with fracture of the spine, and may be caused by forcibly bending the body either backward or forward until the chin becomes impacted against the top of the sternum. It may also be fractured by direct violence or by muscular action. The fracture usually occurs in the upper half of the body of the bone. Dislocation of the gladiolus from the manubrium also takes place, and is sometimes described as a fracture.

The bone, cancellous in structure and being subcutaneous, is frequently the seat of gummatous tumors, and not uncommonly is affected with caries. Occasionally the bone, and especially its eburnous appendix, becomes altered in shape and driven inward by the pressure, in working of tools against the chest.

The ribs are frequently broken, though from their connections and shape they are able to withstand great force, yielding under the injury and recovering themselves like a spring. The middle of the series are the ones most liable to fracture. The first, and to a less extent the second, being protected by the clavicle, are rarely fractured; and the eleventh and twelfth, on account of their loose and floating condition, enjoy a like immunity. The fracture generally occurs from indirect violence, from forcible compression of the chest-wall, and the bone then gives way at its weakest part—i.e., just in front of the angle. But the ribs may also be broken by direct violence, when the bone gives way and is driven inward at the point struck, or they may be broken by muscular action. It seems probable, however, that in the latter case the bone has undergone some atrophic changes. Fracture of the ribs is frequently complicated with some injury to the viscera contained within the thorax or upper part of the abdominal cavity, and this is most likely to occur in fractures from direct violence. Occasionally supernumerary ribs exist. They may come from the lumbar vertebrae or from the cervical vertebrae. A lumbar rib does not cause discomfort. A cervical rib is due to freedom of the costal element of the seventh cervical vertebra. In nearly two-thirds of the reported cases the condition is double. It rarely produces symptoms until after the twentieth year. The symptoms are a superficial pulsation of the subclavian artery, a prominence which can be felt, and evidences of pressure in the brachial plexus (Carl Beck). Beck divides the different types of the condition as follows: "(a) Slight degree: The cervical rib reaches beyond the transverse process. (b) More advanced: The cervical rib reaches beyond the transverse process, either with a free end or touching the first rib. (c) Almost complete: The connection between the cartilage of the first rib is formed either by means of a distinct band or by the end of its long body. (d) Complete: It has become a true rib and possesses a true cartilage which unites with the cartilage of the first rib." A very rare condition is a rib from the sixth cervical vertebra. The diagnosis is confirmed by the x-rays. The treatment of cervical rib is excision.

Fracture of the costal cartilages may also take place, though it is a comparatively rare injury. The thorax is frequently found to be altered in shape in certain diseases.

The shape of the rickety thorax is produced chiefly by atmospheric pressure. The balance between the air on the inside of the chest and the outside during some stage of respiration is not equal, the preponderance being in favor of the air outside; and this, acting on the softened ribs, causes them to be forced in at the junction of the cartilages with the bones, which is the weakest part. In consequence of this the sternum projects forward, with a deep depression on either side caused by the sinking in of the softened ribs. The depression is less on the left side, on account of the ribs being supported by the heart. The condition is known as pigeon-breast. The lower ribs, however, are not involved in this deformity, as they are prevented from falling in by the presence of the stomach, liver, and spleen. And when the liver and spleen are enlarged, as they sometimes are in rickets, the lower ribs may be pushed outward: this causes a transverse constriction just above the costal arch. The anterior extremities of the ribs are usually enlarged in rickets, giving rise to what has been termed the rickety rosary. The phthisical

2 W. E. Beatty's Human Anatomy, p. 155.
chest is often long and narrow, flattened from before backward, and with great obliquity of the ribs and projection of the scapula. In pulmonary emphysema the chest is enlarged in all its diameters, and presents on section an almost circular outline. It has received the name of the barrel-shaped chest. In severe cases of lateral curvature of the spine the thorax becomes much distorted. In consequence of the rotation of the bodies of the vertebrae which takes place in this disease the ribs opposite the convexity of the thoracic curve become extremely convex behind, being thrown out and bulging, and at the same time flattened in front, so that the two ends of the same rib are almost parallel. Coincident with this, the ribs on the opposite side, on the concavity of the curve, are sunk and depressed behind and bulging and convex in front. In addition to this the ribs become occasionally welded together by bony material.

The ribs are frequently the seat of carriers leading to abscesses and sinuses, which may burrow to a considerable extent over the wall of the chest. The only special anatomical point in connection with abscesses and sinuses is that care must be taken in dealing with them that the intercostal space is not punctured and the pleural cavity opened or the intercostal vessels wounded, as the necrosed portion of bone is generally situated on the internal surface of the rib.

In cases of empyema the chest requires opening to evacuate the pus. There is considerable difference of opinion as to the best position to do this. Probably the best place for intercostal drainage is between the fifth and sixth ribs, in or a little in front of the mid-axillary line. This is the last part of the cavity to be closed by the expansion of the lung; it is not thickly covered by soft parts; the space between the two ribs is sufficiently great to allow of the introduction of a fair-sized drainage-tube, and when the patient is confined to bed he does not lie upon the drainage-tube as he does when the opening is posterior. Better than intercostal drainage in the vast majority of cases is rib resection and drainage. A portion of the fifth or sixth rib should be removed in the mid-axillary line. In chronic empyema the lung becomes shrunk and adherent and simple drainage will not bring about a cure. It is necessary in such cases to do an operation that will permit of collapse of the chest wall. Estlander's operation consists in resecting a portion of every rib which overlies the cavity of the empyema. Schede's operation consists in removing ribs from the second rib down over the empyema cavity. The ribs are removed from cartilages to angles, and intercostal muscles and the parietal layer of the pleura are also taken away. Fowler and de Lorme not only practice extensive rib resection and remove the parietal layer of the pleura, but also remove the pulmonary pleura (total pleurectomy or pulmonary decortication).

THE EXTREMITIES.

The extremities, or limbs, are those long, jointed appendages of the body which are connected with the trunk by one end and free in the rest of their extent. They are four in number: an upper or thoracic pair, connected with the thorax through the intervention of the shoulder, and subservient mainly toprehension; and a lower pair, connected with the pelvis, intended for support and locomotion. Both pairs of limbs are constructed after one common type, so that they present numerous analogies, while at the same time certain differences are observed between the upper and lower pair, dependent on the peculiar offices they have to perform.

The bones by which the upper and lower limbs are attached to the trunk are named respectively the shoulder and pelvic girdles, and they are constructed on the same general type, though presenting certain modifications relating to the different uses to which the upper and lower limbs are respectively applied. The shoulder girdle is formed by the scapulae and clavicles, and is imperfect in front and behind. In front, however, the girdle is completed by the upper end of the sternum, with which the inner extremities of the clavicle articulate. Behind, the girdle is widely imperfect and the scapula is connected to the trunk by muscles only. The pelvic girdle is formed by the innominate bones, and is completed in front through the symphysis pubis, at which the two innominate bones articulate with each other. It is imperfect behind, but the intervening gap is filled in by the upper part of the sacrum. The pelvic girdle, therefore, presents, with the sacrum, a complete ring, comparatively fixed, and presenting an arched form which confines upon it a solidity manifestly intended for the support of the trunk, and in marked contrast to the lightness and mobility of the shoulder girdle.
With regard to the morphology of these girdles, the blade of the scapula is generally believed to correspond to the ilium; but with regard to the clavicles there is some difference of opinion: formerly it was believed that they corresponded to the osa pubis, meeting at the symphysis, but it is now generally taught that the clavicle has no homologue in the pelvic girdle, and that the osa pubis and ischium are represented by the small coracoid process in man and most mammals.

THE UPPER EXTREMITY.

The bones of the upper extremity consist of those of the shoulder girdle, of the arm, the forearm, and the hand.

THE SHOULDER GIRDLE.

The shoulder girdle consists of the clavicle and the scapula.

The Clavicle or Collar Bone (Clavicula).

The clavicle or key bone (clavis, a key) obtains its name from its supposed resemblance to the key used by the Romans. It forms the anterior portion of the shoulder girdle. It is a long bone, curved somewhat like the italic letter j, and placed nearly horizontally at the upper and anterior part of the thorax, immediately above the first rib. It articulates by its inner extremity with the upper border of the sternum, and by its outer extremity with the acromion process of the scapula, serving to sustain the upper extremity in the various positions which it assumes, whilst at the same time it allows of great latitude of motion in the arm. It presents a double curvature when looked at in front, the convexity being forward at the sternal end and the concavity at the scapular end. Its outer third is flattened from above downward, and extends, in the natural position of the bone, from a point opposite the coracoid process to the acromion. Its inner two-thirds are of a prismatic form, and extend from the sternum to a point opposite the coracoid process of the scapula.

Outer, External, or Flattened Portion.—The outer third is flattened from above downward, so as to present two surfaces, an upper and a lower; and two borders, an anterior and a posterior.

Surfaces.—The upper surface is flattened, rough, marked by impressions for the attachment of the Deltoid in front and the Trapezius behind; between these two impressions, externally, a small portion of the bone is subcutaneous. The under surface is flattened. At its posterior border, a little external to the point where the prismatic joins with the flattened portion, is a rough eminence, the conoid tubercle (tuberositas coracoidea); this, in the natural position of the bone, surmounts the coracoid process of the scapula and gives attachments to the coracoid ligament. From this tubercle an oblique line, occasionally a depression, passes forward and outward to near the outer end of the anterior border; it is called the oblique line or trapezoid ridge, and affords attachment to the trapezoid ligament.

Borders.—The anterior border is concave, thin, and rough, and gives attachment to the Deltoid; it occasionally presents, at its inner end, at the commencement of the deltoid impression, a tubercle, the deltoid tubercle, which is sometimes to be felt in the living subject. The posterior border is convex, rough, broader than the anterior, and gives attachment to the Trapezius.

The clavicle acts especially as a fulcrum to enable the muscles to give lateral motion to the arm. It is accordingly absent in those animals whose fore limbs are used only for progression, but is present for the most part in those animals whose anterior extremities are clawed and used for prehension, though in some of them—as, for instance, in a large number of the carnivora—it is merely a rudimentary bone suspended among the muscles, and not articulating with the scapula or sternum.—En. of 15th English Edition.
Inner, Internal, or Prismatic Portion.—The prismatic portion forms the inner two-thirds of the bone. It is curved so as to be convex in front, concave behind, and is marked by three borders, separating three surfaces.

Borders.—The anterior border is continuous with the anterior margin of the flat portion. At its commencement it is smooth, and corresponds to the interval between the attachment of the Pectoralis major and Deltoid muscles; at the inner half of the clavicle it forms the lower boundary of an elliptical space for the attachment of the clavicular portion of the Pectoralis major, and approaches the posterior border of the bone. The superior border is continuous with the posterior margin of the flat portion, and separates the anterior from the posterior surface. At its commencement it is smooth and rounded, becomes rough toward the inner third for the attachment of the Sterno-mastoid muscle, and terminates at the upper angle of the sternal extremity. The posterior or subclavian border separates the posterior from the inferior surface, and extends from the conoid tubercle to the rhomboid impression. It forms the posterior boundary of the groove for the Subclavius muscle, and gives attachment to a layer of cervical fascia covering the Omo-hyoid muscle.

Surfaces.—The anterior surface is included between the superior and anterior borders. It is directed forward and a little upward at the sternal end, outward and still more upward at the acromial extremity, where it becomes continuous with the upper surface of the flat portion. Externally, it is smooth, convex, nearly subcutaneous, being covered only by the Platysma; but, corresponding to the inner half of the bone, it is divided by a more or less prominent line into two parts: a lower portion, elliptical in form, rough, and slightly convex, for the attachment of the Pectoralis major; and an upper part, which is rough, for the attachment of the Sterno-cleido-mastoid. Between the two muscular impressions is a small subcutaneous interval. The posterior or cervical surface is smooth, flat, and looks backward toward the root of the neck. It is limited, above, by the superior border; below, by the subclavian border; internally, by the margin of the sternal extremity; externally, it is continuous with the posterior border of the flat portion. It is concave from within outward, and is in relation, by its lower part, with the suprascapular vessels. This surface, at about the junction of the inner and outer curves, is also in close relation with the brachial plexus and subclavian vessels. It gives attachment, near the sternal extremity, to part of the Sterno-hyoid muscle; and presents, at or near the middle, a foramen, nutrient foramen (foramen nutricium). It opens into a canal, nutrient canal (canalis nutricius), which is directed obliquely outward and transmits the chief nutrient artery of the bone. Sometimes there are two foramina on the posterior surface, or one on the posterior, and one on the inferior surface. The inferior or subclavian surface is bounded, in front, by the anterior border; behind, by the subclavian border. It is narrow internally, but gradually increases in width externally, and is continuous with the under surface of the flat portion. Commencing at the sternal extremity may be seen a small facet, the costal facet, for articulation with the cartilage of the first rib. This is continuous with the articular surface at the sternal end of the bone. External to this is a broad, rough surface, the rhomboid impression (tuberositas costalis), rather more than an inch in length, for the attachment of the costo-clavicular (rhomboid) ligament. The remaining part of this surface is occupied by a longitudinal groove, the subclavian groove, broad and smooth externally, narrow and more uneven internally; it gives attachment to the Subclavius muscle, and by its margins to the costo-coracoid membrane, which splits to enclose the muscle. Not infrequently this groove is subdivided into two parts by a longitudinal line, which gives attachment to the intermuscular septum of the Subclavius muscle.
Internal or Sternal Extremity (*extremitas sternalis*).—The internal or sternal extremity of the clavicle is triangular in form, directed inward and a little downward and forward; and presents an **articular facet** (*facies articularis sternalis*), concave from before backward, convex from above downward, which articulates with the sternum through the intervention of an interarticular fibro-cartilage; the circumference of the articular surface is rough, for the attachment of numerous ligaments. The **posterior border** of this surface is prolonged backward, so as to increase the size of the articular facet; the **upper border** gives attachment to the interarticular fibro-cartilage, and the **lower border** is continuous with the costal facet on the inner end of the inferior or subclavian surface, which articulates with the cartilage of the first rib.

Outer or Acromial Extremity (*extremitas acromialis*).—The outer or acromial extremity, directed outward and forward, presents a small, flattened, oval facet, **acromial surface** (*facies articularis acromialis*), which looks obliquely downward, for articulation with the acromion process of the scapula. The circumference of the articular facet is rough, especially above, for the attachment of the acromio-clavicular ligaments.

**Peculiarities of the Bone in the Sexes and in Individuals.**—In the female the clavicle is generally shorter, thinner, less curved, and smoother than in the male. In those persons who perform considerable manual labor, which brings into constant action the muscles connected with this bone, it becomes thicker and more curved, its ridges for muscular attachment become prominently marked. The right clavicle is generally longer, thicker, and rougher than the left.

**Structure.**—The shaft, as well as the extremities, consists of cancellous tissue, invested in a compact layer much thicker in the middle than at either end. The clavicle is highly elastic, by reason of its curves. From the experiments of Mr. Ward it has been shown that it possesses sufficient longitudinal elastic force to project its own weight nearly two feet on a level surface when a smart blow is struck on it; and sufficient transverse elastic force, opposite the centre of its
anterior convexity, to throw its own weight about a foot. This extent of elastic power must serve to moderate very considerably the effect of concussions received upon the point of the shoulder.

Development.—By two centres: one for the shaft and outer extremity and one for the sternal extremity. The centre for the shaft appears very early, before any other bone—according to Boccard, as early as the thirtieth day. The centre for the sternal end makes its appearance about the eighteenth or twentieth year, and unites with the rest of the bone about the twenty-fifth year.

Articulations.—With the sternum, scapula, and cartilage of the first rib.

Attachment of Muscles.—To six: the Sterno-cléido-mastoid, Trapezius, Pectoralis major, Deltoid, Subclavius, and Sterno-hyoid.

Surface Form.—The clavicle can be felt throughout its entire length, even in persons who are very fat. Commencing at the inner end, the enlarged sternal extremity, where the bone projects above the upper margin of the sternum, can be felt, forming with the sternum and the rounded tendon of the Sterno-mastoid a V-shaped notch, the pre-sternal notch. Passing outward, the shaft of the bone can be felt immediately under the skin, with its convexity forward in the inner two-thirds, the surface partially obscured above and below by the attachments of the Sterno-mastoid and Pectoralis major muscles. In the outer third it forms a gentle curve backward, and terminates at the outer end in a somewhat enlarged extremity which articulates with the acromial process of the scapula. The direction of the clavicle is almost, if not quite, horizontal when the arm is lying quietly by the side, though in well-developed subjects it may incline a little upward at its outer end. Its direction is, however, very changeable, altering with the varying movements of the shoulder-joint.

Surgical Anatomy.—The clavicle is the most frequently fractured of any single bone in the body. This is due to the fact that it is much exposed to violence, and is the only bony connection between the upper limb and the trunk. The bone, moreover, is slender, and is very superficial. The bone may be broken by direct or indirect violence or by muscular action. The most common cause is, however, from indirect violence, and the bone then gives way at the junction of the fixed outer one-third with the movable inner two-thirds of the bone. This is the weakest and most slender part of the bone. The fracture is generally oblique, and the displacement of the outer fragments is inward, away from the surface of the body; hence compound fracture of the clavicle is of rare occurrence. The inner fragment as a rule is little displaced (page 505). Beneath the bone the main vessels of the upper limb and the great nerve-cords of the brachial plexus lie on the first rib, and are liable to be wounded in fracture, especially in fracture from direct violence, when the force of the blow drives the broken ends inward. Fortunately, the Subclavius muscle is interposed between these structures and the clavicle, and this often protects them from injury.

The clavicle is not uncommonly the seat of sarcomatous tumors, rendering the operation of excision of the entire bone necessary. This operation is best performed by exposing the bone freely, disarticulating at the acromial end, and turning it inward. The removal of the outer part is comparatively easy, but resection of the inner part is fraught with difficulty, the main danger being the risk of wounding the great veins which are in relation with its under surface.

The Scapula or Shoulder Blade.

The scapula (σκέπαλος, a spade), or blade bone, forms the back part of the shoulder girdle. It is a large, flat bone, triangular in shape, situated at the posterior aspect and side of the thorax, between the second and seventh, or sometimes the eighth, ribs, its internal border or base being about an inch from and nearly but not quite parallel with the spinous processes of the vertebrae, so that it is rather closer to them above than below. It presents for examination: two surfaces, three borders, and three angles.

Surfaces. Anterior or Costal Surface, Ventral Aspect or Venter (facies costalis).—The anterior surface (Fig. 126) presents a broad concavity, the subscapular fossa (fossa subscapularis). It is marked, in the inner two-thirds, by several oblique ridges (lineae musculares), which pass from behind outward and upward; the outer third is smooth. The oblique ridges give attachment to the tendinous intersections, and the surfaces between them to the fleshy fibres, of the Subscapularis muscle. The anterior third of the fossa, which is smooth, is covered
by, but does not afford attachment to, the fibres of this muscle. The venter is separated from the internal border by a smooth, triangular margin at the superior and inferior angles, and in the interval between these by a narrow edge which is often deficient. This marginal surface affords attachment throughout its entire extent to the Serratus magnus muscle. The subscapular fossa presents a transverse depression at its upper part, where the bone appears to be bent on itself, forming a considerable angle, called the subscapular angle (angulus subscapularis), thus giving greater strength to the body of the bone from its arched form, whilst the summit of the arch serves to support the spine and acromion process. It is in

![Diagram of the scapula](image)

**Fig. 126.** Left scapula. Anterior surface or venter.

this situation that the fossa is deepest, so that the thickest part of the Subscapularis muscle lies in a line perpendicular to the plane of the glenoid cavity, and must consequently operate most effectively on the head of the humerus, which is contained in that cavity. The portion of bone between the suprascapular notch and the infraglenoid tubercle is sometimes called the surgical neck.

**Posterior or Dorsal Surface or Dorsum** (facies dorsalis).—The posterior or dorsal surface (Fig. 127) is arched from above downward, alternately concave and
convex from side to side. It is subdivided unequally into two parts by the spine; the portion above the spine is called the supraspinous fossa, and that below it the infraspinous fossa.

The supraspinous fossa (fossa supraspinata), the smaller of the two, is concave, smooth, and broader at the vertebral than at the humeral extremity. It affords attachment by its inner two-thirds to the Supraspinatus muscle.

The infraspinous fossa (fossa infraspinata) is much larger than the preceding; toward its vertebral margin a shallow concavity is seen at its upper part; its centre presents a prominent convexity, whilst toward the axillary border is a deep groove which runs from the upper toward the lower part. The inner two-thirds of this surface affords attachment to the Infraspinatus muscle; the outer third is only covered by it, without giving origin to its fibres. This surface is separated from the axillary border by an elevated ridge, which runs from the lower margin of the glenoid cavity downward and backward to the posterior border, about an inch above the in-
ferior angle. The ridge serves for the attachment of a strong aponeurosis which separates the Infra-spinatus from the two Teres muscles. The surface of bone between this line and the axillary border is narrow in the upper two-thirds of its extent, and traversed near its centre by a groove for the passage of the dorsalis scapulae vessels; it affords attachment to the Teres minor muscle. Its lower third presents a broader, somewhat triangular surface, which gives origin to the Teres major, and over which the Latissimus dorsi glides; sometimes the latter muscle takes origin by a few fibres from this part. The broad and narrow portions of bone above alluded to are separated by an oblique line which runs from the axillary border, downward and backward, to meet the elevated ridge; to it is attached the aponeurosis separating the two Teres muscles from each other.

The spine (spina scapulae) is a prominent plate of bone which crosses obliquely the inner four-fifths of the dorsum of the scapula at its upper part, and separates the supra-from the infraspinous fossa: it commences at the vertebral border by a smooth, triangular surface, over which the Trapezius glides, separated from the bone by a bursa, and, gradually becoming more elevated as it passes outward, terminates in the acromion process, which overhangs the shoulder-joint. The spine is triangular and flattened from above downward, its apex corresponding to the vertebral border, its base (which is directed outward) to the neck of the scapula. It presents two surfaces and three borders. Its superior surface is concave, assists in forming the supraspinous fossa, and affords attachment to part of the Supra-spinatus muscle. Its inferior surface forms part of the infraspinous fossa, gives origin to part of the Infra-spinatus muscle, and presents near its centre the orifice of a nutrient canal. Of the three borders, the anterior is attached to the dorsum of the bone; the posterior, or crest of the spine, is broad, and presents two lips and an intervening rough interval. To the superior lip is attached the Trapezius to the extent shown in the figure. A rough tubercle is generally seen occupying that portion of the spine which receives the insertion of the middle and inferior fibres of this muscle. To the inferior lip, throughout its whole length, is attached the Deltoid. The intervals between the lips is also partly covered by the tendinous fibres of these muscles. The external border, or base, the shortest of the three, is slightly concave, its edge thick and round, continuous above with the under surface of the acromion process, below with the neck of the scapula. The narrow portion of bone external to this border, and separating it from the glenoid cavity, is called the great scapular notch, and serves to connect the supra- and infraspinous fossae.

The acromion process (acromion), so called from forming the summit of the shoulder (ἄκρον, a summit; ἀκρος, the shoulder), is a large and somewhat triangular or oblong process, flattened from behind forward, directed at first a little outward, and then curving forward and upward, so as to overhang the glenoid cavity. Its upper surface, directed upward, backward, and outward, is convex, rough, and gives attachment to some fibres of the Deltoid, and in the rest of its extent it is subcutaneous. Its under surface is smooth and concave. Its outer border is thick and irregular, and presents three or four tubercles for the tendinous origins of the Deltoid muscle. Its inner margin, shorter than the outer, is concave, gives attachment to a portion of the Trapezius muscle, and presents about its centre a small oval surface for articulation with the acromial end of the clavicle. Its apex, which corresponds to the point of meeting of these two borders in front, is thin, and has attached to it the coraco-acromial ligament.

Margins or Borders of the Scapula. Superior Border (margo superior).—Of the three borders of the scapula, the superior is the shortest and thinnest; it is concave and extends from the internal angle to the coracoid process. At its outer part is a deep, semicircular notch, the suprascapular notch (incisura scapulae), formed partly by the base of the coracoid process. The notch is converted into a foramen by the
transverse ligament, and serves for the passage of the suprascapular nerve. Sometimes this foramen is entirely surrounded by bone. The adjacent margin of the superior border affords attachment to the Omohyoid muscle.

External or Axillary Border (margo axillaris).—The external or axillary border is the thickest of the three. It commences above at the lower margin of the glenoid cavity, and inclines obliquely downward and backward to the inferior angle. Immediately below the glenoid cavity is a rough impression, the infraglenoid tubercle (tuberositas infraglenoidalis), about an inch in length, which affords attachment to the long head of the Triceps muscle; in front of this is a longitudinal groove, which extends as far as the lower third of the axillary border and affords origin to part of the Subscapularis muscle. The inferior third of this border, which is thin and sharp, serves for the attachment of a few fibres of the Teres major behind and the Subscapularis in front.

Internal or Vertebral Border (margo vertebralis).—The internal or vertebral border, also named the base, is the longest of the three, and extends from the internal to the inferior angle of the bone. It is arched, is intermediate in thickness between the superior and the external borders, and the portion of it above the spine is bent considerably outward, so as to form an obtuse angle with the lower part. The vertebral border presents an anterior lip, a posterior lip, and an intermediate space. The anterior lip affords attachment to the Serratus magnus; the posterior lip, to the Supraspinatus above the spine, the Infraspinatus below; the interval between the two lips, to the Levator anguli scapulae above the triangular surface at the commencement of the spine, the Rhomboideus minor to the edge of that surface; the Rhomboideus major being attached by means of a fibrous arch connected above to the lower part of the triangular surface at the base of the spine, and below to the lower part of the posterior border.

Angles. Internal or Medial Angle (angulus medialis).—Of the three angles, the internal, formed by the junction of the superior and internal borders, is thin, smooth, rounded, somewhat inclined outward, and gives attachment to a few fibres of the Levator anguli scapulae muscle.

Inferior Angle (angulus inferior).—The inferior angle, thick and rough, is formed by the union of the vertebral and axillary borders, its outer surface affording attachment to the Teres major and frequently to a few fibres of the Latissimus dorsi.

External or Lateral Angle (angulus lateralis).—The external angle is the thickest part of the bone, and forms what is called the head of the scapula. The head presents a shallow, pyriform, articular surface, the glenoid surface or cavity (cavitas glenoidalis, from γλένος, a socket), whose longest diameter is from above downward, and its direction outward and forward. It is broader below than above. Just above it is a rough surface, the supraglenoid tubercle or tuberosity (tuberositas supraglenoidalis), to which is attached the long tendon of the Biceps muscle. The glenoid cavity is covered with cartilage in the recent state; and its margins are slightly raised and give attachment to a fibro-cartilaginous structure, the glenoid ligament, by which its cavity is deepened. The anatomical neck of the scapula (collum scapulae) is the slightly depressed surface which surrounds the head; it is more distinct on the posterior than on the anterior surface, and below than above. In the latter situation it has arising from it a thick prominence, the coracoid process.

The coracoid process (processus coracoides), so called from its fancied resemblance to a crow’s beak (κόρακας, a crow), is a thick, curved process of bone which arises by a broad base from the upper part of the neck of the scapula; it is directed at first upward and inward, then, becoming smaller, it changes its direction and passes forward and outward. The ascending portion, flattened from before backward, presents in front a smooth, concave surface over which passes the Subscapularis
muscle. The horizontal portion is flattened from above downward, its upper surface is convex and irregular, and gives attachment to the Pectoralis minor; its under surface is smooth; its inner border is rough, and gives attachment to the Pectoralis minor; its outer border is also rough for the coraco-acromial ligament, while the apex is embraced by the conjoined tendon of origin of the short head of the Biceps and of the Coraco-brachialis and gives attachment to the costo-coracoid ligament. At the inner side of the root of the coracoid process is a rough impression for the attachment of the conoid ligament; and running from it obliquely forward and outward on the upper surface of the horizontal portion, an elevated ridge for the attachment of the trapezoid ligament.

**Structure.**—In the head, processes, and all the thickened parts of the bone the scapula is composed of cancellous tissue, while in the rest of its extent it is composed of a thin layer of dense, compact tissue. The centre part of the supraspinous fossa and the upper part of the infraspinous fossa, but especially the former, are usually so thin as to be semitransparent; occasionally the bone is found wanting in this situation, and the adjacent muscles come into contact.

**Development** (Fig. 128).—By seven centres. The epiphyses (except one for the coracoid process) appear from fifteen to seventeen years, and unite between twenty-two and twenty-five years of age.

Fig. 128.—Plan of the development of the scapula. By seven centres. The epiphyses (except one for the coracoid process) appear from fifteen to seventeen years, and unite between twenty-two and twenty-five years of age.
cases. The two separate nuclei unite and then join with the extension from the spine. These various epiphyses become joined to the bone between the ages of twenty-two and twenty-five years. Sometimes failure of union between the acromion process and spine occurs, the junction being effected by fibrous tissue or by an imperfect articulation; in some cases of supposed fracture of the acromion with ligamentous union it is probable that the detached segment was never united to the rest of the bone. The upper third of the glenoid cavity is usually ossified from a separate centre (subcoracoid) which makes its appearance between the tenth and eleventh years. Very often, in addition, an epiphysis appears for the lower part of the glenoid cavity.

Articulations.—With the humerus and clavicle.

Attachment of Muscles.—To seventeen: to the anterior surface, the Subscapularis; posterior surface, Supraspinatus, Infraspinatus; spine, Trapezius, Deltoid; superior border, Omo-hyoid; vertebral border, Serratus magnus, Levator anguli scapulae, Rhomboideus minor and major; axillary border, Triceps, Teres minor, Teres major; apex of glenoid cavity, long head of the Biceps; coracoid process, short head of the Biceps, Coraco-brachialis, Pectoralis minor; and to the inferior angle occasionally a few fibres of the Latissimus dorsi.

Surface Form.—The only parts of the scapula which are truly subcutaneous are the spine and acromion process, but, in addition to these, the coracoid process, the internal or vertebral border and inferior angle, and, to a less extent, the axillary border, may be defined. The acromion process and spine of the scapula are easily felt throughout their entire length, forming, with the clavicle, the arch of the shoulder. The acromion can be ascertained to be connected to the clavicle at the acromio-clavicular joint by running the finger along it, its position being often indicated by an irregularity or bony outgrowth from the clavicle close to the joint. The acromion can be felt forming the point of the shoulder, and from this can be traced backward to join the spine of the scapula. The place of junction is usually denoted by a prominence, which is sometimes called the acromial angle. From here the spine of the scapula can be felt as a prominent ridge of bone, marked on the surface as an oblique depression, which becomes less and less distinct, and terminates a little external to the spinous processes of the vertebræ. Its termination is usually indicated by a slight dimple in the skin on a level with the interval between the third and fourth thoracic spines. Below this point the vertebral border of the scapula may be traced, running downward and outward, and thus diverging from the vertebral spines, to the inferior angle of the bone, which can be recognized, although covered by the Latissimus dorsi muscle. From this angle the axillary border can usually be traced through this thick muscular covering, forming, with the muscles, the posterior fold of the axilla. The coracoid process may be felt about an inch below the junction of the middle and outer thirds of the clavicle. Here it is covered by the anterior border of the deltoid and lies a little to the outer side of a slight depression which corresponds to the interval between the Pectoralis major and Deltoid muscles. When the arms are hanging by the side, the upper angle of the scapula corresponds to the upper border of the second rib or the interval between the first and second thoracic spines, the inferior angle to the upper border of the eighth rib or the interval between the seventh and eighth thoracic spines.

Surgical Anatomy.—Fractures of the body of the scapula are rare, owing to the mobility of the bone, the thick layer of muscles by which it is encased on both surfaces, and the elasticity of the ribs on which it rests. Fracture of the neck of the bone is also uncommon. The most frequent course of a line of fracture of the neck is from the suprascapular notch to the infraglenoid tubercle (surgical neck), and it derives its principal interest from its simulation to a subglenoid dislocation of the humerus. The diagnosis can be made by noting the alteration in the position of the coracoid process. A fracture of the neck external to, and not including, the coracoid process (anatomical neck) is said to occur, but it is exceedingly doubtful whether such an accident ever takes place. The acromion process is more frequently broken than any other part of the bone, and there is sometimes, in young subjects, a separation of the epiphysis. It is believed that many of the cases of supposed fracture of the acromion, with fibrous union, which have been found on post-mortem examination are really cases of imperfectly united epiphysis. Sir Astley Cooper believed that most fractures of this bone united by fibrous tissue, and the cause of this mode of union was the difficulty there was in keeping the fractured ends in constant apposition. The coracoid process is occasionally broken off, either from direct violence or perhaps, rarely, from muscular action.

Tumors of various kinds grow from the scapula. Of the innocent form of tumors probably the osteoma are the most common. When an osteoma grows from the venter of the scapula, as it sometimes does, it is of the compact variety, such as usually grows from membrane-formed bones,
as the bones of the skull. This would appear to afford evidence that this portion of the bone is formed from membrane, and not, like the rest of the bone, from cartilage. Sarcomatous tumors sometimes grow from the scapula, and may necessitate removal of the bone, with or without amputation of the upper limb. Removal of the upper limb with the scapula and the outer two-thirds of the clavicle is known as the interscapulo-thoracic amputation. The scapula may be partially resected or completely excised. There are several methods of complete excision. The bone may be excised by a T-shaped incision, and, the flaps being reflected, the removal is commenced from the posterior or vertebral border, so that the subscapular vessels which lie along the axillary border are among the last structures divided, and can be at once secured.

THE ARM.

The arm is that portion of the upper extremity which is situated between the shoulder and the elbow. Its skeleton consists of a single bone, the humerus.

The Humerus or Upper Arm Bone (Figs. 129, 130).

The humerus (from humerus, or more correctly umerus, the shoulder) is the longest and largest bone of the upper extremity; it presents for examination a shaft and two extremities.

Upper Extremity.—The upper extremity presents a large, rounded head, joined to the shaft by a constricted portion, called the neck, and two other eminentures, the greater and lesser tuberosities.

The Head (caput humeri).—The head, nearly hemispherical in form, is directed upward, inward, and slightly backward, and articulates with the glenoid cavity of the scapula; its surface is smooth and coated with cartilage in the recent state. The circumference of its articular surface is slightly constricted, and is termed the anatomical neck, in contradistinction to the constriction which exists below the tuberosities. The latter is called the surgical neck (collum chirurgicum), from its often being the seat of fracture. It should be remembered, however, that fracture of the anatomical neck does sometimes, though rarely, occur.

Anatomical Neck (collum anatomicum).—The anatomical neck is obliquely directed, forming an obtuse angle with the shaft. It is more distinctly marked in the lower half of its circumference than in the upper half, where it presents a narrow groove, separating the head from the tuberosities. Its circumference affords attachment to the capsular ligament and is perforated by numerous vascular foramina.

Greater Tuberosity (tuberculum majus).—The greater tuberosity is situated on the outer side of the head and lesser tuberosity. Its upper surface is rounded and marked by three flat facets, separated by two slight ridges; the highest facet gives attachment to the tendon of the Supraspinatus; the middle one, to the Infraspinatus; the inferior facet and the shaft of the bone below it, to the Teres minor. The outer surface of the great tuberosity is convex, rough, and continuous with the outer side of the shaft.

Lesser Tuberosity (tuberculum minus).—The lesser tuberosity is more prominent, although smaller than the greater; it is situated in front of the head, and is directed inward and forward. Its summit presents a prominent facet for the insertion of the tendon of the Subscapularis muscle. The tuberosities are separated from one another by a deep groove, the bicipital groove (sulcus intertubercularis). This groove lodges the long tendon of the Biceps muscle, with which

1 Though the head is nearly hemispherical in form, its margin, as Sir G. Humphry has shown, is by no means a true circle. Its greatest measurement is from the top of the bicipital groove in a direction downward, inward, and backward. Hence it follows that the greatest elevation of the arm can be obtained by rolling the articular surface in this direction—that is to say, obliquely upward, outward, and forward.—En. of 15th English Edition.
Common origin of
FLEXOR CARPI RADIAlIS,
PALMARIS LONGUS,
FLEXOR SUBLIMIS DIGITORUM,
FLEXOR CARPI ULNARIS.

SUPINATOR RADII LONGUS.

Common origin of
EXTENSOR CARPI RADIAlIS BREVIS,
" COMMUNIS DIGITORUM,
" MINIMI DIGITI,
" CARPI ULNARIS,
SUPINATOR BREVIS.

Fig. 129.—Left humerus. Anterior view.
runs a branch of the anterior circumflex artery. It commences above between the two tuberosities, passes obliquely downward and a little inward, and terminates at the junction of the upper with the middle third of the bone. It is deep and narrow at the commencement, and becomes shallow and a little broader as it descends. Its borders are called, respectively, the external or posterior bicipital ridge (crista tuberculi majoris) and the internal or anterior bicipital ridge (crista tuberculi minoris), and form the upper part of the anterior and internal borders of the shaft of the bone. In the recent state it is covered with a thin layer of cartilage, lined by a prolongation of the synovial membrane of the shoulder-joint, and receives the tendon of insertion of the Latissimus dorsi muscle.

The Shaft (corpus humeri).—The shaft of the humerus is almost cylindrical in the upper half of its extent, prismatic and flattened below, and presents three borders and three surfaces for examination.

Anterior Border.—The anterior border runs from the front of the great tuberosity above to the coronoid depression below, separating the internal from the external surface. Its upper part is very prominent and rough, and forms the outer lip of the bicipital groove. It is sometimes called the posterior bicipital, external bicipital, or pectoral ridge (crista tuberculi majoris), and serves for the attachment of the tendon of the Pectoralis major. About its centre it forms the anterior boundary of the rough deltoid eminence or impression (tuberositas deltoidea); below, it is smooth and rounded, affording attachment to the Brachialis anticus muscle.

External Border (margo lateralis).—The external border runs from the back part of the greater tuberosity to the external condyle, and separates the external from the posterior surface. It is rounded and indistinctly marked in its upper half, serving for the attachment of the lower part of the insertion of the Teres minor muscle, and below this of the external head of the Triceps muscle; its centre is traversed by a broad, but shallow, oblique depression, the musculo-spiral groove (sulcus nervi radialis); its lower part is marked by a prominent, rough margin, a little curved from behind forward, the external supracondylar or epicondylic ridge (margo lateralis), which presents an anterior lip for the attachment of the Supinator longus above and Extensor carpi radialis longior below, a posterior lip for the Triceps, and an intermediate space for the attachment of the external intermuscular septum.

Internal Border (margo medialis).—The internal border extends from the lesser tuberosity to the internal condyle. Its upper third is marked by a prominent ridge, forming the posterior lip of the bicipital groove, and gives attachment to the tendon of the Teres major. About its centre is an impression for the attachment of the Coraco-brachialis, and just below this is seen the entrance of the nutrient canal, directed downward. Sometimes there is a second canal situated at the commencement of the musculo-spiral groove, for a nutrient artery derived from the superior profunda branch of the brachial artery. The inferior third of this border is raised into a slight ridge, the internal supracondylar or epicondylic ridge (margo medialis), which becomes very prominent below; it presents an anterior lip for the attachment of the Brachialis anticus muscle, a posterior lip for the internal head of the Triceps muscle, and an intermediate space for the attachment of the internal intermuscular septum.

External Surface (facies anterior lateralis).—The external surface is directed outward above, where it is smooth, rounded, and covered by the Deltoid muscle; forward and outward below, where it is slightly concave from above downward, and gives origin to part of the Brachialis anticus muscle. About the middle of this surface is seen a rough, triangular impression for the insertion of the Deltoid muscle, deltoid impression (tuberositas deltoidea); and below it the musculo-
spiral groove, directed obliquely from behind, forward and downward, and transmitting the musculo-spiral nerve and superior profunda artery.

Internal Surface (facies anterior medialis).—The internal surface, less extensive than the external, is directed inward above, forward and inward below; at its upper part it is narrow and forms the floor of the bicipital groove: to it is attached the Latissimus dorsi. The middle part of this surface is slightly rough for the attachment of some of the fibres of the tendon of insertion of the Coraco-brachialis; its lower part is smooth, concave from above downward, and gives attachment to the Brachialis anticus muscle. 1 A little below the middle of the shaft is the nutrient foramen (foramen nutrientium). This leads into a nutrient canal (canalis nutritius), which is directed toward the elbow-joint (distally).

Posterior Surface (facies posterior).—The posterior surface (Fig. 130) appears somewhat twisted, so that its upper part is directed a little inward, its lower part backward and a little outward. Nearly the whole of this surface is covered by the external and internal heads of the Triceps, the former of which is attached to its upper and outer part, the latter to its inner and back part, the two being separated by the musculo-spiral groove.

Lower Extremity.—The lower extremity is flattened from before backward, and curved slightly forward; it terminates below in a broad, articular surface which is divided into two parts by a slight ridge. Projecting on either side are the external and internal condyles (epicondylus lateralis and epicondylus medialis). By some anatomists the external condyle is called the external epicondyle and the internal condyle is called the internal epicondyle.

1 A small, hook-shaped process of bone, the supracondylar process, varying from ½ to ¾ of an inch in length, is not infrequently found projecting from the inner surface of the shaft of the humerus two inches above the internal condyle. It is curved downward, forward, and inward, and its pointed extremity is connected to the internal border, just above the inner condyle, by a ligament or fibrous band, which gives origin to a portion of the Pronator radii teres; through the arch completed by this fibrous band the median nerve and brachial artery pass when these structures deviate from their usual course. Sometimes the nerve alone is transmitted through it, or the nerve may be accompanied by the ulnar artery in cases of high division of the brachial. A well-marked groove is usually found behind the process in which the nerve and artery are lodged. This space is analogous to the supracondylar foramen in many animals, and probably serves in them to protect the nerve and artery from compression during the contraction of the muscles in this region. A detailed account of this process is given by Dr. Struthers, in his Anatomical and Physiological Observations, p. 205. An accessory portion of the Coraco-brachialis muscle is frequently connected with this process, according to Mr. J. Wood (Journal of Anat. and Phys., No. 1, November, 1866, p. 47). — Fig. 130.—Left humerus. Posterior surface. En. of 15th English edition.
Others call the internal condyle the *epitrochlea*. The articular surface extends a little lower than the condyles, and is curved slightly forward, so as to occupy the more anterior part of the bone; its greatest breadth is in the transverse diameter, and it is obliquely directed, so that its inner extremity occupies a lower level than the outer. The outer portion of the articular surface presents a smooth, rounded eminence, which has received the name of the *capitellum*, or *radial head* of the humerus (capitulum humeri); it articulates with the cup-shaped depression on the head of the radius, and is limited to the front and lower part of the bone, not extending as far back as the other portion of the articular surface. On the inner side of this eminence is a shallow groove, in which is received the inner margin of the head of the radius. Above the front part of the capitellum is a slight depression, the *radial fossa* (fossa radialis), which receives the anterior border of the head of the radius when the forearm is flexed. The inner portion of the articular surface, the *trochlea* (trochlea humeri), presents a deep depression between two well-marked borders. This surface is convex from before backward, concave from side to side, and occupies the anterior, lower, and posterior parts of the bone. The *external border*, less prominent than the internal, corresponds to the interval between the radius and the ulna. The *internal border* is thicker, more prominent, and consequently of greater length, than the external. The grooved portion of the articular surface fits accurately within the greater sigmoid cavity of the ulna: it is broader and deeper on the posterior than on the anterior aspect of the bone, and is inclined obliquely from behind forward and from without inward. Above the front part of the trochlear surface is seen a smaller depression, the *coronoid fossa* (fossa coronoidea), which receives the coronoid process of the ulna during flexion of the forearm. Above the back part of the trochlear surface is a deep, triangular depression, the *olecranon fossa* (fossa olecrani), in which is received the summit of the olecranon process in extension of the forearm. These fossae are separated from one another by a thin, transparent lamina of bone, which is sometimes perforated by a foramen, the *supratrochlear foramen*; their upper margins afford attachment to the anterior and posterior ligaments of the elbow-joint, and they are lined, in the recent state, by the synovial membrane of this articulation. The articular surfaces, in the recent state, are covered with a thin layer of cartilage. The *external epicondyle* (epicondylus lateralis) is a small, tubercular eminence, less prominent than the internal, curved a little forward, and giving attachment to the external lateral ligament of the elbow-joint, and to a tendon common to the origin of some of the extensor and supinator muscles. The *internal epicondyle* (epitrochlea or epicondylus medialis), larger and more prominent, and therefore more liable to fracture, than the external, is directed a little backward: it gives attachment to the internal lateral ligament, to the Pronator radii teres, and to a tendon common to the origin of some of the flexor muscles of the forearm. The ulnar nerve runs in a groove, the *ulnar groove* (sulcus nervi ulnaris), at the back of the internal condyle, or between it and the olecranon process. These condyles are directly continuous above with the external and internal supracondylar ridges.

**Structure.**—The extremities consist of cancellous tissue, covered with a thin compact layer; the shaft is composed of a cylinder of compact tissue, thicker at the centre than at the extremities, and hollowed out by a large medullary canal, which extends along its whole length. In the head of the humerus the plates of the cancellous tissue are arranged in curves (Fig. 131) known as *pressure curves*. Most of the bone-plates are at right angles to the plane of the articular surface (the lines of greatest pressure), and they are bound together by other bone-fibres, which usually correspond to the plane of the articulation (the lines of greatest tension). This arch-like arrangement strengthens the head of the bone, and it is further strengthened by the binding fibres.
Development.—By seven, or occasionally eight, centres (Fig. 133): one for the shaft, one for the head, one for the tuberosities, one for the radial head, one for the troclear portion of the articular surface, and one for each condyle. The nucleus for the shaft appears near the centre of the bone in the eighth week, and soon extends toward the extremities. At birth the humerus is ossified nearly in its whole length, the extremities remaining cartilaginous. During the first year, sometimes even before birth, ossification commences in the head of the bone, and during the third year the centre for the tuberosities makes its appearance, usually by a single ossific point, but sometimes, according to Béclard, by one for each tuberosity, that for the lesser being small and not appearing until the fifth year. By the sixth year the centres for the head and tuberosities have increased in size and become joined, so as to form a single large epiphysis.

The lower end of the humerus is developed in the following manner: At the end of the second year ossification commences in the capitellum, and from this point extends inward, so as to form the chief part of the articular end of the bone, the centre for the inner part of the trochlea not appearing until about the age of twelve. Ossification commences in the internal condyle about the fifth year, and in the external one not until about the thirteenth or fourteenth year. About sixteen or seventeen years the outer condyle and both portions of the articulating surface (which have already joined) unite with the shaft;
at eighteen years the inner condyle becomes joined; while the upper epiphysis, although the first formed, is not united until about the twentieth year.

Articulations.—With the glenoid cavity of the scapula and with the ulna and radius.

Attachment of the Muscles.—To twenty-four: to the greater tuberosity, the Supraspinatus, Infraspinatus, and Teres minor; to the lesser tuberosity, the Subscapularis; to the anterior bicipital ridge, the Pectoralis major; to the posterior bicipital ridge, the Teres major; to the bicipital groove, the Latissimus dorsi; to the shaft, the Deltoid, Coraco-brachialis, Brachialis anticus, external and internal heads of the Triceps; to the internal condyle, the Pronator radii teres, and common tendon of the Flexor carpi radialis, Palmaris longus, Flexor sublimis digitorum, and Flexor carpi ulnaris; to the external condylar ridge, the Supinator longus and Extensor carpi radialis longior; to the external condyle, the common tendon of the Extensor carpi radialis brevior, Extensor communis digitorum, Extensor minimi digitii, Extensor carpi ulnaris, and Supinator brevis; to the back of the external condyle, the Anconeus.

Surface Form.—The humerus is almost entirely clothed by the muscles which surround it, and the only parts of this bone which are strictly subcutaneous are small portions of the internal and external condyles. In addition to these, the tuberosities and a part of the head of the bone can be felt under the skin and muscles by which they are covered. Of these the greater tuberosity forms the most prominent bony point of the shoulder, extending beyond the acromion process and covered by the Deltoid muscle. It influences materially the surface form of the shoulder. It is best felt while the arm is lying loosely by the side; if the arm be raised, it recedes from under the finger. The lesser tuberosity, directed forward and inward, is to be felt to the inner side of the greater tuberosity, just below the acromio-clavicular joint. Between the two tuberosities lies the bicipital groove. This can be defined by placing the finger and making firm pressure just internal to the greater tuberosity; then, by rotating the humerus, the groove will be felt to pass under the finger as the bone is rotated. With the arm abducted from the side, by pressing deeply in the axilla the lower part of the head of the bone is to be felt. On each side of the elbow-joint, and just above it, the internal and external condyles of the bone are to be felt. Of these the internal is the more prominent, but the ridge passing upward from it, the internal condylid ridge, is much less marked than the external, and, as a rule, is not to be felt. Occasionally, however, we find along this border the hook-shaped process mentioned above. The external condyle is most plainly to be seen during semiflexion of the forearm, and its position is indicated by a depression between the attachment of the adjacent muscles. From it is to be felt a strong bony ridge running up the outer border of the shaft of the bone. This is the external supracondylar ridge; it is concave forward, and corresponds with the curved direction of the lower extremity of the humerus.

Surgical Anatomy.—There are several points of surgical interest connected with the humerus. First, as regards its development. The upper end, though the first to ossify, is the last to join the shaft, and the length of the bone is mainly due to growth from this upper epiphysis. Hence, in cases of amputation of the arm in young subjects the humerus continues to grow considerably, and the end of the bone, which immediately after the operation was covered with a thick cushion of soft tissue, begins to project, thinning the sfit parts and rendering the stump conical. This may necessitate another operation, which consists in the removal of a couple of inches or so of the bone, and even after this operation a recurrence of the conical stump may take place.

There are several points of surgical interest in connection with fractures. First, as regard their causation: the bone may be broken by direct or indirect violence like the other long bones, but, in addition to this, it is probably more frequently fractured by muscular action than any other of this class of bone in the body. It is usually the shaft, just below the insertion of the Deltoid, which is thus broken. Mr. Piek has seen the accident happen from throwing a stone, and in an apparently healthy adult from cutting a piece of hard "cake tobacco" on a table. In this latter case there was no disease of the bone that could be discovered. Fractures of the upper end may take place through the anatomical neck, through the surgical neck, or separation of the greater tuberosity may occur. Fracture of the anatomical neck is a very rare accident; in fact, it is doubted by some whether it ever occurs. These fractures are usually considered to be intra-capsular, but they are probably partly within and partly without the capsule, as the lower part of the capsule is inserted some little distance below the anatomical neck, while the upper part is attached to it. They may be impacted or non-impacted. In most cases there is little or
no displacement on account of the capsule, in whole or in part, remaining attached to the lower fragment. But occasionally a very remarkable alteration in position takes place; the upper fragment turns on its own axis, so that the cartilaginous surface of the head rests against the upper end of the lower fragment. When the fractured end is entirely separated from all its surroundings, its vascular supply must be entirely cut off, and one would expect it, theoretically, to necrose. But this must be exceedingly rare, for Gurlt was unable to find a single authenticated case recorded. Separation of the upper epiphysis of the humerus sometimes occurs in the young subject, and is marked by a characteristic deformity by which the lesion may be at once recognized. This consists in the presence of an abrupt projection at the front of the joint some short distance below the coracoid process, caused by the upper end of the lower fragment. In fractures of the shaft of the humerus the lesion may take place at any point, but appears to be more common in the lower than in the upper part of the bone. The points of interest in connection with these fractures are: (1) That the musculo-spiral nerve may be injured as it lies in the groove on the bone, or may become involved in the callus which is subsequently thrown out; and (2) the frequency of non-union. This is believed to be more common in the humerus than in any other bone, and various causes have been assigned for it. It would seem most probably to be due to the difficulty that there is in fixing the shoulder-joint and the upper fragment, and possibly the elbow-joint and lower fragment also. Other causes which have been assigned for the non-union are: (1) That in attempting passive motion of the elbow-joint to overcome any rigidity which may exist, the movement does not take place at the articulation, but at the seat of fracture; or that the patient, in consequence of the rigidity of the elbow, in attempting to flex or extend the forearm moves the fragment and not the joint. (2) The presence of small portions of muscular tissue between the broken ends. (3) Want of support to the elbow, so that the weight of the arm tends to drag the lower fragment away from the upper. An important distinction to make in fractures of the lower end of the humerus is between those that involve the elbow-joint and those which do not; the former are always serious, as they may lead to stiffness of the joint and impairment of the utility of the limb. They include the T-shaped fracture and oblique fractures which involve the articular surface. The fractures which do not involve the joint are the transverse above the condyles and the so-called epiphrochlear fracture, in which the tip of the internal condyle is broken off, generally by direct violence.

Under the head of separation of the lower epiphysis two separate injuries have been described. One where the whole of the four osseous centres which form the lower extremity of the bone are separated from the shaft; and secondly, where the articular portion is alone separated, the two condyles remaining attached to the shaft of the bone. The epiphysial line between the shaft and lower end runs across the bone just above the tips of the condyles, a point to be borne in mind in performing the operation of excision.

Tumors originating from the humerus are of frequent occurrence. A not uncommon place for a chondroma to grow from is the shaft of the bone somewhere in the neighborhood of the insertion of the deltoid. Sarcomata frequently grow from this bone.

THE FOREARM.

The forearm is that portion of the upper extremity which is situated between the elbow and the wrist. Its skeleton is composed of two bones, the ulna and radius.

The Ulna or Elbow Bone.

The ulna (Figs. 134 and 135), so called from its forming the elbow (οὐλένη), is a long bone, prismatic in form, placed at the inner side of the forearm, parallel with the radius. It is the larger and longer of the two bones. Its upper extremity, of great thickness and strength, forms a large part of the articulation of the elbow-joint; it diminishes in size from above downward, its lower extremity being very small, and excluded from the wrist-joint by the interposition of an interarticular fibro-cartilage. It is divisible into a shaft and two extremities.

Upper Extremity.—The upper extremity, the strongest part of the bone, presents for examination two large, curved processes, the olecranon process and the coronoid process; and two concave, articular cavities, the greater and lesser sigmoid cavities.

Olecranon Process (olecranon).—The olecranon process (οὐλένη, elbow; χρανιόν, head) is a large, thick, curved eminence situated at the upper and back part of
Occasional origin of Flexor Longus Polliss.

Styloid process.

Fig. 134.—Bones of the left forearm. Anterior surface.
the ulna. It is curved forward at the summit so as to present a prominent tip which is received into the olecranon fossa of the humerus in extension of the forearm; its base being contracted where it joins the shaft. This is the narrowest part of the upper end of the ulna, and, consequently, the most usual seat of fracture. The posterior surface of the olecranon, directed backward, is triangular, smooth, subcutaneous, and covered by a bursa. Its upper surface is of a quadrilateral form, marked behind by a rough impression for the attachment of the Triceps muscle; and in front, near the margin, by a slight transverse groove for the attachment of part of the posterior ligament of the elbow-joint. Its interior surface is smooth, concave, covered with cartilage in the recent state, and forms the upper and back part of the great sigmoid cavity. The lateral borders present a continuation of the same groove that was seen on the margin of the superior surface; they serve for the attachment of ligaments—viz., the back part of the internal lateral ligament internally, the posterior ligament externally. To the inner border is also attached a part of the Flexor carpi ulnaris, while to the outer border is attached the Anconeus muscle.

Coronoid Process (processus coronoides).—The coronoid process (κορώνιον, anything hooked like a crow’s beak) is a triangular eminence of bone which projects horizontally forward from the upper and front part of the ulna. Its base is continuous with the shaft, and of considerable strength; so much so that fracture of it is an accident of rare occurrence. Its apex is pointed, slightly curved upward, and is received into the coronoid depression of the humerus in flexion of the forearm. Its upper surface is smooth, concave, and forms the lower part of the greater sigmoid cavity. The under surface is concave. At the junction of this surface with the shaft is a rough eminence, the tubercle of the ulna (tuberositas ulnae), for the attachment of the oblique ligament of the superior radio-ulnar articulation and the Brachialis anticus muscle. Its outer surface presents a narrow, oblong, articular depression, the lesser sigmoid cavity. The inner surface, by its prominent, free margin, serves for the attachment of part of the internal lateral ligament. At the front part of this surface is a small, rounded eminence for the attachment of one head of the Flexor sublimis digitorum; behind the eminence, a depression for part of the origin of the Flexor profundus digitorum; and, descending from the eminence, a ridge which gives attachment to one head of the Pronator radii teres. Generally, the Flexor longus pollicis has an origin from the lower part of the coronoid process by a rounded bundle of muscular fibres.

Greater Sigmoid Cavity (incisura semilunaris).—The greater sigmoid cavity, so called from its resemblance to the old shape of the Greek letter Σ, is a semilunar depression of large size, formed by the olecranon and coronoid processes, and serving for articulation with the trochlear surface of the humerus. About the middle of either lateral border of this cavity is a notch which contracts it somewhat, and serves to indicate the junction of the two processes of which it is formed. The cavity is concave from above downward, and divided into two lateral parts by a smooth, elevated ridge which runs from the summit of the olecranon to the tip of the coronoid process. Of these two portions, the internal is the larger, and is slightly concave transversely; the external portion is convex above, slightlyconcave below. The articular surface, in the recent state, is covered with a thin layer of cartilage.

Lesser Sigmoid Cavity (incisura radialis).—The lesser sigmoid cavity is a narrow, oblong, articular depression, placed on the outer side of the coronoid process, and receives the lateral articular surface of the head of the radius. It is concave from before backward, and its extremities, which are prominent, serve for the attachment of the orbicular ligament. In the recent state it is covered with a thin layer of cartilage.
Bones of the left forearm. Posterior surface.
The Shaft (corpus ulnae).—The shaft, at its upper part, is prismatic in form, and curved from behind forward and from without inward, so as to be convex behind and externally; its central part is quite straight; its lower part rounded, smooth, and bent a little outward; it tapers gradually from above downward, and presents for examination three borders and three surfaces.

Anterior or Palmar Border (margo volaris).—The anterior border commences above at the prominent inner angle of the coronoid process, and terminates below in front of the styloid process. It is well marked above, smooth and rounded in the middle of its extent, and affords attachment to the Flexor profundus digitorum: its lower fourth, marked off from the rest of the border by the commencement of an oblique ridge on the anterior surface, serves for the attachment of the Pronator quadratus. It separates the anterior from the internal surface.

Posterior or Dorsal Border (margo dorsalis).—The posterior border commences above at the apex of the triangular subcutaneous surface at the back part of the olecranon, and terminates below at the back part of the styloid process; it is well marked in the upper three-fourths, and gives attachment to the aponeurosis common to the Flexor carpi ulnaris, the Extensor carpi ulnaris, and the Flexor profundus digitorum muscles; its lower fourth is smooth and rounded. This border separates the internal from the posterior surface.

External or Interosseous Border (crista interossea).—The external or interosseous border commences above by the union of two lines, which converge one from each extremity of the lesser sigmoid cavity, enclosing between them a triangular space for the attachment of part of the Supinator brevis. The external line is the crista m. supinatoris. The interosseous border of the ulna terminates below at the middle of the head of the ulna. Its two middle fourths are very prominent; its lower fourth is smooth and rounded. This border gives attachment to the interosseous membrane, and separates the anterior from the posterior surface.

Anterior or Palmar Surface (facies volaris).—The anterior surface, much broader above than below, is concave in the upper three-fourths of its extent, and affords attachment to the Flexor profundus digitorum; its lower fourth, also concave, is covered by the Pronator quadratus. The lower fourth is separated from the remaining portion of the bone by a prominent ridge, directed obliquely from above downward and inward; this ridge, the oblique or pronator ridge, marks the extent of attachment of the Pronator quadratus. At the junction of the upper with the middle third of the bone is the nutrient foramen (foramen nutrientium). It opens into the nutrient canal (canalis nutriticus), which is directed obliquely upward and inward (proximally).

Posterior or Dorsal Surface (facies dorsalis).—The posterior surface, directed backward and outward, is broad and concave above, somewhat narrower and convex in the middle of its course, narrow, smooth, and rounded below. It presents, above, an oblique ridge, which runs from the posterior extremity of the lesser sigmoid cavity, downward to the posterior border; the triangular surface above this ridge receives the insertion of the Anconeus muscle, whilst the upper part of the ridge itself affords attachment to the Supinator brevis. The surface of bone below this is subdivided by a longitudinal ridge, sometimes called the perpendicular line, into two parts; the internal part is smooth, and covered by the Extensor carpi ulnaris; the external portion, wider and rougher, gives attachment from above downward to part of the Supinator brevis, the Extensor ossis metacarpi pollicis, the Extensor longus pollicis, and the Extensor indicis muscles.

Internal Surface (facies medialis).—The internal surface is broad and concave above, narrow and convex below. It gives attachment by its upper three-fourths to the Flexor profundus digitorum muscle: its lower fourth is subcutaneous. The anterior and the inner surfaces constitute the flexor surface.
Lower Extremity.—The lower extremity of the ulna is of small size, and excluded from the articulation of the wrist-joint. It presents for examination two eminences, the outer and larger of which is a rounded, articular eminence, termed the head of the ulna (capitulum ulnae), the inner, narrower and more projecting, is a non-articular eminence, the styloid process (processus styloideus). The head presents an articular facet, part of which, of an oval or semilunar form, is directed downward, and articulates with the upper surface of the interarticular fibro-cartilage which separates it from the wrist-joint; the remaining portion, directed outward, is narrow, convex, and received into the sigmoid cavity of the radius. The peripheral margin of the portion of the head which articulates with the ulna is called the articular circumference (circumferentia articularis). The styloid process projects from the inner and back part of the bone, and descends a little lower than the head, terminating in a rounded summit, which affords attachment to the internal lateral ligament of the wrist. The head is separated from the styloid process by a depression for the attachment of the triangular interarticular fibro-cartilage; and behind, by a shallow groove for the passage of the tendon of the Extensor carpi ulnaris.

Structure.—Similar to that of the other long bones.

Development.—By three centres: one for the shaft, one for the inferior extremity, and one for the olecranon (Fig. 136). Ossification commences near the middle of the shaft about the eighth week, and soon extends through the greater part of the bone. At birth the ends are cartilaginous. About the fourth year a separate osseous nucleus appears in the middle of the head, which soon extends into the styloid process. About the tenth year ossific matter appears in the olecranon near its extremity, the chief part of this process being formed from an extension of the shaft of the bone into it. At about the sixteenth year the upper epiphysis becomes joined, and at about the twentieth year the lower one.

Articulations.—With the humerus and radius.

Attachment of Muscles.—To sixteen: to the olecranon, the Triceps, Anconeus, and one head of the Flexor carpi ulnaris. To the coronoid process, the Brachialis anticus, Pronator radii teres, Flexor sublimis digitorum, and Flexor profundus digitorum; generally also the Flexor longus pollicis. To the shaft, the Flexor profundus digitorum, Pronator quadratus, Flexor carpi ulnaris, Extensor carpi ulnaris, Anconeus, Supinator brevis, Extensor ossis metacarpi pollicis, Extensor longus pollicis, and Extensor indicis.

Surface Form.—The most prominent part of the ulna on the surface of the body is the olecranon process, which can always be felt at the back of the elbow-joint. When the forearm is flexed, the upper quadrilateral surface can be felt, directed backward; during extension it recedes into the olecranon fossa, and the contracting fibres of the triceps prevent its being perceived. At the back of the olecranon is the smooth, triangular, subcutaneous surface, which below is continuous with the posterior border of the shaft of the bone, and felt in every position of the forearm. During extension the upper border of the olecranon is slightly above the level of the internal condyle, and the process itself is nearer to this condyle than the outer one. Running down the back of the forearm, from the apex of the triangular surface which forms the posterior surface of the olecranon, is a prominent ridge of bone, the posterior border of the ulna. This is to be felt throughout the entire length of the shaft of the bone, from the olecranon above to the styloid process below. As it passes down the forearm it pursues a sinuous course
and inclines to the inner side, so that, though it is situated in the middle of the back of the limb above, it is on the inner side of the wrist at its termination. It becomes rounded off in its lower third, and may be traced below to the small, subcutaneous surface of the styloid process. Internal to this border the lower fourth of the inner surface is to be felt. The styloid process is to be felt as a prominent tubercle of bone, continuous above with the posterior subcutaneous border of the ulna, and terminating below in a blunt apex, which lies a little internal and behind, but on a level with, the wrist-joint. The styloid process is best felt when the hand is in the same line as the bones of the forearm, and in a position midway between supination and pronation. If the forearm is pronated while the finger is placed on the process, it will be felt to recede, and another prominence of bone will appear just behind and above it. This is the head of the ulna, which articulates with the lower end of the radius and the triangular interarticular fibro-cartilage, and now projects between the tendons of the Extensor carpi ulnaris and the Extensor minimi digitii muscles.

The Radius.

The radius (radius, a ray, or spoke of a wheel) is so called because it is the rotary bone of the forearm. It is situated on the outer side of the forearm, lying side by side with the ulna, which exceeds it in length and size (Figs. 134 and 135). Its upper end is small, and forms only a small part of the elbow-joint; but its lower end is large, and forms the chief part of the wrist. It is one of the long bones, prismatic in form, slightly curved longitudinally, and, like other long bones, has a shaft and two extremities.

Upper Extremity.—The upper extremity presents a head, neck, and tuberosity.

The Head.—The head (capitulum radii) is of a cylindrical form, depressed on its upper surface into a shallow cup (fovea capituli radii), which articulates with the capitellum or radial head of the humerus. In the recent state it is covered with a layer of cartilage which is thinnest at its centre. Around the circumference of the head is a smooth, articular surface (circumferentia articularis), broad internally where it articulates with the lesser sigmoid cavity of the ulna; narrow in the rest of its circumference, where it rotates within the orbicular ligament. It is coated with cartilage in the recent state. The head is supported on a round, smooth, and constricted portion of bone, called the neck (col lum radii), which presents, behind, a slight ridge, for the attachment of part of the Supinator brevis. Beneath the neck, at the inner and front aspect of the bone, is a rough eminence, the bicipital tuberosity (tuberositas radii). Its surface is divided into two parts by a vertical line—a posterior, rough portion, for the insertion of the tendon of the Biceps muscle; and an anterior, smooth portion, on which a bursa is interposed between the tendon and the bone.

The Shaft (corpus radii).—The shaft of the bone is prismoid in form, narrower above than below, and slightly curved, so as to be convex outward. It presents three surfaces, separated by three borders.

Anterior or Palmar Border (margo volaris).—The anterior border extends from the lower part of the tuberosity above to the anterior part of the base of the styloid process below. It separates the anterior from the external surface. Its upper third is very prominent; and from its oblique direction, downward and outward, has received the name of the oblique line of the radius. It gives attachment externally to the Supinator brevis, internally to the Flexor longus pollicis, and between these to the Flexor sublimis digitorum. The middle third of the anterior border is indistinct and rounded. Its lower fourth is sharp, prominent, affords attachment to the Pronator quadratus and to the posterior annular ligament of the wrist, and terminates in a small tubercle at the base of the styloid process, into which is inserted the tendon of the Supinator longus.

Posterior or Dorsal Border (margo dorsalis).—The posterior border commences above at the back part of the neck of the radius, and terminates below at the
posterior part of the base of the styloid process; it separates the posterior from the external surface. It is indistinct above and below, but well marked in the middle third of the bone.

**Internal or Intersosseous Border (crista interossea).**—The internal or intersosseous border commences above at the back part of the tuberosity, where it is rounded and indistinct, becomes sharp and prominent as it descends, and at its lower part divides into two ridges, which descend to the anterior and posterior margins of the sigmoid cavity. This border separates the anterior from the posterior surface, and has the intersosseous membrane attached to it throughout the greater part of its extent.

**Anterior or Palmar or Flexor Surface (facies volaris).**—The anterior surface is concave for its upper three-fourths, and gives attachment to the Flexor longus pollicis muscle; it is broad and flat for its lower fourth, and gives attachment to the Pronator quadratus. A prominent ridge limits the attachment of the Pronator quadratus below, and between this and the inferior border is a triangular rough surface for the attachment of the anterior ligament of the wrist-joint. At the junction of the upper and middle third of this surface is the nutrient foramen (foramen nutritium), the opening of the nutrient canal (canalis nutritius), which is directed obliquely upward (proximally).

**Posterior or Dorsal or Extensor Surface (facies dorsalis).**—The posterior surface is rounded, convex, and smooth in the upper third of its extent, and covered by the Supinator brevis muscle. Its middle third is broad, slightly concave, and gives attachment to the Extensor ossis metacarpi pollicis above, the Extensor brevis pollicis below. Its lower third is broad, convex, and covered by the tendons of the muscles, which subsequently run in the grooves on the lower end of the bone.

**External Surface (facies lateralis).**—The external surface is rounded and convex throughout its entire extent. Its upper third gives attachment to the Supinator brevis muscle. About its centre is seen a rough ridge, for the insertion of the Pronator radii teres muscle. Its lower part is narrow, and covered by the tendons of the Extensor ossis metacarpi pollicis and Extensor brevis pollicis muscles.

**Lower Extremity.**—The lower extremity of the radius is large, of quadrilateral form, and provided with two articular surfaces—one at the extremity, for articulation with the carpus, and one at the inner side of the bone, for articulation with the ulna. The carpal articular surface (facies articularis carpea) is of triangular form, concave, smooth, and divided by a slight antero-posterior ridge into two parts. Of these, the external is of a triangular form, and articulates with the scaphoid bone; the inner is quadrilateral and articulates with the semilunar bone. The articular surface for the head of the ulna is called the sigmoid cavity of the radius (incisura ulnaris); it is narrow, concave, smooth, and articulates with the head of the ulna. The circumference of this end of the bone presents three surfaces—an anterior, external, and posterior. The anterior surface, rough and irregular, affords attachment to the anterior ligament of the wrist-joint. The external surface is prolonged obliquely downward into a strong, conical projection, the styloid process (processus styloideus), which gives attachment by its base to the tendon of the Supinator longus, and by its apex to the external lateral ligament of the wrist-joint. The outer surface of this process is marked by a flat groove, which runs obliquely downward and forward, and gives passage to the tendons of the Extensor ossis metacarpi pollicis and the Extensor brevis pollicis. The posterior surface is convex, affords attachment to the posterior ligament of the wrist, and is marked by three grooves. Proceeding from without inwards, the first groove is broad but shallow, and subdivided into two by a slightly elevated ridge: the outer of these two transmits the tendon of the Extensor carpi radialis longior, the inner the tendon of the Extensor carpi radialis brevior. The second,
which is near the centre of the bone, is a deep but narrow groove, bounded on its outer side by a sharply-defined ridge; it is directed obliquely from above, downward and outward, and transmits the tendon of the Extensor longus pollicis. The third, lying most internally, is a broad groove, for the passage of the tendons of the Extensor indicis and Extensor communis digitorum.

**Structure.**—Similar to that of the other long bones.

**Development** (Fig. 137).—By three centres: one for the shaft and one for each extremity. That for the shaft makes its appearance near the centre of the bone, about the eighth week of foetal life. About the end of the second year ossification commences in the lower epiphysis, and about the fifth year in the upper end. At the age of seventeen or eighteen the upper epiphysis becomes joined to the shaft, the lower epiphysis becoming united about the twentieth year.

**Articulation.**—With four bones: the humerus, ulna, scaphoid, and semilunar.

**Attachment of Muscles.**—To nine: to the tuberosity, the Biceps, to the oblique ridge, the Supinator brevis, Flexor sublimis digitorum, and Flexor longus pollicis: to the shaft (its anterior surface), the Flexor longus pollicis and Pronator quadratus; (its posterior surface), the Extensor ossis metacarpi pollicis and Extensor brevis pollicis; (its outer surface), the Pronator radii teres; and to the styloid process, the Supinator longus.

**Surface Form.**—Just below and a little in front of the posterior surface of the external condyle a part of the head of the radius may be felt, covered by the orbicular and external lateral ligaments. There is in this situation a little dimple in the skin, which is most visible when the arm is extended, and which marks the position of the head of the bone. If the finger be placed on this dimple and the forearm pronated and supinated, the head of the bone will be distinctly perceived rotating in the lesser sigmoid cavity. The upper half of the shaft of the radius cannot be felt, as it is surrounded by the fleshy bellies of the muscles arising from the external condyle. The lower half of the shaft can be readily examined, though covered by tendons and muscles and not strictly subcutaneous. If traced downward, the shaft will be felt to terminate in a lozenge-shaped, convex surface on the outer side of the base of the styloid process. This is the only subcutaneous part of the bone, and from its lower extremity the apex of the styloid process will be felt bending inward toward the wrist. About the middle of the posterior aspect of the lower extremity of the bone is a well-marked ridge, best perceived when the hand is slightly flexed on the wrist. It forms the outer boundary of the oblique groove on the posterior surface of the bone, through which the tendon of the Extensor longus pollicis runs, and serves to keep that tendon in place.

**Surgical Anatomy of the Radius and Ulna.**—The two bones of the forearm are more often broken together than is either the radius or ulna separately. It is therefore convenient to consider fractures of both bones in the first instance, and subsequently to mention the principal fractures which take place in each bone individually. These fractures may be produced by either direct or indirect violence, though more commonly by direct violence. When indirect force is applied to the forearm the radius generally alone gives way, though both bones may suffer. The fracture from indirect force generally takes place somewhere about the middle of the bones; fracture from direct violence may occur at any part, more often, however, in the lower half of the bone. The fracture is usually transverse, but may be more or less oblique. A point of interest in connection with these fractures is the tendency that there is for the two bones to unite across the interosseous membrane; the limb should therefore be put up in a position midway between supination and pronation, which is not only the most comfortable position, but also separates the bones most widely from each other, and therefore diminishes the risk of the bones
THE CARPUS

becoming united across the interosseous membrane. The splints, anterior and posterior, which are applied in these cases should be rather wider than the limb, so as to prevent any lateral pressure on the bones. In these cases there is a greater liability to gangrene from the pressure of the splints than in other parts of the body. This is no doubt due principally to two causes: (1) the flexion of the forearm compressing to a certain extent the brachial artery and retarding the flow of blood to the limb; and (2) the superficial position of the two main arteries of the forearm in part of their course, and their liability to be compressed by the splints. The special fractures of the ulna are—(1) Fracture of the olecranon. This may be caused by direct violence, falls on the elbow, with the forearm flexed, or by muscular action by the sudden contraction of the triceps. The most common place for the fracture to occur is at the constricted portion where the olecranon joins the shaft of the bone, and the fracture may be either transverse or oblique; but any part may be broken, even a thin shell may be torn off. Fractures from direct violence are occasionally comminuted. The displacement is sometimes very slight, owing to the fibrous structures around the process not being torn. (2) Fracture of the coronoid process sometimes occurs as a complication of dislocation backward of the bones of the forearm, but it is doubtful if it ever occurs as an uncomplicated injury. (3) Fractures of the shaft of the ulna may occur at any part, but usually takes place at the middle of the bone or a little below it. They are almost always the result of direct violence. (4) The styloid process may be knocked off by direct violence. Fractures of the radius consist of—(1) Fracture of the head of the bone; this generally occurs in conjunction with some other lesion, but may occur as an uncomplicated injury. (2) Fracture of the neck may also take place, but is generally complicated with other injury. (3) Fractures of the shaft of the radius are very common, and may take place at any part of the bone. They may take place from either direct or indirect violence. In fractures of the upper third of the shaft of the bone, that is to say, above the insertion of the Pronator radii teres, the displacement is very great. The upper fragment is strongly supinated by the Biceps and Supinator brevis, and flexed by the Biceps; while the lower fragment is pronated and drawn toward the ulna by the two pronators. If such a fracture is put up in the ordinary position, midway between supination and pronation, the fracture will unite with the upper fragment in a position of supination, and the lower one in the mid-position, and thus considerable impairment of the movements of the hand will result. The limb should be put up with the forearm supinated. (4) The most important fracture of the radius is that of the lower end (Colles's fracture). The fracture is transverse, and generally takes place about an inch from the lower extremity. It is caused by falls on the palm of the hand, and is an injury of advanced life, occurring more frequently in the female than the male. In consequence of the manner in which the fracture is caused, the upper fragment becomes driven into the lower, and impaction is the result; or else the lower fragment becomes split up into two or more pieces, so that no fixation occurs. Separation of the lower epiphysis of the radius may take place in the young. This injury and Colles's fracture may be distinguished from other injuries in this neighborhood—especially dislocation, with which it is liable to be confounded—by observing the relative positions of the styloid processes of the ulna and radius. In the natural condition of parts, with the arm hanging by the side, the styloid process of the radius is on a lower level than that of the ulna; that is to say, nearer the ground. After fracture or separation of the epiphysis this process is on the same or a higher level than that of the ulna, whereas it would be unaltered in position in dislocation.

THE HAND.

The skeleton of the hand is subdivided into three segments—the carpus or wrist bones; the metacarpus or bones of the palm; and the phalanges or bones of the digits.

The Carpus (Ossa Carpi) (Figs. 138, 139).

The bones of the carpus (καρπός, the wrist), eight in number, are arranged in two rows. Those of the upper row, enumerated from the radial to the ulnar side, are the scaphoid, semilunar, cuneiform, and pisiform; those of the lower row, enumerated in the same order, are the trapezium, trapezoid, os magnum, and unciform.

Common Characters of the Carpal Bones.—Each bone (excepting the pisiform) presents six surfaces. Of these the anterior, palmar, or volar, and the posterior or dorsal are rough for ligamentous attachment, the dorsal surface being the broader, except in the scaphoid and semilunar. The superior or proximal and inferior or distal are articular, the superior generally convex, the inferior concave; and the
internal and external are also articular when in contact with contiguous bones, otherwise rough and tubercular. The structure in all is similar, consisting of cancellous tissue enclosed in a layer of compact bone. Each bone is also developed from a single centre of ossification.

Fig. 138.—Bones of the left hand. Dorsal surface.
Bones of the Upper Row.

Scaphoid or Navicular Bone (*os naviculare manus*, the boat-like bone) (Fig. 140).—The scaphoid (σκάφος, a boat, εἴδος, like) is the largest bone of the first row. It has received its name from its fancied resemblance to a boat, being broad at one end and narrowed like a prow at the opposite. It is situated at
the upper and outer part of the carpus, its long axis being from above downward, outward, and forward.

**Surfaces.**—The *superior surface* is convex, smooth, of triangular shape, and articulates with the lower end of the radius. The *inferior surface*, directed downward, outward, and backward, is smooth, convex, also triangular, and divided by a slight ridge into two parts, the external of which articulates with the trapezium, the inner with the trapezoid. The *posterior* or *dorsal surface* presents a narrow, rough groove which runs the entire length of the bone and serves for the attachment of ligaments. The *anterior* or *palmar surface* is concave above, and elevated at its lower and outer part into a prominent rounded *tuberosity* (*tuberculum ossis naviculare*), which projects forward from the front of the carpus and gives attachment to the anterior annular ligament of the wrist and sometimes a few fibres of the Abductor pollicis. The *external surface* is rough and narrow, and gives attachment to the external lateral ligament of the wrist. The *internal surface* presents two articular facets: of these, the superior or smaller one is flattened, of semilunar form, and articulates with the semilunar; the inferior or larger is concave, forming, with the semilunar bone, a concavity for the head of the os magnum.

To ascertain to which side the bone belongs, hold it with the superior or radial convex, articular surface upward, and the posterior surface—*i.e.*, the narrow, non-articular, grooved surface—toward you. The tubercle on the outer surface points to the side to which the bone belongs.\(^1\)

**Articulations.**—With five bones: the radius above, trapezium and trapezoid below, os magnum and semilunar internally.

**Attachment of Muscles.**—Occasionally a few fibres of the Abductor pollicis.

**Semilunar (os lunatum)** (Fig. 141).—The semilunar (*semi*, half; *luna*, moon) bone may be distinguished by its deep concavity and crescentic outline. It is situated in the centre of the upper row of the carpus, between the scaphoid and cuneiform.

**Surfaces.**—The *superior surface*, convex, smooth, and bounded by four edges, articulates with the radius. The *inferior surface* is deeply concave, and of greater

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\(^1\) In these directions each bone is supposed to be placed in its natural position—that is, such a position as it would occupy when the arm is hanging by the side, the forearm in a position of supination, the thumb being directed outward, and the palm of the hand looking forward.—Ed. of 15th English Edition.
extent from before backward than transversely; it articulates with the head of the os magnum and by a long, narrow facet (separated by a ridge from the general surface) with the unciform bone. The anterior or palmar and posterior or dorsal surfaces are rough, for the attachment of ligaments, the former being the broader and of a somewhat rounded form. The external surface presents a narrow, flattened, semilunar facet for articulation with the scaphoid. The internal surface is marked by a smooth, quadrilateral facet, for articulation with the cuneiform.

Hold it with the convex articular surface for the radius upward, and the narrowest non-articular surface toward you. The semilunar facet for the scaphoid will be on the side to which the bone belongs.

Articulations.—With five bones: the radius above, os magnum and unciform below, scaphoid and cuneiform on either side.

Cuneiform (os triquetrum, the wedge-shaped bone) (Fig. 142).—The cuneiform (cuneus, a wedge; forma, likeness) may be distinguished by its pyramidal shape, and by its having an oval, isolated facet for articulation with the pisiform bone. It is situated at the upper and inner side of the carpus.

Surfaces.—The superior surface presents an internal, rough, non-articular portion, and an external or articular portion, which is convex, smooth, and articulates with the triangular interarticular fibro-cartilage of the wrist. The inferior surface, directed outward, is concave, sinusuously curved, and smooth for articulation with the unciform. The posterior or dorsal surface is rough, for the attachment of ligaments. The anterior or palmar surface presents, at its inner side, an oval facet, for articulation with the pisiform; and is rough externally, for ligamentous attachment. The external surface, the base of the pyramid, is marked by a flat, quadrilateral, smooth facet, for articulation with the semilunar. The internal surface, the summit of the pyramid, is pointed and roughened, for the attachment of the internal lateral ligament of the wrist.

Hold the bone with the surface supporting the pisiform facet away from you, and the concavo-convex surface for the unciform downward. The base of the wedge (i.e., the broad end of the bone) will be on the side to which it belongs.

Articulations.—With three bones: the semilunar externally, the pisiform in front, the unciform below; and with the triangular, interarticular fibro-cartilage which separates it from the lower end of the ulna.

Pisiform (os pisiforme) (Fig. 143).—The pisiform (pisum, a pea; forma, likeness) may be known by its small size and by its presenting a single articular facet. It is situated on a plane anterior to the other bones of the carpus; it is spheroidal in form, with its long diameter directed vertically.

Surfaces.—Its posterior surface is a smooth, oval facet, for articulation with the cuneiform. This facet approaches the superior, but not the inferior border of the bone. The anterior or palmar surface is rounded and rough, and gives attachment to the anterior annular ligament and to the Flexor carpi ulnaris and Abductor minimi digitii muscles. The outer and inner surfaces are also rough, the former being concave, the latter usually convex.

Hold the bone with the posterior surface—that which presents the articular facet—toward you, in such a manner that the faceted portion of the surface is uppermost. The outer, concave surface will point to the side to which it belongs.

Articulations.—With one bone, the cuneiform.

Attachment of Muscles.—To two: the Flexor carpi ulnaris and Abductor minimi digitii; and to the anterior annular ligament.
Bones of the Lower Row.

Trapezium (os multangulum majus) (Fig. 144).—The trapezium (τράπεζα, a table) is of very irregular form. It may be distinguished by a deep groove, for the tendon of the Flexor carpi radialis muscle. It is situated at the external and inferior part of the carpus between the scaphoid and first metacarpal bone.

Surfaces.—The superior surface, concave and smooth, is directed upward and inward, and articulates with the scaphoid. The inferior surface, directed downward and inward, is oval, concave from side to side, convex from before backward, so as to form a saddle-shaped surface, for articulation with the base of the first metacarpal bone. The anterior or palmar surface is narrow and rough. At its upper part is a deep groove running from above obliquely downward and inward; it transmits the tendon of the Flexor carpi radialis, and is bounded externally by a prominent ridge, the oblique ridge of the trapezium (tuberculum ossis multanguli majoris). This surface gives attachment to the Abductor pollicis, Flexor ossis metacarpi pollicis, and Flexor brevis pollicis muscles, and the anterior annular ligament. The posterior or dorsal surface is rough. The external surface is also broad and rough, for the attachment of ligaments. The internal surface presents two articular facets: the upper one, large and concave, articulates with the trapezoid; the lower one, small and oval, with the base of the second metacarpal bone.

Hold the bone with the saddle-shaped surface downward and the grooved surface away from you. The prominent, rough, non-articular surface points to the side to which the bone belongs.

Articulations.—With four bones: the scaphoid above, the trapezoid and second metacarpal bones internally, the first metacarpal below.

Attachment of Muscles.—Abductor pollicis, Flexor ossis metacarpi pollicis, and part of the Flexor brevis pollicis.

Trapezoid (os multangulum minus) (Fig. 145).—The trapezoid is the smallest bone in the second row. It may be known by its wedge-shaped form, the broad end of the wedge forming the dorsal, the narrow end the palmar, surface, and by its having four articular surfaces touching each other and separated by sharp edges.

Surfaces.—The superior surface, quadrilateral in form, smooth, and slightly concave, articulates with the scaphoid. The inferior surface articulates with the upper
end of the second metacarpal bone; it is convex from side to side, concave from before backward, and subdivided by an elevated ridge into two unequal lateral facets. The posterior or dorsal and anterior or palmar surfaces are rough, for the attachment of ligaments, the former being the larger of the two. The external surface, convex and smooth, articulates with the trapezium. The internal surface is concave and smooth in front, for articulation with the os magnum; rough behind, for the attachment of an interosseous ligament.

Hold the bone with the larger, non-articular surface toward you, and the smooth, quadrilateral articular surface upward. The convex articular surface will point to the side to which the bone belongs.1

Articulations.—With four bones: the scaphoid above, second metacarpal bone below, trapezium externally, os magnum internally.

Os Magnum (os capitatum) (Fig. 146).—The os magnum is the largest bone of the carpus, and occupies the centre of the wrist. It presents, above, a rounded portion or head, which is received into the concavity formed by the scaphoid and semilunar bones; a constricted portion or neck; and, below, the body.

Surfaces.—The superior surface is rounded, smooth, and articulates with the semilunar. The inferior surface is divided by two ridges into three facets for articulation with the second, third, and fourth metacarpal bones, that for the third (the middle facet) being the largest of the three. The posterior or dorsal surface is broad and rough; the anterior or palmar, narrow, rounded, and also rough, for the attachment of ligaments and a part of the Adductor obliquus pollicis. The external surface articulates with the trapezoid by a small facet at its anterior inferior angle, behind which is a rough depression for the attachment of an interosseous ligament. Above this is a deep and rough groove, which forms part of the neck and serves for the attachment of ligaments, bounded superiorly by a smooth, convex surface, for articulation with the scaphoid. The internal surface articulates with the unciform by a smooth, concave, oblong facet which occupies its posterior and superior parts, and is rough in front, for the attachment of an interosseous ligament.

Hold the bone with the broader, non-articular surface toward you, and the head upward. The small, articular facet at the anterior inferior angle of the external surface will point to the side to which the bone belongs.

Articulations.—With seven bones: the scaphoid and semilunar above; the second, third, and fourth metacarpal below; the trapezoid on the radial side; and the unciform on the ulnar side.

Attachment of Muscles.—Part of the Adductor obliquus pollicis.

Unciform (os hamatum) (Fig. 147).—The unciform or hook bone (uncus, a hook; forma, likeness) may be readily distinguished by its wedge-shaped form and the hook-like process that projects from its palmar surface. It is situated at the inner

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1 Occasionally in a badly marked bone there is some difficulty in ascertaining to which side the bone belongs; the following method will sometimes be found useful: Hold the bone with its broader, non-articular surface upward, so that its sloping border is directed toward you. The border will slope to the side to which the bone belongs.—En. of 15th English Edition.
and lower angle of the carpus, with its base downward, resting on the two inner metacarpal bones, and its apex directed upward and outward.

**Surfaces.**—The superior surface, the apex of the wedge, is narrow, convex, smooth, and articulates with the semilunar. The inferior surface articulates with the fourth and fifth metacarpal bones, the concave surface for each being separated by a ridge which runs from before backward. The posterior or dorsal surface is triangular and rough, for ligamentous attachment. The anterior or palmar surface presents, at its lower and inner side, a curved, hook-like process of bone, the unciform process (hamulus ossis hamati), directed from the palmar surface forward and outward. It gives attachment by its apex to the annular ligament and Flexor carpi ulnaris; by its inner surface to the Flexor brevis minimi digiti and the Opponens minimi digiti; and is grooved on its outer side, for the passage of the Flexor tendons into the palm of the hand. This is one of the four eminences on the front of the carpus to which the anterior annular ligament is attached, the others being the pisiform internally, the oblique ridge of the trapezium and the tuberosity of the scaphoid externally. The internal surface articulates with the cuneiform by an oblong facet cut obliquely from above, downward and inward. The external surface articulates with the os magnum by its upper and posterior part, the remaining portion being rough, for the attachment of ligaments.

Hold the bone with the hooked process away from you, and the articular surface, divided into two parts, for the metacarpal bones, downward. The concavity of the process will be on the side to which the bone belongs.

**Articulations.**—With five bones: the semilunar above, the fourth and fifth metacarpal below, the cuneiform internally, the os magnum externally.

**Attachment of Muscles.**—To three: the Flexor brevis minimi digiti, the Opponens minimi digiti, the Flexor carpi ulnaris.

### The Metacarpus (Ossa Metacarpalia) (Figs. 138, 139).

The metacarpal bones are five in number, and they are numbered from 1 to 5 inclusive, the first being the metacarpal bone of the thumb, the fifth the metacarpal bone of the index finger. They are long, cylindrical bones, presenting for examination a shaft and two extremities.

**Common Characters of the Metacarpal Bones.** The **Shaft** (corpus).—The shaft is prismatic in form and curved longitudinally, so as to be convex in the longitudinal direction behind, concave in front. It presents three surfaces: two lateral and one posterior. The two lateral surfaces constitute the palmar or volar surface. The lateral surfaces are concave, for the attachment of the Interossei muscles, and separated from one another by a prominent anterior ridge. The posterior or dorsal surface presents in its distal half a smooth, triangular, flattened area which is covered, in the recent state, by the tendons of the Extensor muscles. This triangular surface is bounded by two lines, which commence in
small tubercles situated on the dorsal aspect on either side of the digital extremity, and, running backward, converge to meet together a little behind the centre of the bone and form a ridge which runs along the rest of the dorsal surface to the carpal extremity. This ridge separates two lateral, sloping surfaces for the attachment of the Dorsal interossei muscles. To the tubercles on the digital extremities are attached the lateral ligaments of the metacarpo-phalangeal joints. On the palmar surface of each metacarpal bone is a nutrient foramen (foramen nutricium), which opens into a nutrient canal (canalis nutricius). In the thumb metacarpal the direction of this foramen is toward the periphery (distally). In each of the other metacarpals it is from the periphery (proximally).

**Carpal or Proximal Extremity or Base (basis).**—The carpal extremity, or base, is of a cuboidal form, and broader behind than in front; it articulates above with the carpus, and on each side with the adjoining metacarpal bones; its dorsal and palmar surfaces are rough, for the attachment of tendons and ligaments.

**Digital or Distal Extremity or Head (capitulum).**—The digital extremity, or head, presents an oblong surface, markedly convex from before backward, less so from side to side, and flattened laterally; it articulates with the proximal phalangeal joint. The posterior surface, broad and flat, supports the Extensor tendons; the anterior surface is grooved in the middle line for the passage of the Flexor tendons, and marked on each side by an articular eminence continuous with the terminal articular surface. The metacarpal spaces (spatia interossea metacarpi) are the intervals between the metacarpal bones. They are occupied by the Interossei muscles. The broadest space is between the metacarpal bones of the thumb and index finger.

**Peculiar Characters of the Metacarpal Bones.**—The Metacarpal Bone of the Thumb (os metacarpe I) (Fig. 148) is shorter and wider than the rest, diverges to a greater degree from the carpus, and its palmar surface is directed inward toward the palm. The shaft is flattened and broad on its dorsal aspect, and does not present the ridge which is found on the other metacarpal bones; it is concave from above downward, on its palmar surface. The carpal extremity, or base, presents a concavo-convex surface, for articulation with the trapezium; it has no lateral facets, but presents externally a tubercle for the insertion of the Extensor ossis metacarpi pollicis. The digital extremity is less convex than that of the other metacarpal bones, broader from side to side than from before backward. It presents on its palmar aspect two distinct articular eminences for the two sesamoid bones in the tendons of the Flexor brevis pollicis, the outer one being the larger of the two.

The side to which this bone belongs may be known by holding it in the position it occupies in the hand, with the carpal extremity upward and the dorsal surface backward; the tubercle for the Extensor ossis metacarpi pollicis will point to the side to which it belongs.

**Attachment of Muscles.**—To four: the Flexor ossis metacarpi pollicis, the Extensor ossis metacarpi pollicis, the Flexor brevis pollicis, and the First dorsal interosseous.

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1 By these sloping surfaces the metacarpal bones of the hand may be at once differentiated from the metatarsal bone of the foot.—Ed. of 15th English Edition.
The Metacarpal Bone of the Index Finger (os metacarpale II) (Fig. 149) is the longest and its base the largest of the other four. Its carpal extremity is prolonged upward and inward, forming a prominent ridge. The dorsal and palmar surfaces of this extremity are rough, for the attachment of tendons and ligaments. It presents four articular facets: three on the upper aspect of the base: the middle one of the three is the largest, concave from side to side, convex from before backward, for articulation with the trapezoid; the external one is a small, flat, oval facet, for articulation with the trapezium; the internal one on the summit of the ridge is long and narrow, for articulation with the os magnum. The fourth facet is on the inner or ulnar side of the extremity of the bone, and is for articulation with the third metacarpal bone.

The side to which this bone belongs is indicated by the absence of the lateral facet on the outer (radial) side of its base, so that if the bone is placed with the base toward the student and the palmar surface upward, the side on which there is no lateral facet will be that to which it belongs.

Attachment of Muscles.—To six: Flexor carpi radialis, Extensor carpi radialis longior, Adductor obliqueus pollicis, First and Second dorsal interosseous, and First palmar interosseous.

The Metacarpal Bone of the Middle Finger (os metacarpale III) (Fig. 150) is a little smaller than the preceding: it presents a pyramidal eminence, the styloid process (processus styloideus), on the radial side of its base (dorsal aspect), which extends upward behind the os magnum; immediately below this, on the dorsal aspect, is a rough surface for the attachment of the Extensor carpi radialis brevior. The carpal, articular facet is concave behind, flat in front, and articulates with the os magnum. On the radial side is a smooth, concave facet, for articulation with the second metacarpal bone, and on the ulnar side two small, oval facets, for articulation with the fourth metacarpal.

The side to which this bone belongs is easily recognized by the styloid process on the radial side of its base. With the palmar surface uppermost and the base toward the student, this process points toward the side to which the bone belongs.
Attachment of Muscles.—To six: Extensor carpi radialis brevior, Flexor carpi radialis, Adductor transversus pollicis, Adductor obliquus pollicis, and Second and Third dorsal intersosseous.

The Metacarpal Bone of the Ring Finger (os metacarpale IV) (Fig. 151) is shorter and smaller than the preceding, and its base small and quadrilateral; the carpal surface of the base presenting two facets, a large one externally, for articulation with the unciform, and a small one internally, for the os magnum. On the radial side are two oval facets, for articulation with the third metacarpal bone; and on the ulnar side a single concave facet, for the fifth metacarpal.

If this bone is placed with the base toward the student and the palmar surface upward, the radial side of the base, which has two facets for articulation with the third metacarpal bone, will be on the side to which it belongs. If, as sometimes happens in badly marked bones, one of these facets is indistinguishable, the side may be known by selecting the surface on which the larger articular facet is present. This facet is for the fifth metacarpal bone, and would therefore be situated on the ulnar side—that is, the one to which the bone does not belong.

Attachment of Muscles.—To three: the Third and Fourth dorsal and Second palmar intersosseous.

The Metacarpal Bone of the Little Finger (os metacarpale V) (Fig. 152) presents on its base one facet, which is concavo-convex, and which articulates with the unciform bone, and one lateral, articular facet, which articulates with the fourth metacarpal bone. On its ulnar side is a prominent tubercle, for the insertion of the tendon of the Extensor carpi ulnaris. The dorsal surface of the shaft is marked by an oblique ridge which extends from near the ulnar side of the upper extremity to the radial side of the lower. The outer division of this surface serves for the attachment of the Fourth dorsal intersosseous muscle; the inner division is smooth and covered by the Extensor tendons of the little finger.

If this bone is placed with its base toward the student and its palmar surface upward, the side of the head which has a lateral facet will be that to which the bone belongs.

Attachment of Muscles.—To five: the Extensor carpi ulnaris, Flexor carpi ulnaris, Flexor ossis metacarpi minimi digiti, Fourth dorsal, and Third palmar intersosseous.
Articulations.—Besides the phalangeal articulations, the first metacarpal bone articulates with the trapezium; the second with the trapezium, trapezoid, os magnum, and third metacarpal bones; the third with the os magnum and second and fourth metacarpal bones; the fourth with the os magnum, unciform, and third and fifth metacarpal bones; and the fifth with the unciform and fourth metacarpal.

The first has no lateral facets on its carpal extremity; the second has no lateral facet on its radial side, but one on its ulnar side; the third has one on its radial and two on its ulnar side; the fourth has two on its radial and one on its ulnar side; and the fifth has only one on its radial side.

The Phalanges of the Hand (Phalanges Digitorum Manus).

The phalanges (internodia) are the bones of the fingers; they are fourteen in number, three for each finger, and two for the thumb. In numbering them the proximal bone is designated as the first phalanx (phalanx I). They are long bones, and present for examination a shaft and two extremities. The shaft (corpus phalangis) tapers from above downward, is convex posteriorly, concave in front from above downward, flat from side to side, and marked laterally by rough ridges, which give attachment to the fibrous sheaths of the Flexor tendons. A nutrient foramen on the palmar surface leads into a nutrient canal which runs toward the periphery (distalward). The metacarpal extremity or base (basis phalangis) of each phalanx in the first row presents an oval, concave, articular surface, broader from side to side than from before backward; and the same extremity in the other two rows, a double concavity, separated by a longitudinal median ridge, extending from before backward. The distal extremity of the first phalanx of the thumb and of the first and second phalanx of each of the fingers is smaller than the base, and terminates in two small, lateral condyles, separated by a slight groove (trochlea phalangis); the articular surface being prolonged farther forward on the palmar than on the dorsal surface, especially in the first row.

The Ungual Phalanges (distal) are convex on their dorsal, flat on their palmar, surfaces; they are recognized by their small size and by a roughened, elevated surface of a horseshoe form on the palmar aspect of their ungual extremity (tuberositas unguicularis), which serves to support the sensitive pulp of the finger.

Articulations.—The first row, with the metacarpal bones and the second row of phalanges; the second row, with the first and third; the third, with the second row.

Attachment of Muscles.—To the base of the first phalanx of the thumb, five muscles: the Extensor brevis pollicis, Flexor brevis pollicis, Adductor pollicis, Adductor transversus and Obliquus pollicis. To the second phalanx, two: the Flexor longus pollicis and the Extensor longus pollicis. To the base of the first phalanx of the index finger, the First dorsal and the First palmar interosseous; to that of the middle finger, the Second and Third dorsal interosseous; to that of the ring finger, the Fourth dorsal and the Second palmar interosseous; and to that of the little finger, the Third palmar interosseous, the Flexor brevis minimi digitii, and Abductor minimi digitii. To the second phalanges, the Extensor sublimis digitorum, Extensor communis digitorum, and, in addition, the Extensor indicis to the index finger, the Extensor minimi digitii to the little finger. To the third phalanges, the Flexor profundus digitorum and Extensor communis digitorum.

Surface Form.—On the front of the wrist are two subcutaneous eminences, one on the radial side, the larger and flatter, due to the tuberosity of the scaphoid and the ridge on the trapezium; the other, on the ulnar side, caused by the pisiform bone. The tubercle of the scaphoid is to be felt just below and in front of the apex of the styloid process of the radius. It is best perceived by extending the hand on the forearm. Immediately below is to be felt another prominence, better marked than the tubercle; this is the ridge on the trapezium which gives attachment to some of the short muscles of the thumb. On the inner side of the front of
the wrist the pisiform bone is to be felt, forming a small but prominent projection in this situation. It is some distance below the styloid process of the ulna, and may be said to be just below the level of the styloid process of the radius. The rest of the front of the carpus is covered by tendons and the annular ligament, and entirely concealed, with the exception of the hooked process of the unciform, which can only be made out with difficulty. The back of the carpus is convex and covered by the Extensor tendons, so that none of the posterior surfaces of the bones are to be felt, with the exception of the cuneiform on the inner side. Below the carpus the dorsal surfaces of the metacarpal bones, except the fifth, are covered by tendons, and are scarcely visible except in very thin hands. The dorsal surface of the fifth is, however, subcutaneous throughout almost its whole length, and is plainly to be perceived and felt. In addition to this, slightly external to the middle line of the hand, is a prominence, frequently well marked, but occasionally indistinct, formed by the base of the metacarpal of the middle finger. The heads of the metacarpal bones are plainly to be felt and seen, rounded in contour and standing out in bold relief under the skin, when the fist is clenched. It should be borne in mind that when the fingers are flexed on the hand, the articular surfaces of the first phalanges glide off the heads of the metacarpal bones on to their anterior surfaces, so that the head of these bones form the prominence of the knuckles and receive the force of any blow which may be given. The head of the third metacarpal bone is the most prominent, and receives the greater part of the shock of the blow. This bone articulates with the os magnum, so that the concussion is carried through this bone to the scaphoid and semilunar, with which the head of the os magnum articulates, and by these bones is transferred to the radius, along which it may be carried to the capitellum of the humerus. The enlarged extremities of the phalanges are to be plainly felt: they form the joints of the fingers. When the digits are bent the proximal phalanges of the joints form prominences, which in the joint between the first and second phalanges is slightly hollowed, in accordance with the grooved shape of their articular surfaces, whilst at the last row the prominence is flattened and square-shaped. In the palm of the hand the four inner metacarpal bones are covered by muscles, tendons, and the palmar fascia, and no part of them but their heads is to be distinguished. With regard to the thumb, on the dorsal aspect the base of the metacarpal bone forms a prominence below the styloid process of the radius; the shaft is to be felt, covered by tendons, terminating at its head in a flattened prominence, in front of which can be felt the sesamoid bones.

**Surgical Anatomy.**—The carpal bones are not very liable to fracture, except from extreme violence, when the parts may be so comminuted as to necessitate amputation. Occasionally they are the seat of *tuberculous* disease. The metacarpal bones and the phalanges are not unfrequently broken by direct violence. The first metacarpal bone is the one most commonly fractured; then the second, the fourth, and the fifth, the third being the one least frequently broken. There are two diseases of the metacarpal bones and phalanges which require special mention on account of the frequency of their occurrence. One is *tuberculous dactylitis*, consisting in a deposit of tuberculous material in the medullary canal, expanding the bone, with subsequent caseation and resulting necrosis. The other is *chondroma*, which is perhaps more frequently found in connection with the metacarpal bones and phalanges than with any other bones. When chondromatous growth takes place there are usually multiple tumors, and they may spring either from the medullary canal or from the periosteum.

**Development of the Bones of the Hand.**

The Carpal Bones are each developed by a single centre. At birth they are all cartilaginous. Ossification proceeds in the following order (Fig. 153): In the os magnum and unciform an ossific point appears during the first year, the former preceding the latter; in the cuneiform, at the third year; in the trapezium and semilunar, at the fifth year, the former preceding the latter; in the scaphoid, at the sixth year; in the trapezoid, during the eighth year; and in the pisiform, about the twelfth year.

Occasionally an additional bone, the os centrale, is found in the carpus, lying between the scaphoid, trapezoid, and os magnum. During the second month of foetal life it is represented by a small cartilaginous nodule, which, however, fuses with the cartilaginous scaphoid about the third month. Sometimes the styloid process of the third metacarpal is detached and forms an additional ossicle.

The Metacarpal Bones are each developed by two centres: one for the shaft and one for the digital extremity for the four inner metacarpal bones; one for the shaft and one for the base for the metacarpal bone of the thumb, which in this
respect resembles the phalanges. Ossification commences in the centre of the shaft about the eighth or ninth week, and gradually proceeds to either end of the bone: about the third year the digital extremities of the four inner metacarpal bones and the base of the first metacarpal begin to ossify, and they unite about the twentieth year.

Carpus.
One centre for each bone. All cartilaginous at birth.

Metacarpus.
Two centres for each bone:
One for shaft, One for digital extremity, except first.

Phalanges.
Two centres for each bone:
One for shaft, One for metacarpal extremity.

The **Phalanges** are each developed by two centres; one for the shaft and one for the base. Ossification commences in the shaft, in all three rows, at about the eighth week, and gradually involves the whole of the bone excepting the upper extremity. Ossification of the base commences in the first row between the third and fourth years, and a year later in those of the second and third rows. The two centres become united, in each row, between the eighteenth and twentieth years.

In the ungual phalanges the centre for the shaft appears at the distal extremity of the phalanx, instead of at the middle of the shaft, as is the case with the other phalanges.

**THE LOWER EXTREMITY.**

The bones of the lower extremity consist of those of the **pelvis**, of the **thigh**, of the **leg**, and of the **foot**.

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1. Allan Thomson has demonstrated the fact that the first metacarpal bone is often developed from three centres; that is to say, there is a separate nucleus for the distal end, forming a distinct epiphysis, visible at the age of seven or eight years. He also states that there are traces of a proximal epiphysis in the second metacarpal bone.—*Journal of Anatomy*, 1869.
THE PELVIS (Figs. 154, 155).

The pelvis, so called from its resemblance to a basin (L. pelvis), is stronger and more massively constructed than either the cranial or thoracic cavity; it is a bony ring, interposed between the lower end of the spine, which it supports, and the lower extremities, upon which it rests. It is composed of four bones: the two *ossa innominata*, which bound it on either side and in front, and the *sacrum* and *coccyx*, which complete it behind. The pelvis is divided by an oblique plane passing through the prominence of the sacrum, the linea ilio-pectinea, and the upper margin of the symphysis pubis into the false and true pelvis.

The False Pelvis (pelvis major).—The false pelvis is the expanded portion of the pelvic cavity which is situated above this plane. It is bounded on each side by the *ossa ili*; in front it is incomplete, presenting a wide interval between the spinous processes of the ilia on either side, which is filled up in the recent state by the parietes of the abdomen; behind, in the middle line, is a deep notch. This broad, shallow cavity is fitted to support the intestines and to transmit part of their weight to the anterior wall of the abdomen, and is, in fact, really a portion of the abdominal cavity. The term false pelvis is incorrect, and this space ought more properly to be regarded as part of the hypogastric and iliac regions of the abdomen.

The True Pelvis (pelvis minor).—The true pelvis is that part of the pelvic cavity which is situated beneath the plane. It is smaller than the false pelvis, but its walls are more perfect. For convenience of description it is divided into a superior circumference or inlet, an inferior circumference or outlet, and a cavity.

The Superior Circumference or Inlet (apertura pelvis superior).—The superior circumference forms the brim of the pelvis, the included space being called the inlet. It is formed by the linea ilio-pectinea, completed in front by the crests of the pubic bones, and behind by the anterior margin of the base of the sacrum and sacro-vertebral angle. The brim of the pelvis is the name often given to the
margin of the inlet. The inlet of the pelvis is somewhat heart-shaped, obtusely pointed in front, diverging on either side, and encroached upon behind by the projection forward of the promontory of the sacrum. It has three principal diameters: antero-posterior (sacro-pubic), transverse, and oblique. The antero-posterior or conjugate diameter (conjugata) extends from the sacro-vertebral angle to the symphysis pubis. The anatomical conjugate (conjugata anatomica) is the distance between the sacro-vertebral angle and the top of the symphysis pubis. Its average measurement is four inches in the male and four and three-fifths inches in the female. The true, available, or obstetric conjugate (conjugata gynaeologica) is the distance between the sacro-vertebral angle and the nearest point upon the symphysis. This point is a little behind and below the upper margin (Webster).

The average distance in women is four and three-eighths inches. The diagonal conjugate (diagonale conjugata) is measured from the sacro-vertebral angle to the subpubic ligament. The distance exceeds the true conjugate by one-half or two-thirds of an inch. The transverse diameter (diameter transversa) extends across the greatest width of the inlet, from the middle of the brim on one side to the same point on the opposite; its average measurement is five inches in the male, five and one-fourth inches in the female. The oblique diameter (diameter obliqua) extends from the margin of the pelvis, corresponding to the ilio-pectineal eminence on one side, to the sacro-iliac articulation on the opposite side; its average measurement is four and a quarter inches in the male and five in the female. The oblique diameters are named right or left oblique, according to the sacro-iliac joint from which the measurement is taken.

The Cavity.—The cavity of the true pelvis is bounded in front by the symphysis pubis; behind, by the concavity of the sacrum and coccyx, which, curving forward above and below, contracts the inlet and outlet of the canal; and laterally it is bounded by a broad, smooth, quadrangular surface of bone, corresponding to the inner surface of the body of the ischium and that part of the ilium which is below the ilio-pectineal line. The cavity is shallow in front, measuring at the symphysis an inch and a half in depth, three inches and a half in the middle, and four inches and a half posteriorly. From this description it will be seen that the cavity of the pelvis is a short, curved canal, considerably deeper on its posterior than on its anterior wall. This cavity contains, in the recent subject, the rectum, bladder, and part of the organs of generation. The rectum is placed at the back.
of the pelvis, and corresponds to the curve of the sacro-coccygeal column; the bladder in front, behind the symphysis pubis. In the female the uterus and vagina occupy the interval between these viscera.

The Lower Circumference or Outlet (apertura pelvis inferior).—The lower circumference of the pelvis is very irregular, and forms what is called the outlet. It is bounded by three prominent prominences: one posterior, formed by the point of the coccyx; and one on each side, the tuberosities of the ischia. These prominences are separated by three notches; one in front, the pubic arch (arcus pubis), formed by the convergence of the rami of the ischia and pubic bones on each side. The other notches, one on each side, are formed by the sacrum and coccyx behind, the ischium in front, and the ilium above; they are called the sacro-sciatic notches; in the natural state they are converted into foramina by the lesser and greater sacro-sciatic ligaments. In the recent state, when the ligaments are in situ, the outlet of the pelvis is lozenge-shaped, bounded in front by the subpubic ligament and the rami of the os pubis and ischium; on each side by the tuberosities of the ischia; and behind by the great sacro-sciatic ligaments and the tip of the coccyx.

The diameters of the outlet of the pelvis are two, antero-posterior and transverse. The antero-posterior (conjugated) diameter (diameter recta of the outlet) extends from the tip of the coccyx to the lower part of the symphysis pubis; its average measurement is three and three-quarter inches in the male and four and one-half inches in the female. The antero-posterior diameter varies with the length of the coccyx, and is capable of increase or diminution on account of the mobility of that bone. During labor the coccyx may be bent back so that the conjugate is increased one inch, or even one and one-fourth inches. The transverse diameter extends from the posterior part of one ischiatic tuberosity to the same point on the opposite side: the average measurement is three and a half inches in the male and four and three-fourths in the female.1

Oblique diameters are not employed, as there are no fixed points from which to measure them.

Position of the Pelvis.—In the erect posture the pelvis is placed obliquely with regard to the trunk of the body: the bony ring, which forms the brim of the true pelvis, is placed so as to form an angle of about 60 to 65 degrees with the ground on which we stand (inclinatio pelvis). The pelvic surface of the symphysis pubis looks upward and backward, the concavity of the sacrum and coccyx downward and forward, the base of the sacrum in well-formed female bodies being nearly four inches above the upper border of the symphysis pubis, and the apex of the coccyx a little more than half an inch above its lower border. In consequence of the obliquity of the pelvis the line of gravity of the head, which passes through the middle of the odontoid process of the axis and through the points of junction of the curves of the vertebral column to the sacro-vertebral angle, descends toward the front of the cavity, so that it bisects a line drawn transversely through the middle of the heads of the thigh bones. And thus the centre of gravity of the head is placed immediately over the heads of the thigh bones on which the trunk is supported.

Axes of the Pelvis (Fig. 156).—The plane of the inlet of the true pelvis will be represented by a line drawn from the base of the sacrum to the upper margin

1 The measurements of the pelvis given above are, I believe, fairly accurate, but different measurements are given by various authors, no doubt due in a great measure to differences in the physique and stature of the population from whom the measurements have been taken. The accompanying chart has been formulated to show the measurements of the pelvis which are adopted by many obstetricians.—Ed.

Diameters of the True Pelvis in Woman.

<table>
<thead>
<tr>
<th></th>
<th>Antero-posterior</th>
<th>Transverse</th>
</tr>
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<tbody>
<tr>
<td>Of inlet</td>
<td>4½ inches (118 mm.)</td>
<td>5 inches (127 mm.)</td>
</tr>
<tr>
<td>Of outlet</td>
<td>4½ inches (115 mm.)</td>
<td>4½ inches (120 mm.)</td>
</tr>
</tbody>
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of the symphysis pubis. A line carried at right angles with this at its middle would correspond at one extremity with the umbilicus, and at the other with the middle of the coccyx: the axis of the inlet is therefore directed downward and backward. The axis of the outlet, prolonged upward, would touch the base of the sacrum, and is therefore directed downward and forward. The axis of the cavity is curved like the cavity itself; this curve corresponds to the concavity of the sacrum and coccyx, the extremities being indicated by the central points of the inlet and outlet. A knowledge of the direction of these axes serves to explain the course of the fetus in the passage through the pelvis during parturition. It is also important to the surgeon, as indicating the direction of the force required in the removal of calculi from the bladder by the sub-pubie operation, and as determining the direction in which instruments should be used in operations upon the pelvic viscera.

 Differences between the Male and the Female Pelvis.—The female pelvis, looked at as a whole, is distinguished from the male by the bones being more delicate, by its width being greater and its depth smaller. The whole pelvis is less massive, and its bones are lighter and more slender, and its muscular impressions are slightly marked. The iliac fossae are shallow, and the anterior iliac spines widely separated; hence the greater prominence of the hips. The inlet in the female is larger than in the male; it is more nearly circular, and the sacro-vertebral angle projects less forward. The cavity is shallower and wider; the sacrum is shorter, wider, and less curved; the obturator foramina are triangular, and smaller in size than in the male. The outlet is larger and the coccyx more movable. The spines of the ischia project less inward. The tuber-
osities of the ischia and the acetabula are wider apart. The pubic arch is wider and more rounded than in the male, where it is an angle rather than an arch. In consequence of this the width of the fore part of the pelvic outlet is much increased and the passage of the foetal head facilitated.

The size of the pelvis varies not only in the two sexes, but also in different members of the same sex. This does not appear to be influenced in any way by the height of the individual. Women of short stature, as a rule, have broad pelves. Occasionally the pelvis is equally contracted in all its dimensions, so much so that all its diameters measure an inch less than the average, and this even in women of average height and otherwise well formed. The principal divergences, however, are found at the inlet, and affect the relation of the antero-posterior to the transverse diameter. Thus we may have a pelvis the inlet of which is elliptical either in a transverse or antero-posterior direction; the transverse diameter in the former and the antero-posterior in the latter greatly exceeding the other diameters. Again, the inlet of the pelvis in some instances is seen to be almost circular. The same differences are found in various races. European women are said to have the most roomy pelves. That of the negro is smaller, circular in shape, and with a narrow pubic arch. The Hottentots and Bushwomen possess the smallest pelves.

In the fetus and for several years after birth the pelvis is small in proportion to that of the adult. The cavity is deep, and the projection of the sacro-vertebral angle less marked. The generally accepted opinion that the female pelvis does not acquire its sexual characters until after puberty has been shown by recent observations\(^1\) to be erroneous, the characteristic differences between the male and female pelvis being distinctly indicated as early as the fourth month of foetal life. At birth these differences are distinct (Romiti), the female pelvis possessing less straight ilia, a broader subpubic arch, and less height than the male.

**The Os Inominatum, called also Os Coxaе, Hip Bone, Haunch Bone, the Nameless Bone** (Figs. 159, 160).

The os inominatum (in, not; nomino, I name) is so called from bearing no resemblance to any known object. It is a large, irregularly shaped, flat bone, constricted in the centre and expanded above and below. With its fellow of the

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opposite side it forms the sides and anterior wall of the pelvic cavity. In young subjects it consists of three separate parts, which meet and form the large, cup-like cavity, the *acetabulum*, situated near the middle of the outer surface of the bone; and, although in the adult these have become united, it is usual to describe the bone as divisible into three portions—the *ilium*, the *ischium*, and the *pubis*.

The *ilium*, so called from its supporting the flank (*ilium* or *ileum*, the flank), is the superior, broad, and expanded portion which runs upward from the acetabulum and forms the prominence of the hip.

The *ischium* (*ischiôv*, the hip) is the inferior and strongest portion of the bone; it proceeds downward from the acetabulum, expands into a large tuberosity, and then, curving forward, forms, with the descending ramus of the *os pubis*, a large aperture, the obturator foramen.
The os pubis is that portion which extends inward and downward from the acetabulum to articulate in the middle line with the bone of the opposite side: it forms the front of the pelvis, supports the external organs of generation, and has received its name from the skin over it being covered with hair (pubes).

The ilium (os ilium).—The lower or constricted part of the ilium is thick, though narrower than the expanded portion. It aids in the formation of the acetabulum and is called the body (corpus ossis ilium). The broad expanded portion of the ilium is thin in many places. It is called the ala (ala ossis ilium). The ilium presents for examination two surfaces, an external and an internal; a crest, and two borders, an anterior and a posterior.

External Surface or Dorsum of the Ilium (Fig. 159).—The posterior part of this surface is directed backward and outward; its front part, downward and outward. It is smooth, convex in front, deeply concave behind; bounded above by the crest,
below by the upper border of the acetabulum; in front and behind by the anterior and posterior borders. This surface is crossed in an arched direction by three semicircular lines—the superior, middle, and inferior curved lines. The superior curved line, or the posterior gluteal line (linea glutea posterior), the shortest of the three, commences at the crest, about two inches in front of its posterior extremity; it is at first distinctly marked, but as it passes downward and backward to the upper part of the great sacro-sciatic notch, where it terminates, it becomes less marked, and is often altogether lost. Behind this line is a narrow semilunar surface, the upper part of which is rough and affords attachment to part of the Gluteus maximus; the lower part is smooth and has no muscular fibres attached to it. The middle curved line, or the anterior gluteal line (linea glutea anterior), the longest of the three, commences at the crest, about an inch behind its anterior extremity, and, taking a curved direction downward and backward, terminates at the upper part of the great sacro-sciatic notch. The space between the superior and middle curved lines and the crest is concave, and affords attachment to the Gluteus medius muscle. Near the central part of this line may often be observed the orifice of a nutrient foramen. The inferior curved or inferior gluteal line (linea glutea inferior), the least distinct of the three, commences in front at the notch on the anterior border, and, taking a curved direction backward and downward, terminates at the middle of the great sacro-sciatic notch. The surface of bone included between the middle and inferior curved lines is concave from above downward, convex from before backward, and affords attachment to the Gluteus minimus muscle. Beneath the inferior curved line, and corresponding to the upper part of the acetabulum, is a roughened surface (sometimes a depression), to which is attached the reflected tendon of the Rectus femoris muscle.

Internal Surface.—The internal surface (Fig. 160) of the ilium is bounded above by the crest; below it is continuous with the pelvic surface of the os pubis and ischium, a faint line only indicating the place of union; and before and behind it is bounded by the anterior and posterior borders. It presents a large, smooth, concave surface, called the iliac fossa, or venter ili (fossa iliaca), which lodges the Iliacus muscle, and presents at its lower part the orifice of a nutrient canal (foramen nutricium); and below this a smooth, rounded border, the ilio-pectinea line or the linea ilio-pectinea (linea arcuata), which separates the iliac fossa from that portion of the internal surface which enters into the formation of the true pelvis, and which gives attachment to part of the Obturator internus muscle. Behind the iliac fossa is a rough surface divided into two portions, an anterior and a posterior. The anterior or auricular surface (facies auricularis), so called from its resemblance in shape to the ear, is coated with cartilage in the recent state, and articulates with a surface of similar shape on the side of the sacrum. The posterior portion (tuberositas iliaca) is rough, for the attachment of the posterior sacro-iliac ligaments and for a part of the origin of the Erector and Multifidus spinae. In many bones a furrow exists in front, under and behind the auricular surface. This furrow is the paraglenoid sulcus (sulcus paraglenoidalis), and it affords attachment to the sacro-sciatic ligaments.

The Crest of the Ilium (crista iliaca).—The crest of the ilium is convex in its general outline and sinuously curved, being concave inward in front, concave outward behind. It is longer in the female than in the male, very thick behind, and thinner at the centre than at the extremities. It terminates at either end in a prominent eminence, the anterior superior and posterior superior spinous process (spina iliaca anterior superior et spina iliaca posterior superior). The surface of the crest is broad, and divided into an external lip (labium externum), an internal lip (labium internum), and an intermediate space (linea intermedia). About two inches behind the anterior superior spinous process there is a prominent
THE OS INNOMINATUM

217
tubercle on the outer lip. To the external lip is attached the Tensor fasciae femoris, Obliquus externus abdominis, and Latissimus dorsi, and along its whole length, the fascia lata; to the space between the lips, the Internal oblique; to the internal lip, the Transversalis, Quadratus lumbarum, and Erector spine, the Iliacus, and the fascia iliaca.

Anterior Border.—The anterior border of the ilium is concave. It presents two projections, separated by a notch. Of these, the uppermost, situated at the junction of the crest and anterior border, is called the anterior superior spinous process of the ilium (spina iliaca anterior superior), the outer border of which gives attachment to the fascia lata and the origin of the Tensor fasciae femoris (tensor vaginae femoris); its inner border, to the Iliacus; while its extremity affords attachment to Poupart’s ligament and the origin of the Sartorius. Beneath this eminence is a notch which gives attachment to the Sartorius muscle, and across which passes the external cutaneous nerve. Below the notch is the anterior inferior spinous process (spina iliaca anterior inferior), which terminates in the upper lip of the acetabulum; it gives attachment to the straight tendon of the Rectus femoris muscle and the ilio-femoral ligament. On the inner side of the anterior inferior spinous process is a broad, shallow groove, over which passes the Ilio-psosas muscle. This groove is bounded internally by an eminence, the ilio-pectineal eminence (eminentia iliopectinea), which marks the point of union of the ilium and os pubis.

Posterior Border.—The posterior border of the ilium, shorter than the anterior, also presents two projections separated by a notch, the posterior superior spinous process (spina iliaca posterior superior) and the posterior inferior spinous process (spina iliaca posterior inferior). The former corresponds with that portion of the inner surface of the ilium which serves for the attachment of the oblique portion of the sacro-iliac ligaments and the Multifidus spine muscle; the latter, to the auricular portion which articulates with the sacrum. Below the posterior inferior spinous process is a deep notch, the great sciatic, ilio-sciatic, or the great sacro-sciatic notch (incisura ischiadica major).

The Ischium (os ischi).—The ischium forms the lower and back part of the os innominatum. It is divisible into a thick and solid portion—the body; a large, rough eminence, on which the trunk rests in sitting—the tuberosity; and a thin part which passes forward and slightly upward—the ramus.

The Body (corpus osis ischi).—The body, somewhat triangular in form, presents three surfaces, external, internal, and posterior; and three borders, external, internal, and posterior. The external surface corresponds to that portion of the acetabulum formed by the ischium; it is smooth and concave, and forms a little more than two-fifths of the acetabular cavity; its outer margin is bounded by a prominent rim or lip, the external border, to which the cotyloid fibro-cartilage is attached. Below the acetabulum, between it and the tuberosity, is a deep groove, along which the tendon of the Obturator externus muscle runs as it passes outward to be inserted into the digital fossa of the femur. The internal surface is smooth, concave, and enters into the formation of the lateral boundary of the true pelvic cavity. This surface is perforated by two or three large, vascular foramina, and affords attachment to part of the Obturator internus muscle. The posterior surface is quadrilateral in form, broad and smooth. Below, where it joins the tuberosity, it presents a groove, the obturator groove (sulcus obturatorius), continuous with that on the external surface, for the tendon of the Obturator externus muscle. The lower edge of this groove is formed by the tuberosity of the ischium, and affords attachment to the Gemellus inferior muscle. This surface is limited, externally, by the margin of the acetabulum; behind, by the posterior border; it supports the Pyriformis, the two Gemelli, and the Obturator internus muscles in their passage outward to the great trochanter.
The external border forms the prominent rim of the acetabulum, and separates the posterior from the external surface. To it is attached the cotyloid fibrocartilage. The internal border is thin, and forms the outer circumference of the obturator foramen. The posterior border of the body of the ischium presents, a little below the centre, a thin and pointed, triangular eminence, the spine of the ischium (spina ischiadica), more or less elongated in different subjects; its external surface gives attachment to the Gemellus superior, its internal surface to the Coccygeus and Levator ani; whilst to the pointed extremity is connected the lesser sacro-sciatic ligament. Above the spine is a notch of large size, the great sacro-sciatic notch (incisura ischiadica major), converted into a foramen, the great sacro-sciatic foramen (foramen ischiadicum major), by the lesser sacro-sciatic ligament; it transmits the Pyriformis muscle, the gluteal vessels, and superior and inferior gluteal nerves; the sciatic vessels, the greater and lesser sciatic nerves, the internal pudic vessels and nerve, and the nerves to the Obturator internus and Quadratus femoris. Of these, the gluteal vessels and superior gluteal nerve pass out above the Pyriformis muscle, the other structures, below it. Below the spine is a smaller notch, the lesser sacro-sciatic notch (incisura ischiadica minor); it is smooth, coated in the recent state with cartilage, the surface of which presents two or three ridges corresponding to the subdivisions of the tendon of the Obturator internus, which winds over it. It is converted into a foramen, the lesser sacro-sciatic foramen (foramen ischiadicum minus), by the sacro-sciatic ligaments, and transmits the tendon of the Obturator internus, the nerve which supplies that muscle, and the internal pudic vessels and nerve.

The Tuberosity of the Ischium (tuber ischiadicum).—The tuberosity of the ischium is the portion of bone between the body and the ascending ramus. Some anatomists name this portion of bone the descending or superior ramus (ramus superior ossis ischii), and restrict the term tuberosity to the surface of the bone which is rough, and is directed backward and outward. The tuberosity presents for examination three surfaces: external, internal, and posterior. The external surface is quadrilateral in shape, and rough for the attachment of muscles. It is bounded above by the groove for the tendon of the Obturator externus; in front it is limited by the posterior margin of the obturator foramen, and below it is continuous with the ramus of the bone; behind, it is bounded by a prominent margin which separates it from the posterior surface. In front of this margin the surface gives attachment to the Quadratus femoris, and anterior to this to some of the fibres of origin of the Obturator externus. The lower part of the surface gives origin to part of the Adductor magnus. The internal surface forms part of the bony wall of the true pelvis. In front it is limited by the posterior margin of the obturator foramen. Behind, it is bounded by a sharp ridge, for the attachment of a falciform prolongation of the great sacro-sciatic ligament; it sometimes presents a groove on the inner side of this ridge for the lodgement of the internal pudic vessels and nerve; and, more anteriorly, has attached the Transversus perinei and Erector penis muscles. The posterior surface is divided into two portions—a lower rough, somewhat triangular part, and an upper smooth, quadrilateral portion. The anterior portion is subdivided by a prominent vertical ridge, passing from base to apex, into two parts; the outer one gives attachment to the Adductor magnus; the inner to the great sacro-sciatic ligament. The upper portion is subdivided into two facets by an oblique ridge which runs downward and outward; from the upper and outer facet arises the Semimembranosus; from the lower and inner, the Biceps and Semitendinosus.

The Ramus or Inferior Ramus or Ascending Ramus of the Ischium (ramus inferior ossis ischii).—The ramus is the thin, flattened part of the ischium which ascends from the tuberosity upward and inward, and joins the descending ramus of the os pubis, their point of junction being indicated in the adult by a rough line.
The outer surface of the ramus is rough, for the attachment of the Obturator externus muscle, and also some fibres of the Adductor magnus; its inner surface forms part of the anterior wall of the pelvis. Its inner border is thick, rough, slightly everted, forms part of the outlet of the pelvis, and presents two ridges and an intervening space. The ridges are continuous with similar ones on the descending ramus of the os pubis: to the outer one is attached the deep layer of the superficial perineal fascia, and to the inner, the superficial layer of the triangular ligament of the urethra. If these two ridges are traced downward, they will be found to join with each other just behind the point of origin of the Transversus perinei muscle; here the two layers of fascia are continuous behind the posterior border of the muscle. To the intervening space, just in front of the point of junction of the ridges, is attached the Transversus perinei muscle, and in front of this a portion of the crus penis vel clitoridis and the Erector penis vel clitoridis muscle. Its outer border is thin and sharp, and forms part of the inner margin of the obturator foramen.

The Pubis (os pubis).—The os pubis forms the anterior part of the os innominatum, and, with the bone of the opposite side, forms the front boundary of the true pelvic cavity. It is divisible into a body, a superior or ascending and an inferior or descending ramus.

The Body (corpus ossis pubis).—The body is the broad portion of bone formed by the junction of the two rami. It is somewhat quadrilateral in shape, and presents for examination two surfaces and three borders: The anterior surface is rough, directed downward and outward, and serves for the attachment of various muscles. To the upper and inner angle, immediately below the crest, is attached the Adductor longus; lower down, from without inward, are attached the Obturator externus, the Adductor brevis, and the upper part of the Gracilis. The posterior surface, convex from above downward, concave from side to side, is smooth, and forms part of the anterior wall of the pelvis. It gives attachment to the Levator ani, Obturator internus, a few muscular fibres prolonged from the bladder, and the pubo-prostatic ligaments. The upper border presents for examination a prominent tubercle, which projects forward and is called the spine (tuberculum pubicum); to it are attached the outer pillar of the external abdominal ring and Poupart's ligament. Passing upward and outward from this is a prominent ridge, forming part of the ilio-pectineal line (linea arcuata), and called the pecten ossis pubis. It marks the brim of the true pelvis: to it are attached a portion of the conjoined tendon of the Internal oblique and Transversalis muscles, Gimbernat's ligament, and the triangular fascia of the abdomen. Internal to the spine of the os pubis is the crest, which extends from this process to the inner extremity of the bone. It affords attachment, anteriorly, to the conjoined tendon of the Internal oblique and Transversalis; and posteriorly, to the Rectus and Pyramidalis muscles. The point of junction of the crest with the inner border of the bone (symphysis) is called the angle; to it, as well as to the symphysis, is attached the internal pillar of the external abdominal ring. The internal border is articular; it is oval, covered by eight or nine transverse ridges, or a series of nipple-like processes arranged in rows, separated by grooves; they serve for the attachment of a thin layer of cartilage, placed between it and the central fibro-cartilage. The outer border presents a sharp margin, which forms part of the circumference of the obturator foramen and affords attachment to the obturator membrane.

The Ascending or Superior Ramus of the Pubis (ramus superior ossis pubis).—The ascending or superior ramus extends from the body to the point of junction of the os pubis with the ilium, and forms the upper part of the circumference of the obturator foramen. It presents for examination a superior, inferior, and posterior surface, and an outer extremity. The superior surface presents a con-
tinuation of the ilio-pectineal line, already mentioned as commencing at the pubic spine. In front of this ridge the surface of bone is triangular in form, wider externally than internally, smooth, and is covered by the Pectineus muscle. The surface is bounded externally by a rough eminence, the ilio-pectineal eminence (eminentia iliopectinea), which serves to indicate the point of junction of the ilium and os pubis, and gives attachment to the Psoas parvus, when this muscle is present. The triangular surface is bounded below by a prominent ridge, the obturator crest (crista obturatoria), which extends from the cotyloid notch to the spine of the os pubis. The inferior surface forms the upper boundary of the obturator foramen, and presents externally a broad and deep oblique groove, the obturator groove (sulcus obturatorius), for the passage of the obturator vessels and nerve; and internally a sharp margin which forms part of the circumference of the obturator foramen, and to which the obturator membrane is attached. The posterior surface forms part of the anterior boundary of the true pelvis. It is smooth, convex from above downward, and affords attachment to some fibres of the Obturator internus. The outer extremity, the thickest part of the ramus, forms one-fifth of the cavity of the acetabulum.

The Descending or Inferior Ramus of the Pubis (ramus inferior ossis pubis).—The descending or inferior ramus of the os pubis is thin and flattened. It passes outward and downward, becoming narrower as it descends, and joins with the ramus of the ischium. Its anterior surface is rough, for the attachment of muscles—the Gracilis along its inner border; a portion of the Obturator externus where it enters into the formation of the foramen of that name; and between these two muscles the Adductores brevis and magnus from within outward. The posterior surface is smooth, and gives attachment to the Obturator internus, and, close to the inner margin, to the Compressor urethrae. The inner border is thick, rough, and everted, especially in females. It presents two ridges, separated by an intervening space. The ridges extend downward, and are continuous with similar ridges on the ascending ramus of the ischium; to the external one is attached the deep layer of the superficial perineal fascia, and to the internal one the superficial layer of the triangular ligament of the urethra. The outer border is thin and sharp, forms part of the circumference of the obturator foramen, and gives attachment to the obturator membrane.

The Cotyloid Cavity or Acetabulum.—The cotyloid cavity, or acetabulum, is a deep, cup-shaped, hemispherical depression, directed downward, outward, and forward; formed internally by the os pubis, above by the ilium, behind and below by the ischium, a little less than two-fifths being formed by the ilium, a little more than two-fifths by the ischium, and the remaining fifth by the pubic bone. It is bounded by a prominent, uneven rim, which is thick and strong above, and serves for the attachment of the cotyloid ligament, which contracts its orifice and deepens the surface for articulation. It presents below a deep notch, the cotyloid notch (incisura acetabuli), which is continuous with a circular depression, the fossa of the acetabulum (fossa acetabuli), at the bottom of the cavity: this depression is perforated by numerous apertures, lodges a mass of fat, and its margins, as well as those of the notch, serve for the attachment of the ligamentum teres. In front, above and behind the fossa acetabuli, is a concave rim of bone (facies lunata). The cotyloid notch is converted, in the natural state, into a foramen by a dense ligamentous band which passes across it. Through this foramen the nutrient vessels and nerves enter the joint.

The Obturator or Thyroid Foramen (foramen obturatum).—The obturator or thyroid foramen is a large aperture situated between the ischium and os pubis. In the male it is large, of an oval form, its longest diameter being obliquely from before backward; in the female it is smaller and more triangular. It is bounded by a thin, uneven margin, to which a strong membrane is attached, and presents,
anteriorly, a deep groove, the *obturator groove* (*sulcus obturatorius*), which runs from the pelvis obliquely inward and downward. This groove is converted into a foramen by the obturator membrane, and transmits the obturator vessels and nerve.

**Structure.**—This bone consists of much cancellous tissue, especially where it is thick, enclosed between two layers of dense, compact tissue. In the thinner parts of the bone, as at the bottom of the acetabulum and centre of the iliac fossa, it is usually semitransparent, and composed entirely of compact tissue.

**Development** (Fig. 161).—By *eight* centres: three primary—one for the ilium, one for the ischium, and one for the os pubis; and *five* secondary—one for the crest of the ilium, one for the anterior inferior spinous process (said to occur more frequently in the male than in the female), one for the tuberosity of the ischium, one for the symphysis pubis (more frequent in the female than the male), and one or more for the Y-shaped piece at the bottom of the acetabulum. These various centres appear in the following order: First, in the ilium, at the lower part of the bone, immediately above the sciatic notch, at about the eighth or ninth week; secondly, in the body of the ischium, at about the third month of foetal life; thirdly, in the body of the os pubis, between the fourth and fifth months. At birth the three primary centres are quite separate, the crest, the bottom of the acetabulum, the ischial tuberosity, and the rami of the ischium and pubes being still cartilaginous. At about the seventh or eighth year the rami of the os pubis and ischium are almost completely united by bone. About the thirteenth or fourteenth year the three divisions of the bone have extended their growth into the bottom of the acetabulum, being separated from each other by a Y-shaped portion of cartilage, which now presents traces of ossification, often by two or
more centres. One of these, the os acetabuli, appears about the age of twelve, between the ilium and os pubis, and fuses with them about the age of eighteen. It forms the pubic part of the acetabulum. The ilium and ischium then become joined, and lastly the os pubis to the ischium, through the intervention of this Y-shaped portion. At about the age of puberty ossification takes place in each of the remaining portions, and they become joined to the rest of the bone between the twentieth and twenty-fifth years. Separate centres are frequently found for the pubic and ischial spines

Articulations.—With its fellow of the opposite side, the sacrum, and femur.

Attachment of Muscles.—To the ilium, sixteen. To the outer lip of the crest, the Tensor vaginae femoris, Obtliquis externus abdominis, and Latissimus dorsi; to the internal lip, the Iliacus, Transversalis, Quadratus lumborum, and Erector spinae; to the interspace between the lips, the Obliquus internus. To the outer surface of the ilium, the Gluteus maximus, Gluteus medius, Gluteus minimus, reflected tendon of the Rectus; to the upper part of the great sacro-sciatic notch, a portion of the Pyriformis; to the internal surface, the Iliacus; to that portion of the internal surface below the linea ilio-pectinea, the Obturator internus to the internal surface of the posterior superior spine, and the Multifidus spine; to the anterior border, the Sartorius and straight tendon of the Rectus. To the ischium, thirteen. To the outer surface of the ramus, the Obturator externus and Adductor magnus; to the internal surface, the Obturator internus and Erector penis. To the spine, the Gemellus superior, Levator ani, and Coccygeus. To the tuberosity, the Biceps, Semitendinosus, Semimembranosus, Quadratus femoris, Adductor magnus, Gemellus inferior, Transversus perinæ, Erector penis. To the pubis, sixteen: Obtliquis externus, Obtliquis internus, Transversalis, Rectus, Pyramidalis, Psoas parvis, Pectineus, Adductor magnus, Adductor longus, Adductor brevis, Gracilis, Obturator externus and internus, Levator ani, Compressor urethre, and occasionally a few fibres of the Accelerator urine.

Surface Form.—The pelvic bones are so thickly covered with muscles that it is only at certain points that they approach the surface and can be felt through the skin. In front, the anterior superior spinous process is easily recognized; a portion of it is subcutaneous, and in thin subjects may be seen to stand out as a prominence at the outer extremity of the fold of the groin. In fat subjects its position is marked by an oblique depression amongst the surrounding fat, at the bottom of which the bony process may be felt. Proceeding upward and outward from this process, the crest of the ilium may be traced throughout its whole length, sinuously curved. It is represented, in muscular subjects, on the surface, by a groove or furrow, the iliac furrow, caused by the projection of fleshy fibres of the External oblique muscles of the abdomen; the iliac furrow lies slightly below the level of the crest. It terminates behind in the posterior superior spinous process, the position of which is indicated by a slight depression on a level with the spinous process of the second sacral vertebra. Between the two posterior superior spinous processes, but at a lower level, is to be felt the spinous process of the third sacral vertebra (see page 69). Another part of the bony pelvis easily accessible to touch is the tuberosity of the ischium, situated beneath the gluteal fold, and, when the hip is flexed, it is easily felt, as it is then to a great extent uncovered by muscle. Finally, the spine of the os pubis can always be readily felt, and constitutes an important surgical guide, especially in connection with the subject of hernia. It is nearly in the same horizontal line with the upper edge of the great trochanter. In thin subjects it is very apparent, but in the obese it is obscured by the pubic fat. It can, however, be detected by following up the tendon of origin of the Adductor longus muscle.

Surgical Anatomy.—There is arrest of development in the bones of the pelvis in cases of extroversion of the bladder; the anterior part of the pelvic girdle being deficient, the bodies of the pubic bones imperfectly developed, and the symphysis absent. The pubic bones are separated to the extent of from two to four inches, the superior rami shortened and directed forward, and the obturator foramen diminished in size, narrowed, and turned outward. The iliac bones are straightened out more than normal. The sacrum is very peculiar. The lateral curve, instead of being concave, is flattened out or even convex, with the ilio-sacral facets turned more outward than normal, while the vertical curve is straightened.1

Fractures of the pelvis are divided into fractures of the false pelvis and of the true pelvis. Fractures of the false pelvis vary in extent: a small portion of the iliac crest may be broken or one of the spinous processes may be torn off, and this may be the result of muscular action; or the bone may be extensively comminuted. This latter accident is the result of some crushing violence, and may be complicated with fracture of the true pelvis. These cases may be accompanied by injury to the intestine as it lies in the hollow of the bone, or to the iliac vessels as they course along the margin of the true pelvis. Fractures of the true pelvis generally occur through the ascending ramus of the os pubis and the ramus of the ischium, as this is the weakest part of the bony ring, and may be caused either by crushing violence applied in an antero-posterior direction, when the fracture occurs from direct force, or by compression laterally, when the acetabula are pressed together, and the bone gives way in the same place from indirect violence. Occasionally the injury may be double, a break occurring on both sides of the body. In fracture of the true pelvis the contained visera are liable to be damaged: the small intestines, the urethra, the bladder, the rectum, the vagina, and even the uterus, in the female, have all been lacerated by a displaced fragment. Fractures of the acetabulum are occasionally met with: either a portion of the rim may be broken off, or a fracture may take place through the bottom of the cavity, and the head of the femur may be driven inward and project into the pelvic cavity. Separation of the Y-shaped cartilage at the bottom of the acetabulum may also occur in the young subject, dispersing the bone into its three anatomical portions.

The sacrum is seldom broken. The cause is direct violence—i.e., blows, kicks, or falls on the part. The lesion may be complicated with injury to the nerves of the sacral plexus, leading to paralysis and loss of sensation in the lower extremity or to incontinence of faces from paralysis of the Sphincter ani.

Fracture of the coccyx is a very rare injury, but does occasionally take place. Some supposed dislocations of this bone have been fractures and so have some of the cures diagnosed as coccygodynia. A fracture of the coccyx is due to direct force.

The pelvic bones often undergo important deformity in rickets, the effect of which in the adult woman may interfere seriously with childbearing. The deformity is due mainly to the weight of the spine and trunk, which presses on the sacro-vertebral angle and greatly increases it, so that the antero-posterior diameter of the pelvis is diminished. But, in addition to this, the weight of the visera on the venter ilii causes those bones to expand and the tuberosities of the ischia to incurve. In osteomalacia also great deformity may occur. The weight of the trunk causes an increase in the sacro-vertebral angle and a lessening of the antero-posterior diameter of the inlet, and at the same time the pressure of the acetabula on the heads of the thigh-bones causes these cavities, with the adjacent bone, to be pushed upward and backward, so that the oblique diameters of the pelvis are also diminished, and the cavity of the pelvis assumes a triradiate shape, with the symphysis pubis pushed forward.

THE THIGH.

The thigh is that portion of the lower extremity which is situated between the pelvis and the knee. It consists in the skeleton of a single bone, the femur.

The Femur, or Thigh Bone (Figs. 162, 163).

The femur (femur, the thigh) is the longest, largest, and strongest bone in the skeleton, and almost perfectly cylindrical throughout the greater part of its extent. In the erect posture it is not vertical, being separated from its fellow above by a considerable interval, which corresponds to the entire breadth of the pelvis, but inclining gradually downward and inward, so as to approach its fellow toward its lower part, for the purpose of bringing the knee-joint near the line of gravity of the body. The degree of this inclination varies in different persons, and is greater in the female than the male, on account of the greater breadth of the pelvis. The femur, like other long bones, is divisible into a shaft and two extremities.

**Upper Extremity.**—The upper extremity presents for examination a head, a neck, and a great and lesser trochanters.

**Head of the Femur (caput femoris).**—The head, which is globular, and forms rather more than a hemisphere, is directed upward, inward, and a little

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1 In a man six feet high it measures eighteen inches—one-fourth of the whole body.—Ed. of 15th English Edition.
forward, the greater part of its convexity being above and in front. Its surface is smooth, coated with cartilage in the recent state, except at a little behind and below its centre, where is an ovoid depression (jovea capitis femoris), for the attachment for the Ligamentum teres.

The Neck of the Femur (collum femoris).—The neck is a flattened pyramidal process of bone which connects the head with the shaft. It varies in length and obliquity at various periods in life and under different circumstances. The angle is widest in infancy, and becomes lessened during growth, so that at puberty it forms a gentle curve from the axis of the shaft. In the adult it forms an angle of about 130 degrees with the shaft, but varies in inverse proportion to the development of the pelvis and the stature. In consequence of the prominence of the hips and widening of the pelvis in the female, the neck of the thigh bone forms more nearly a right angle with the shaft than it does in man. It has been stated that the angle diminishes in old age and the direction of the neck becomes horizontal, but this statement is founded on insufficient evidence. Sir George Humphry states that the angle decreases during the period of growth, but after full growth has been attained it does not usually undergo any change, even in old age. He further states that the angle varies considerably in different persons of the same age. It is smaller in short than in long bones, and when the pelvis is wide.\(^1\) The neck is flattened from before backward, contracted in the middle, and broader at its outer extremity, where it is connected with the shaft, than at its summit, where it is attached to the head. The vertical diameter of the outer half is increased by the thickening of the lower edge, which slopes downward to join the shaft at the lesser trochanter, so that the outer half of the neck is flattened from before backward, and its vertical diameter measures one-third more than the antero-posterior. The inner half is smaller and of a more circular shape. The anterior surface of the neck is perforated by numerous vascular foramina. The posterior surface is smooth, and is broader and more concave than the anterior; it gives attachment to the posterior part of the capsular ligament of the hip-joint, about half an inch above the posterior intertrochanteric line. The superior border is short and

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\(^1\) Journal of Anatomy and Physiology.
THE FEMUR, OR THIGH BONE

thick, and terminates externally at the great trochanter; its surface is perforated by large foramina. The inferior border, long and narrow, curves a little backward, to terminate at the lesser trochanter.

The Trochanters.—The trochanters (πρόχως, to run or roll) are prominent processes of bone which afford leverage to the muscles which rotate the thigh on its axis. They are two in number, the greater and the lesser.

The great trochanter (trochanter major) is a large, irregular, quadrilateral eminence, situated at the outer side of the neck, at its junction with the upper part of the shaft. It is directed a little outward and backward, and in the adult is about three-quarters of an inch lower than the head. It presents for examination two surfaces and four borders. The external surface, quadrilateral in form, is broad, rough, convex, and marked by a prominent diagonal impression, which extends from the posterior superior to the anterior inferior angle, and serves for the attachment of the tendon of the Gluteus medius. Above the impression is a triangular surface, sometimes rough for part of the tendon of the same muscle, sometimes smooth for the interposition of a bursa between that tendon and the bone. Below and behind the diagonal line is a smooth, triangular surface, over which the tendon of the Gluteus maximus muscle plays, a bursa being interposed. The internal surface is of much less extent than the external, and presents at its base a deep depression, the digital or trochanteric fossa (fossa trochanterica), for the attachment of the tendon of the Obturator externus muscle: above and in front of this is an impression for the attachment of the Obturator internus and Gemelli. The superior border is free; it is thick and irregular, and marked near the centre by an impression for the attachment of the Pyriformis. The inferior border corresponds to the point of junction of the base of the trochanter with the outer surface of the shaft; it is marked by a rough, prominent, slightly curved ridge, which gives attachment to the upper part of the Vastus externus muscle. The anterior border is prominent, somewhat irregular, as well as the surface of bone immediately below it; it affords attachment at its outer part to the Gluteus minimus. The posterior border is very prominent, and appears as a free, rounded edge, which forms the back part of the digital fossa.

The lesser trochanter (trochanter minor) is a conical eminence which varies in size in different subjects; it projects from the lower and back parts of the base of the neck. Its base is triangular, and connected with the adjacent parts of the bone by three well-marked borders: two of these are above—the internal border, continuous with the lower border of the neck, the external border with the posterior intertrochanteric line—while the inferior border is continuous with the middle division of the linea aspera. Its summit, which is directed inward and backward, is rough, and gives insertion to the tendon of the Ilio-psosas. The Iliacus is also inserted into the shaft below the lesser trochanter between the Vastus internus in front and the Pectineus behind.

A well-marked prominence of variable size, which projects from the upper and front part of the neck at its junction with the great trochanter, is called the tubercle of the femur; it is the point of meeting of five muscles: the Gluteus minimus externally, the Vastus externus below, and the tendon of the Obturator internus and Gemelli above. Running obliquely downward and inward from the tubercle is the spiral line of the femur, or anterior intertrochanteric line (linea intertrochanterica); it winds round the inner side of the shaft, below the lesser trochanter, and terminates in the linea aspera, about two inches below this eminence. Its upper half is rough, and affords attachment to the ilio-femoral ligament of the hip-joint; its lower half is less prominent, and gives attachment to the upper part of the Vastus internus. Running obliquely downward and inward from the summit of the great trochanter on the posterior surface of the neck is a very prominent, well-marked ridge, the posterior intertrochanteric line (crista intertrochanterica). Its upper half forms the posterior border of the great trochanter, and its lower
half runs downward and inward to the upper and back part of the lesser trochanter. A slight ridge sometimes commences about the middle of the posterior intertrochanteric line, and passes vertically downward for about two inches along the back part of the shaft: it is called the linea quadrati, and gives attachment to the Quadratus femoris and a few fibres of the Adductor magnus muscles. ¹

The Shaft of the Femur (corpus femoris).—The shaft, almost cylindrical in form, is a little broader above than in the centre, and somewhat flattened below, from before backward. It is slightly arched, so as to be convex in front and concave behind, where it is strengthened by a prominent longitudinal ridge, the linea aspera. It presents for examination three borders, separating three surfaces. Of the three borders, one, the linea aspera, is posterior; the other two are placed laterally.

The Linea Aspera.—The linea aspera (Fig. 163) is a prominent longitudinal ridge or crest, on the middle third of the bone, presenting an external lip (labium laterale), an internal lip (labium mediale), and a rough intermediate space. Above, this crest is prolonged by three ridges. The most external ridge is very rough, and is continued almost vertically upward to the base of the great trochanter. It is sometimes termed the gluteal ridge (tuberositas glutea), and gives attachment to part of the Gluteus maximus muscle; its upper part is sometimes elongated into a roughened crest, on which is a more or less well-marked, rounded tubercle, a rudimental third trochanter (trochanter tertius). The middle ridge (linea pectinea), the least dis-

¹Generally there is merely a slight thickening about the centre of the intertrochanteric line, marking the point of attachment of the Quadratus femoris. This is termed by some anatomists the tubercle of the Quadratus.—Ed. of 15th English Edition.
tinct, is continued to the base of the trochanter minor, and the **internal ridge** is lost above in the spiral line of the femur. Below, the linea aspera is prolonged by two ridges, which pass to the condyles and enclose between them a triangular space, the **popliteal surface** (planum popliteum), upon which rests the popliteal artery. Of these two ridges, the **outer** one is the more prominent, and descends to the summit of the outer condyle. The **inner** one is less marked, especially at its upper part, where it is crossed by the femoral artery. It terminates, below, at the summit of the internal condyle, in a small tubercle, the **adductor tubercle**, which affords attachment to the tendon of the Adductor magnus. To the inner lip of the linea aspera and its inner prolongation above and below is attached the Vastus internus, and to the outer lip and its outer prolongation above is attached the Vastus externus. The Adductor magnus is attached to the linea aspera, to its outer prolongation above and its inner prolongation below. Between the Vastus externus and the Adductor magnus are attached two muscles —viz., the Gluteus maximus above, and the short head of the Biceps below. Between the Adductor magnus and the Vastus internus four muscles are attached: the Iliacus and Pectineus above, the Adductor brevis and Adductor longus below. A little below the centre of the linea aspera is the **nutrient foramen** (foramen nutricium), the orifice of the **nutrient canal** (canalis nutricius), which is directed obliquely upward (proximally).

**Lateral Borders.**—The two lateral borders of the femur are only slightly marked, the outer one extending from the anterior inferior angle of the great trochanter to the anterior extremity of the external condyle; the inner one from the spiral line at a point opposite the trochanter minor, to the anterior extremity of the internal condyle. The internal border marks the limit of attachment of the Crureus muscle internally.

**Anterior Surface.**—The anterior surface includes that portion of the shaft which is situated between the two lateral borders. It is smooth, convex, broader above and below than in the centre, slightly twisted, so that its upper part is directed forward and a little outward, its lower part forward and a little inward. To the upper three-fourths of this surface the Crureus is attached; the lower fourth is separated from the muscle by the intervention of the synovial membrane of the knee-joint and a bursa, and affords attachment to the Subcrureus to a small extent.

**External Surface.**—The external surface includes the portion of bone between the external border and the outer lip of the linea aspera; it is continuous above with the outer surface of the great trochanter, below with the outer surface of the external condyle; to its upper three-fourths is attached the outer portion of the Crureus muscle.

**Internal Surface.**—The internal surface includes the portion of bone between the internal border and the inner lip of the linea aspera; it is continuous above with the lower border of the neck, below with the inner side of the internal condyle: it is covered by the Vastus internus muscle.

**Lower Extremity.**—The lower extremity, larger than the upper, is of a cuboid form, flattened from before backward, and divided into two large eminences, the **condyles** (condyli, from κόνδυλος, a knuckle), by an interval which presents a smooth depression in front called the **trochanter** (facies patellaris), and a notch of considerable size behind—the **intercondyloid notch** (fossa intercondylóidea). The **external condyle** (condyulus lateralis) is the more prominent anteriorly, and is the broader both in the antero-posterior and transverse diameters. The **internal condyle** (condyulus medialis) is the narrower, longer, and more prominent inferiorly. This difference in the length of the two condyles is only observed when the bone is perpendicular and depends upon the obliquity of the thigh bones, in consequence of their separation above at the articulation with the pelvis. If the femur is held obliquely, the surfaces of the two condyles will be seen to be nearly hori-
zontal. The two condyles are directly continuous in front, and form a smooth, trochlear surface, the **trochlea**, which articulates with the patella. It presents a median groove, which extends downward and backward to the intercondylar notch; and two lateral convexities, of which the external is the broader, more prominent, and prolonged farther upward upon the front of the outer condyle. The external border of this articular surface is also more prominent, and ascends higher than the internal one. The intercondylar notch lodges the crucial ligaments; it is bounded laterally by the opposed surfaces of the two condyles, and in front by the lower end of the shaft. Between the popliteal surface and the floor of the intercondylar notch is an elevation (**linea intercondylidea**), which affords attachment to the posterior ligament of the knee-joint.

**Outer or External Condyle** (**condylus lateralis**).—The outer surface of the external condyle presents, a little behind its centre, an eminence, the **outer tuberosity** or **outer epicondyle** (**epicondylus lateralis**); it is less prominent than the inner tuberosity, and gives attachment to the external lateral ligaments of the knee. Immediately beneath it is a **groove**, the **popliteal groove** (**sulcus popliteus**), which commences at a depression a little behind the centre of the lower border of this surface: the front part of this depression gives origin to the Popliteus muscle, the tendon of which is lodged in the groove during flexion of the knee. The groove is smooth, covered with cartilage in the recent state, and runs upward and backward to the posterior extremity of the condyle. The **inner surface** of the outer condyle forms one of the lateral boundaries of the intercondylar notch, and gives attachment, by its posterior part, to the anterior crucial ligament. The **inferior surface** is convex, smooth, and broader than that of the internal condyle. The posterior extremity is convex and smooth: just above and to the outer side of the articular surface is a depression for the tendon of the outer head of the gastrocnemius, above which is the origin of the **Plantaris**.

**Inner or Internal Condyle** (**condylus medialis**).—The **inner surface** of the inner condyle presents a convex eminence, the **inner tuberosity** or **inner epicondyle** (**epicondylus medialis**), rough for the attachment of the internal lateral ligament. The **outer side** of the inner condyle forms one of the lateral boundaries of the intercondylar notch, and gives attachment, by its anterior part, to the posterior crucial ligament. Its **inferior or articular surface** is convex, and presents a less extensive surface than the external condyle. Just above the articular surface of the condyle, behind, is a depression for the tendon of origin of the inner head of the gastrocnemius.

**Structure.**—The shaft of the femur is a cylinder of compact tissue, hollowed by a large medullary canal. The cylinder is of great thickness and density in the middle third of the shaft, where the bone is narrowest and the medullary canal well formed; but above and below this the cylinder gradually becomes thinner, owing to a separation of the layers of the bone into cancelli, which project into the medullary canal and finally obliterate it, so that the upper and lower ends of the shaft, and the articular extremities more especially, consist of cancellated tissue invested by a thin, compact layer.

The arrangement of the cancelli in the ends of the femur is remarkable. In the upper end they are arranged in two sets. One, starting from the top of the
head, the upper surface of the neck, and the great trochanter, converge to the inner circumference of the shaft (Figs. 164 and 165); these are placed in the direction of greatest pressure, and serve to support the vertical weight of the body. The second set are planes of lamellae intersecting the former nearly at right angles, and are

Fig. 165.—Right femur, upper extremity, ground frontal section, from in front. (Spalteholz.)

situated in the line of the greatest tension—that is to say, along the lines in which the muscles and ligaments exert their traction. In the head of the bone these planes are arranged in a curved form, in order to strengthen the bone when exposed to pressure in all directions. In the midst of the cancellous tissue of the neck is a vertical plane of compact bone, the femoral spur (calcar femorale), which com-
mences at the point where the neck joins the shaft midway between the lesser trochanter and the internal border of the shaft of the bone, and extends in the direction of the digital fossa (Fig. 167). This materially strengthens this portion of the bone. Another point in connection with the structure of the neck of the femur requires mention, especially on account of its influence on the production of fracture in this situation. It will be noticed that a considerable portion of the great trochanter lies behind the level of the posterior surface of the neck; and if a section be made through the trochanter at this level, it will be seen that the posterior wall of the neck is prolonged into the trochanter. This prolongation is termed by Bigelow the true neck, and forms a thin, dense plate of bone, which passes beneath the posterior intertrochanteric ridge toward the outer surface of the bone. In the lower end the cancelli spring on all sides from the inner surface of the cylinder, and descend in a perpendicular direction to the articular surface, the cancelli being strongest and having a more accurately perpendicular course above the condyles. In addition to this, however, horizontal planes of cancellous tissue are to be seen, so that the spongy tissue in this situation presents an appearance of being mapped out into a series of rectangular areas.

1 Bigelow on the Hip, p. 121.
Articulations.—With three bones: the os innominatum, tibia, and patella.

Development (Fig. 168).—The femur is developed by five centres: one for the shaft, one for each extremity, and one for each trochanter. Of all the long bones, except the clavicle, it is the first to show traces of ossification: this commences in the shaft, at about the seventh week of foetal life, the centres of ossification in the epiphyses appearing in the following order: First, in the lower end of the bone, at the ninth month of foetal life1 (from this the condyles and tuberosities are formed); in the head at the end of the first year after birth; in the great trochanter, during the fourth year; and in the lesser trochanter, between the thirteenth and fourteenth. The order in which the epiphyses are joined to the shaft is the reverse of that of their appearance: their junction does not commence until after puberty, the lesser trochanter being first joined, then the great, then the head, and, lastly, the inferior extremity (the first in which ossification commenced), which is not united until the twentieth year.

Attachment of Muscles.—To twenty-three. To the great trochanter: the Gluteus medius, Gluteus minimus, Pyriformis, Obturator internus, Obturator externus, Gemellus superior, Gemellus inferior, and Quadratus femoris. To the lesser trochanter: the Psoas magnus and the Iliacus below it. To the shaft: the Vastus externus, Gluteus maximus, short head of the Biceps, Vastus internus, Adductor magnus, Pectineus, Adductor brevis, Adductor longus, Crureus, and Subcrureus. To the condyles: the Gastrocnemius, Plantaris, and Popliteus.

Surface Form.—The femur is covered with muscles, so that in fairly muscular subjects the shaft is not to be detected through its fleshy covering, and the only parts accessible to the touch are the outer surface of the great trochanter and the lower expanded end of the bone. The external surface of the great trochanter is to be felt, especially in certain positions of the limb. Its

1 This is said to be the only epiphysis in which ossification begins before birth; though according to some observers, the centre for the upper epiphysis of the tibia also appears before birth.—Ed. of 15th English Edition.
position is generally indicated by a depression, owing to the thickness of the Gluteus medius and minimus, which project above it. When, however, the thigh is flexed, and especially if crossed over the opposite one, the trochanter produces a blunt eminence on the surface. The upper border is about on a line with the spine of the os pubis, and its exact level is indicated by a line drawn from the anterior superior spinous process of the ilium, over the outer side of the hip, to the most prominent point of the tuberosity of the ischium. This is known as Nélaton's line. The outer and inner condyles of the lower extremity are easily to be felt. The outer one is more subcutaneous than the inner one and readily felt. The tuberosity on it is comparatively little developed, but can be more or less easily recognized. The inner condyle is more thickly covered, and this gives a general convex outline to this part, especially when the knee is flexed. The tuberosity on it is easily felt, and at the upper part of the condyle the sharp tubercle for the insertion of the tendon of the Adductor magnus can be recognized without difficulty. When the knee is flexed, and the patella situated in the interval between the condyles and the upper end of the tibia, a part of the trochlear surface of the femur can be made out above the patella.

Surgical Anatomy.—There are one or two points about the ossification of the femur bearing on practice to which allusion must be made. It has been stated above that the lower end of the femur is the only epiphysis in which ossification has commenced at the time of birth. The presence of the ossific centre in newly born children found dead is, therefore, a proof that the child has arrived at the full period of utero-gestation, and is always relied upon in medico-legal investigations. The position of the epiphyseal line should be carefully noted. It is on a level with the adductor tubercle, and the epiphysis does not, therefore, form the whole of the cartilage-clad portion of the lower end of the bone. It is essential to bear this point in mind in performing excision of the knee, since growth in length of the femur takes place chiefly from the lower epiphysis, and any interference with the epithysial cartilage in a young child would involve such ultimate shortening of the limb, from want of growth, as to render it almost useless. Separation of the lower epiphysis may take place up to the age of twenty, at which time it becomes completely joined to the shaft of the bone; but, as a matter of fact, few cases occur after the age of sixteen or seventeen. The epiphysis of the head of the femur is of interest principally on account of its being the seat of origin of a large number of cases of tuberculous disease of the hip-joint. The disease commences in the majority of cases in the highly vascular and growing tissue in the neighborhood of the epiphysis, and from here extends into the joint. In the condition known as coxa vara the head of the femur falls to a lower level than normal. The angle between the neck and shaft is greatly diminished and may become a right angle or the head may actually descend to a lower level than that of the trochanter. The neck is also bent with a convexity forward; coxa vara is due to rickets.

Fractures of the femur are divided, like those of the other long bones, into fractures of the upper end; of the shaft; and of the lower end. The fractures of the upper end may be classified into (1) fracture of the neck; (2) fracture at the junction of the neck with the great trochanter; (3) fracture of the great trochanter; and (4) separation of the epiphysis, either of the head or of the great trochanter. The first of these, fracture of the neck, is usually termed intracapsular fracture, but this is scarcely a correct designation, as owing to the attachment of the capsular ligament, the fracture may be partly within and partly without the capsule, when the fracture occurs at the lower part of the neck. It generally occurs in old people, principally women, and usually from a very slight degree of indirect violence. Probably the main cause of the fracture taking place in old people is in consequence of the degenerative changes which the bone has undergone. Merkel believes that it is mainly due to the absorption of the calcareous femoral. These fractures are occasionally impacted. As a rule they unite by fibrous tissue, and frequently no union takes place, and the surfaces of the fracture become smooth and eburnated. The lack of reparative power in intracapsular fracture is due to lack of apposition of the fragments and diminution in the amount of blood sent to the smaller fragment. The head of the bone receives blood from the neck through the reflected portions of the capsule and through the Ligamentum teres. A fracture cuts off the supply by the neck and by the reflected portions of the capsule. Fractures at the junction of the neck with the great trochanter are usually termed extracapsular, but this designation is also incorrect, as the fracture is partly within the capsule, owing to its attachment in front to the anterior intertrochanteric line, which is situated below the line of fracture. These fractures are produced by direct violence to the great trochanter, as from a blow or fall laterally on the hip. From the manner in which the accident is caused, the neck of the bone is driven into the trochanter, where it may remain impacted or the trochanter may be split up into two or more fragments, and thus no fixation takes place. Fractures of the great trochanter may be either "oblique fracture through the trochanter major, without implicating the neck of the bone" (Anstey Cooper), or separation of the great trochanter. Most of the recorded cases of this latter injury occurred in young persons, and were probably cases of separation of the epiphysis of the great trochanter. Separation of the epiphysis of the head of the femur has been said to occur, but has probably never been verified by post-mortem examination.
centre of the bone. They may be caused by direct or indirect violence or by muscular action. Fractures of the upper third of the shaft are almost always the result of indirect violence, whilst those of the lower third are the result, for the most part, of direct violence. In the middle third fractures occur from both forms of injury in about equal proportions. Fractures of the shaft are generally oblique, but they may be transverse, longitudinal, or spiral. The transverse fracture occurs most frequently in children. The fractures of the lower end of the femur include transverse fracture above the condyles, the most common; and this may be complicated by a vertical fracture between the condyles, constituting the T-shaped fracture. In these cases the popliteal artery is in danger of being wounded. Oblique fracture, separating either the internal or external condyle, and a longitudinal incomplete fracture between the condyles, may also take place.

The femur and also the bones of the leg are frequently the seat of acute osteomyelitis in young children. This is no doubt due to their greater exposure to injury, which is often the exciting cause of this disease. Tumors not unfrequently are found growing from the femur: the most common forms being sarcoma, which may grow either from the periosteum or from the medullary tissue within the interior of the bone; and exostosis, which is commonly found originating in the neighborhood of the epiphyseal cartilage of the lower end.

Genu varum is a form of bow-leg in which the tibia and femur are curved outward, the knees being widely separated. Both extremities are usually affected. In early life the disease is due to rickets. In elderly people it may be due to arthritis deformans. Genu valgum (knock-knee) is a condition in which the knees are close together, the feet are wide apart, and the internal lateral ligament of the knee-joint is stretched. It is due to excessive growth of the inner condyle of the femur, the shaft of the femur curving inward. It may be due to rickets, attitude of an occupation, or flat-foot, and one or both knees may be affected.

THE LEG.

The skeleton of the leg consists of three bones: the patella, a large sesamoid bone, placed in front of the knee; the tibia; and the fibula.

The Patella, or Knee-cap (Fig. 169).

The patella (patella, a small pan), the knee-cap or knee-pan, is a flat, triangular bone, situated at the anterior part of the knee-joint. It is usually regarded as a sesamoid bone, developed in the tendon of the Quadriceps extensor. It resembles these bones (1) in its being developed in a tendon; (2) in its centre of ossification presenting a knotty or tuberculated outline; (3) in its structure being composed mainly of dense cancellous tissue, as in the other sesamoid bones. It serves to protect the front of the joint, and increases the leverage of the Quadriceps extensor by making it act at a greater angle. It presents an anterior and a posterior surface, three borders, and an apex.

Surfaces. Anterior Surface.—The anterior surface is convex, perforated by small apertures, for the passage of nutrient vessels, and marked by numerous rough, longitudinal strie. This surface is covered, in the recent state, by an expansion from the tendon of the Quadriceps extensor, which is continuous below with the superficial fibres of the ligamentum patelle. It is separated from the integument by a bursa.

Posterior Surface.—The posterior surface presents a smooth, oval-shaped, articular surface (facies articularis), covered with cartilage in the recent state, and divided into two facets by a vertical ridge, which descends from the superior border toward the inferior angle of the bone. The ridge corresponds to the groove on the trochlear surface of the femur, and the two facets to the articular surfaces of the two condyles; the outer facet, for articulation with the
outer condyle, being broader and deeper. This character serves to indicate the side to which the bone belongs. Below the articular surface is a rough, convex, non-articular depression, the lower half of which gives attachment to the ligamentum patellae, the upper half being separated from the head of the tibia by adipose tissue.

Borders. Superior Border.—The superior border (basis patellae) is thick, and sloped from behind, downward and forward; it gives attachment to that portion of the Quadriceps extensor which is derived from the Rectus and Crureus muscles.

Lateral Borders.—The lateral borders are thinner, converging below. They give attachment to that portion of the Quadriceps extensor derived from the external and internal Vastus muscles.

The Apex (apex patellae).—The apex is pointed, and gives attachment to the ligamentum patellae.

Structure.—It consists of a nearly uniform, dense cancellous tissue covered by a thin compact lamina. The cancelli immediately beneath the anterior surface are arranged parallel with it. In the rest of the bone they radiate from the posterior articular surface toward the other parts of the bone.

Development.—By a single centre, which makes its appearance, according to Bécard, about the third year. In two instances Mr. Pick has seen this bone cartilaginous throughout, at a much later period (six years). More rarely, the bone is developed by two centres, placed side by side. Ossification is completed about the age of puberty.

Articulations.—With the two condyles of the femur.

Attachment of Muscles.—To four: the Rectus, Crureus, Vastus internus, and Vastus externus. These muscles, joined at their insertion, constitute the Quadriceps extensor cruris.

Surface Form.—The external surface of the patella can be seen and felt in front of the knee. In the extended position of the limb the internal border is a little more prominent than the outer, and if the Quadriceps extensor is relaxed the bone can be moved from side to side and appears to be loosely fixed. If the joint is flexed, the patella recedes into the hollow between the condyles of the femur and the upper end of the tibia, and becomes firmly fixed against the femur.

Surgical Anatomy.—The main surgical interest about the patella is in connection with fractures, which are of common occurrence. They may be produced by muscular action; that is to say, by violent contraction of the Quadriceps extensor while the limb is in a position of semi-flexion, so that the bone is snapped across the condyles; or by direct violence, such as falls on the knee. Most fractures are due to muscular action; in fact, the patella is more often broken by muscular action than is any other bone. In fractures by muscular action the line of fracture is transverse. In fractures by direct force the line of fracture may be oblique, longitudinal, stellate, or the bone variously comminuted. The principal interest in these cases attaches to their treatment. Owing to the wide separation of the fragments, and the difficulty there is in maintaining them in apposition, union takes place by fibrous tissue, and this may subsequently stretch, producing wide separation of the fragments and permanent lameness. Various plans, including opening the joint and suturing the fragments, have been advocated for overcoming this difficulty. In many cases a portion of fascia or capsule gets between the fragments. In such a condition operation is necessary.

In the larger number of cases of fracture of the patella the knee-joint is involved, the cartilage which covers its posterior surface being torn, the synovial membrane lacerated, the lateral fibrous expansions ruptured, and the patellar bursa torn open. In cases of fracture from direct violence, however, this need not necessarily happen, the lesion may involve only the superficial part of the bone; and, as Morris has pointed out, it is an anatomical possibility, in complete fracture, if the lesion involve only the lower and non-articular part of the bone, for it to take place without injury to the synovial membrane.

The Tibia, or Shin Bone (Figs. 170, 171).

The tibia (tibia, a flute or pipe) is situated at the front and inner side of the leg, and, excepting the femur, is the longest and largest bone in the skeleton. It is prismoid in form, expanded above, where it enters into the knee-joint, more
THE TIBIA, OR SHIN BONE

Head.

Styloid process.

External malleolus.

Internal malleolus.

Fibula.

Tibia.

Articulates with femur.

Fig. 170.—Bones of the right leg. Anterior surface.

Fig. 171.—Bones of the right leg. Posterior surface.
slightly enlarged below. In the male its direction is vertical and parallel with the bone of the opposite side; but in the female it has a slightly oblique direction downward and outward, to compensate for the oblique direction of the femur inward. It presents for examination a **shaft** and two **extremities**.

**Upper Extremity.**—The upper extremity, or **head**, is large, and expanded on each side into two lateral eminences, the internal and external **tuberosities** (**condylus medialis** and **condylus lateralis**). Superiorly, each tuberosity presents a smooth, concave surface (**facies articularis superior**), which articulates with a condyle of the femur. The internal, articular surface is longer, deeper, and narrower than the external, oval from before backward, to articulate with the internal condyle; the external one is broader and more circular, concave from side to side, but slightly convex from before backward, especially at its posterior part, where it is prolonged on to the posterior surface for a short distance, to articulate with the external condyle. Between the two articular surfaces, and nearer the posterior than the anterior aspect of the bone, is an eminence, the **spinous process of the tibia** (**eminentia intercondylodea**); surmounted by a prominent tubercle on each side (**the tuberculum intercondylodeum mediale and the tuberculum intercondylodeum laterale**), on to the lateral aspect of which the facets just described are prolonged; in front and behind the spinous process is a rough depression (**fossa intercondylodea anterior and the fossa intercondylodea posterior**) for the attachment of the anterior and posterior crucial ligaments and the semilunar fibro-cartilages (Fig. 172).

The anterior surfaces of the tuberosities are continuous with one another, forming a single large surface, which is somewhat flattened: it is triangular, broad above, and perforated by large vascular foramina; narrow below, where it terminates in a prominent oblong elevation of large size, the **tubercle of the tibia** (**tuberositas tibiae**); the lower half of this tubercle is rough, for the attachment of the ligamentum patentia; the upper half presents a smooth facet supporting, in the recent state, a bursa which separates the ligament from the bone. **Posteriorly** the tuberosities are separated from each other by a shallow depression, the **popliteal notch** (**incisura poplitea**), which gives attachment to part of the posterior crucial ligament and part of the posterior ligament of the knee-joint. The **inner tuberosity** presents posteriorly a deep transverse groove, for the insertion of one of the fasciculi of the tendon of the Semi-membranosus. Its lateral surface is convex, rough, and prominent, and gives attachment to the internal lateral ligament. The **outer tuberosity** presents posteriorly a flat articular facet (**facies articularis fibularis**), nearly circular in form, directed downward, backward, and outward, for articulation with the fibula. Its lateral surface is convex and rough, more prominent in front than the internal, and presents a prominent rough eminence, situated on

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FIG. 172.—Upper articular surface of the tibia, showing the attachments of the ligaments. (Poirier and Charpy.)
a level with the upper border of the tubercle of the tibia at the junction of its anterior and outer surfaces, for the attachment of the **ilio-tibial band**. Just below this the Extensor longus digitorum and a slip from the Biceps are attached. The **infraglenoid margin** (**margo infraglenoidalis**) is at the outer edge of the superior articular surface. From this point the bone rapidly narrows distally.

**Shaft of the Tibia (corpus tibiae).**—The shaft of the tibia is of a triangular prismatic form, broad above, gradually decreasing in size to its most slender part, at the commencement of its lower fourth, where fracture most frequently occurs; it then enlarges again toward its lower extremity. It presents for examination three borders and three surfaces.

**Anterior Border.**—The anterior border, the most prominent of the three, is called the **crest of the tibia** (**crista anterior**), or, in popular language, the **shin**; it commences above at the tubercle, and terminates below at the anterior margin of the inner malleolus. This border is very prominent in the upper two-thirds of its extent, smooth and rounded below. It presents a very flexuous course, being usually curved outward above and inward below; it gives attachment to the deep fascia of the leg.

**Internal Border** (**margo medialis**).—The internal border is smooth and rounded above and below, but more prominent in the centre; it commences at the back part of the inner tuberosity, and terminates at the posterior border of the internal malleolus; its upper part gives attachment to the internal lateral ligament of the knee to the extent of about two inches, and to some fibres of the Popliteus muscle, and its middle third to some fibres of the Soleus and Flexor longus digitorum muscles.

**External Border** (**crista interossea**).—The external border, or **interosseous ridge**, is thin and prominent, especially its central part, and gives attachment to the interosseous membrane; it commences above in front of the fibular articular facet, and bifurcates below, to form the boundaries of a triangular rough surface, for the attachment of the interosseous ligament connecting the tibia and fibula.

**Internal Surface** (**facies medialis**).—The internal surface is smooth, convex, and broader above than below; its upper third, directed forward and inward, is covered by the aponeurosis derived from the tendon of the Sartorius, and by the tendons of the Gracilis and Semitendinosus, all of which are inserted nearly as far forward as the anterior border; in the rest of its extent it is subcutaneous.

**External Surface** (**facies lateralis**).—The external surface is narrower than the internal; its upper two-thirds presents a shallow groove for the attachment of the Tibialis anticus muscle; its lower third is smooth, convex, curves gradually forward to the anterior aspect of the bone, and is covered from within outward by the tendons of the following muscles: Tibialis anticus, Extensor proprius hallucis, Extensor longus digitorum.

**Posterior Surface** (**facies posterior**).—The posterior surface (Fig. 171) presents, at its upper part, a prominent ridge, the **popliteal line** or the **oblique line of the tibia** (**linea poplitea**), which extends from the back part of the articular facet for the fibula obliquely downward, to the internal border, at the junction of its upper and middle thirds. It marks the lower limit for the insertion of the Popliteus muscle, and serves for the attachment of the popliteal fascia and part of the Soleus, Flexor longus digitorum, and Tibialis posticus muscles; the triangular concave surface, above and to the inner side of this line, gives attachment to the Popliteus muscle. The middle third of the posterior surface is divided by a vertical ridge into two lateral halves: the ridge is well marked at its commencement at the oblique line, but becomes gradually indistinct below; the inner and broader half gives attachment to the Flexor longus digitorum, the outer and narrower to part of the Tibialis posticus. The remaining part of the bone presents a smooth surface covered by the Tibialis posticus, Flexor longus
digitatus, and Flexor longus hallucis muscles. Immediately below the oblique line is the nutritive foramen (foramen nutritium), which is large and directed obliquely downward. It is the opening of the nutrient canal, which is directed toward the periphery.

**Lower Extremity.**—The lower extremity, much smaller than the upper, presents five surfaces; it is prolonged downward, on its inner side, to a strong process, the internal malleolus (malleolus medialis).

**Inferior Surface** (facies articularis inferior).—The inferior surface of the bone is quadrilateral, and smooth for articulation with the astragalus. This surface is concave from before backward, and broader in front than behind. It is traversed from before backward by a slight elevation, separating two lateral depressions. It is narrow internally, where the articular surface becomes continuous with that on the inner malleolus (facies articularis malleolaris).

**Anterior Surface**.—The anterior surface of the lower extremity is smooth and rounded above, and covered by the tendons of the Extensor muscles of the toes; its lower margin presents a rough transverse depression, for the attachment of the anterior ligament of the ankle-joint.

**Posterior Surface**.—The posterior surface presents a superficial groove directed obliquely downward and inward, continuous with a similar groove on the posterior surface of the astragalus, and serving for the passage of the tendon of the Flexor longus hallucis.

**External Surface**.—The external surface presents a triangular rough depression for the attachment of the interior interosseous ligament, connecting it with the fibula; the lower part of this depression, the fibular notch (incisura fibularis), is smooth, covered with cartilage in the recent state, and articulates with the fibula. This surface is bounded by two prominent borders, continuous above with the interosseous ridge; they afford attachment to the anterior inferior and posterior inferior tibio-fibular ligaments.

**Internal Surface**.—The internal surface of the lower extremity is prolonged downward to form a strong pyramidal process, flattened from without inward—the internal malleolus (malleolus medialis). The inner surface of this process is convex and subcutaneous; its outer surface is smooth and slightly concave, and articulates with the astragalus; its anterior border is rough, for the attachment of the anterior fibres of the internal lateral or Deltoid ligament; its posterior border presents a broad and deep groove (sulcus malleolaris), directed obliquely downward and inward, which is occasionally double: this groove transmits the tendons of the Tibialis posterior and Flexor longus digitatus muscles. The summit of the internal malleolus is marked by a rough depression behind, for the attachment of the internal lateral ligament of the ankle-joint.

**Structure.**—Like that of the other long bones. At the junction of the middle and lower third, where the bone is smallest, the wall of the shaft is thicker than in other parts, in order to compensate for the smallness of the calibre of the bone.

**Development.**—By three centres (Fig. 173): one for the shaft and one for each extremity. Ossification commences in the centre of the shaft about the seventh week, and gradually extends toward either extremity. The centre for the upper epiphysis appears before or shortly after birth; it is flattened in form, and has a thin, tongue-shaped process in front which forms the tubercle. That for the lower epiphysis appears in the second year. The lower epiphysis joins the shaft at about the eighteenth, and the upper one about the twentieth year. Two additional centres occasionally exist—one for the tongue-shaped process of the upper epiphysis, which forms the tubercle, and one for the inner malleolus.

**Articulations.**—With three bones: the femur, fibula, and astragalus.

**Attachment of Muscles.**—To twelve: to the inner tuberosity, the Semimembranosus; to the outer tuberosity, the Tibialis anticus and Extensor longus digi-
torum and Biceps; to the shaft, its internal surface, the Sartorius, Gracilis, and Semitendinosus; to its external surface, the Tibialis anticus; to its posterior surface, the Popliteus, Soleus, Flexor longus digitorum, and Tibialis posticus; to the tubercle, the ligamentum patellae, by which the Quadriceps extensor muscle is inserted into the tibia. In addition to these muscles, the Tensor fasciae latae is inserted indirectly into the tibia, through the ilio-tibial band, and the Peroneus longus occasionally derives a few fibres of origin from the outer tuberosity.

**Surface Form.**—A considerable portion of the tibia is subcutaneous and easily to be felt. At the upper extremity the tuberosities are to be recognized just below the knee. The internal one is broad and smooth, and merges into the subcutaneous surface of the shaft below. The external one is narrower and more prominent, and on it, about midway between the apex of the patella and the head of the fibula, may be felt a prominent tubercle for the insertion of the ilipectal band. In front of the upper end of the bone, between the tuberosities, is an oval eminence which is continuous below with the anterior border or crest of the bone. This border can be felt, forming the prominence of the shin, in the upper two-thirds of its extent as a sharp and flexuous ridge, curved outward above and inward below. In the lower third of the leg the border disappears, and the bone is concealed by the tendons of the muscles on the front of the leg. Internal to the anterior border is to be felt the broad internal surface of the tibia, slightly encroached upon by the muscles in front and behind. It commences above at the wide expanded inner tuberosity, and terminates below at the internal malleolus. The internal malleolus is a broad prominence situated on a higher level and somewhat farther forward than the external malleolus. It overhangs the inner border of the arch of the foot. Its anterior border is nearly straight; its posterior border presents a sharp edge which forms the inner margin of the groove for the tendon of the Tibialis posticus muscle.

**The Fibula, or Calf Bone** (Figs. 170, 171).

The fibula (fibula, a clasp) is situated at the outer side of the leg. It is the smaller of the two bones, and, in proportion to its length, the most slender of all the long bones; it is placed on the outer side of the tibia, with which it is connected above and below. Its upper extremity is small, placed toward the back of the head of the tibia and below the level of the knee-joint, and excluded from its formation; the lower extremity inclines a little forward, so as to be on a plane anterior to that of the upper end, projects below the tibia, and forms the outer ankle. It presents for examination a shaft and two extremities.

**Upper Extremity.**—The upper extremity, or head (capitulum fibulae), is of an irregular quadrature form, presenting above a flattened articular facet, directed upward, forward, and inward, for articulation with a corresponding facet on the external tuberosity of the tibia. On the outer side is a thick and rough prominence, continued behind into a pointed eminence, the styloid process of the fibula (apex capituli fibulae), which projects upward from the posterior part of the head. The prominence gives attachment to the tendon of the Biceps muscle and to the long external lateral ligament of the knee, the ligament dividing the tendon into two parts. The summit of the styloid process gives attachment to
the short external lateral ligament. The remaining part of the circumference of the head is rough, for the attachment of muscles and ligaments. It presents in front a tubercle for the origin of the upper and anterior part of the Peroneus longus, and the adjacent surface gives attachment to the anterior superior tibio-fibular ligament; and behind, another tubercle for the attachment of the posterior superior tibio-fibular ligament and the upper fibres of the Soleus muscle.

**Shaft of the Fibula (corpus fibulae).**—The shaft presents four borders—the antero-external, the antero-internal, the postero-external, and the postero-internal; and four surfaces—anterior, posterior, internal, and external.

**Antero-external Border** (crista anterior).—The antero-external border commences above in front of the head, runs vertically downward to a little below the middle of the bone, and then, curving somewhat outward, bifurcates so as to embrace the triangular subcutaneous surface immediately above the outer surface of the external malleolus. This border gives attachment to an intermuscular septum, which separates the extensor muscles on the anterior surface of the leg from the Peroneus longus and brevis muscles on the outer surface.

**Antero-internal Border** (crista interossea).—The antero-internal border, or interosseous ridge, is situated close to the inner side of the preceding, and runs nearly parallel with it in the upper third of its extent, but diverges from it so as to include a broader space in the lower two-thirds. It commences above, just beneath the head of the bone (sometimes it is quite indistinct for about an inch below the head), and terminates below at the apex of a rough triangular surface immediately above the articular facet of the external malleolus. It serves for the attachment of the interosseous membrane, which separates the extensor muscles in front from the flexor muscles behind.

**Postero-external Border** (crista lateralis).—The postero-external border is prominent; it commences above at the base of the styloid process, and terminates below in the posterior border of the outer malleolus. It is directed outward above, backward in the middle of its course, backward and a little inward below, and gives attachment to an aponeurosis which separates the Peronei muscles on the outer surface of the shaft from the flexor muscles on its posterior surface.

**Postero-internal Border** (crista medialis).—The postero-internal border, sometimes called the oblique line, commences above at the inner side of the head, and terminates by becoming continuous with the antero-internal border or interosseous ridge at the lower fourth of the bone. It is well marked and prominent at the upper and middle parts of the bone. It gives attachment to an aponeurosis which separates the Tibialis posticus from the Soleus above and the Flexor longus hallucis below.

**Anterior Surface** (facies anterior).—The anterior surface is the interval between the antero-external and antero-internal borders. It is extremely narrow and flat in the upper third of its extent; broader and grooved longitudinally in its lower third; it serves for the attachment of three muscles, the Extensor longus digitorum, Peroneus tertius, and Extensor proprius hallucis.

**External Surface** (facies lateralis).—The external surface is the space between the antero-external and postero-external borders. It is much broader than the preceding, and often deeply grooved, is directed outward in the upper two-thirds of its course, backward in the lower third, where it is continuous with the posterior border of the external malleolus. This surface is completely occupied by the Peroneus longus and brevis muscles.

**Internal Surface** (facies medialis).—The internal surface is the interval included between the antero-internal and the postero-internal borders. It is directed inward, and is grooved for the attachment of the Tibialis posticus muscle.

**Posterior Surface** (facies posterior).—The posterior surface is the space included between the postero-external and the postero-internal borders, it is continuous
below with the rough triangular surface above the articular facet of the outer malleolus; it is directed backward above, backward and inward at its middle, directly inward below. Its upper third is rough, for the attachment of the Soleus muscle; its lower part presents a triangular rough surface, connected to the tibia by a strong intersosseous ligament, and between these two points the entire surface is covered by the fibres of origin of the Flexor longus hallucis muscle. At about the middle of this surface is the nutrient foramen (foramen nutricium). It opens into the nutrient canal (canalis nutricia), which is directed downward.

**Lower Extremity.**—The lower extremity, or external malleolus (malleolus lateralis), is of a pyramidal form, somewhat flattened from without inward, and is longer, and descends lower than the internal malleolus. Its external surface is convex, subcutaneous, and continuous with the triangular (also subcutaneous) surface on the outer side of the shaft. The internal surface presents in front a smooth triangular facet (facies articularis malleoli), broader above than below, and convex from above downward, which articulates with a corresponding surface on the outer side of the astragalus. Behind and beneath the articular surface is a rough depression which gives attachment to the posterior fasciculus of the external lateral ligament of the ankle. The anterior border is thick and rough, and marked below by a depression for the attachment of the anterior fasciculus of the external lateral ligament. The posterior border is broad and marked by a shallow groove (sulcus malleolaris), for the passage of the tendons of the Peroneus longus and brevis muscles. The summit is rounded, and gives attachment to the middle fasciculus of the external lateral ligament.

In order to distinguish the side to which the bone belongs, hold it with the lower extremity downward and the broad groove for the Peronei tendons backward—i.e., toward the holder; the triangular subcutaneous surface will then be directed to the side to which the bone belongs.

**Articulations.**—With two bones: the tibia and astragalus.

**Development.**—By three centres (Fig. 174): one for the shaft, and one for each extremity. Ossification commences in the shaft about the eighth week of foetal life, a little later than in the tibia, and extends gradually toward the extremities. At birth both ends are cartilaginous. Ossification commences in the lower end in the second year, and in the upper one about the fourth year. The lower epiphysis, the first in which ossification commences, becomes united to the shaft about the twentieth year; the upper epiphysis joins about the twenty-fifth year. Ossification appearing first in the lower epiphysis is contrary to the rule which prevails with regard to the commencement of ossification in epiphyses—viz., that epiphysis toward which the nutrient artery is directed commences to ossify last; but it follows the rule which prevails with regard to the union of epiphyses, by unifying first.

**Attachment of Muscles.**—To nine: to the head, the Biceps, Soleus, and Peroneus longus; to the shaft, its anterior surface, the Extensor longus digitorum, Peroneus tertius, and Extensor proprius hallucis; to the internal surface, the Tibialis posticus; to the posterior surface, the Soleus and Flexor longus hallucis, to the external surface, the Peroneus longus and brevis.

**Surface Form.**—The only parts of the fibula which are to be felt are the head and the lower part of the external surface of the shaft and the external malleolus. The head is to be seen
THE SKELETON

Groove for peroneus longus.

Groove for peroneus brevis.

Groove for peroneus longus.

Astragalus.

Artic. with 2 bones.

Tarsus.

Metatarsus.

Phalanges.

EXTENSOR LONGUS ET BREVIS DIGITORUM.

EXTENSOR GALTUS HALLUCIS.

FIG. 175—Bones of the right foot. Dorsal surface.
Fig. 176.—Bones of the right foot. Plantar surface.
and felt behind and to the outer side of the outer tuberosity of the tibia. It presents a small, prominent triangular eminence slightly above the level of the tubercle of the tibia. The external malleolus presents a narrow elongated prominence, situated on a plane posterior to the internal malleolus and reaching to a lower level. From it may be traced the lower third or half of the external surface of the shaft of the bone in the interval between the Peroneus tertius in front and the other two Peronei tendons behind.

**Surgical Anatomy.**—In fractures of the bones of the leg both bones are usually fractured, but either bone may be broken separately, the fibula more frequently than the tibia. Fracture of both bones may be caused either by direct or indirect violence. When it occurs from indirect force, the fracture in the tibia is usually at the junction of the middle and lower third of the bone. Many causes conduce to render this the weakest part of the bone. The fracture of the fibula is usually at rather a higher level. These fractures present great variety, both as regards their direction and condition. They may be oblique, transverse, longitudinal, or spiral. When oblique, they are usually the result of indirect violence, and the direction of the fracture is from behind, downward, forward, and inward in many cases, but may be downward and outward or downward and backward. When transverse, the fracture is often at the upper part of the bone, and is the result of direct violence. The spiral fracture usually commences as a vertical fissure, involving the ankle-joint, and is associated with fracture of the fibula higher up. It is the result of torsion, from twisting of the body whilst the foot is fixed.

Fractures of the tibia alone are almost always the result of direct violence, except where the malleolus is broken off by twists of the foot. Fractures of the fibula alone may arise from indirect or direct force, those of the lower end being usually the result of the former, and those higher up being caused by a direct blow on the part.

The tibia and fibula, like the femur, are frequently the seat of acute osteomyelitis. Tuberculous abscess is more frequently met with in the cancellous tissue of the head and lower end of the tibia than in any other bone of the body. The abscess is of small size, very chronic, and probably the result of tuberculous osteitis in the highly vascular growing tissue at the end of the shaft near the epiphysial cartilage in the young subject. Such an abscess in bone is called Brodie’s abscess.

The tibia is the bone which is most frequently and most extensively distorted in rickets. It gives way at the junction of the middle and lower third, its weakest part, and presents a curve forward and outward. Bow-leg is due to outward curvature of the femur, tibia, and fibula, the bend being about the junction of the shafts and lower extremities.

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**THE FOOT** (Figs. 175, 176).

The skeleton of the foot consists of three divisions: the tarsus, metatarsus, and phalanges.

**The Tarsus (Ossa Tarsi).**

The bones of the tarsus are seven in number—viz., the calcaneus or os calcis, astragalus, cuboid, scaphoid, internal, middle, and external cuneiform.

**The Calcaneus, or Heel Bone** (Fig. 177).—It is also called the os calcis. The name is derived from calc, the heel. The heel bone is the largest and strongest of the tarsal bones. It is irregularly cuboidal in form, having its long axis directed forward and outward. It is situated at the lower and back part of the foot, serving to transmit the weight of the body to the ground, and forming a strong lever for the muscles of the calf. It is composed of a body (corpus calcanei), an anterior extremity or greater process, and a posterior extremity or tuberosity (tuber calcanei). It presents for examination six surfaces: superior, inferior, external, internal, anterior, and posterior.

**Superior Surface.**—The superior surface is formed behind by the upper aspect of that part of the os calcis which projects backward to form the heel. It varies in length in different individuals; is convex from side to side, concave from before backward, and corresponds above to a mass of adipose substance placed in front of the tendo Achilles. In the middle of the superior surface are two (sometimes three) articular facets, separated by a broad shallow groove (sulcus calcanei), which is directed obliquely forward and outward, and is rough for the attachment of the interosseous ligament connecting the astragalus and os calcis. When the calcaneus is in contact with the astragalus this groove is converted into
a canal (sinus tarsi). Of the articular surfaces, the external or posterior articular surface (facies articularis calcanea posterior) is the larger, and is situated on the body of the bone: it is of an oblong form, wider behind than in front, and convex from before backward. The internal or anterior articular surface is usually divided into two facets. The anterior facet is the facies articularis calcanea anterior, and it supports the head of the astragalus. The more posteriorly situated facet is the facies articularis calcanea media. It articulates with the middle facet on the under surface of the astragalus. The internal articular surface is supported on a projecting process of bone, called the lesser process of the calcaneus (sustentaculum tali); it is also oblong, concave longitudinally, and sometimes subdivided into two parts, which differ in size and shape. More anteriorly is seen the upper surface of the greater process of the calcaneus, marked by a rough depression for the attachment of numerous ligaments, and a tubercle for the origin of the Extensor brevis digitorum muscle.

Inferior Surface.—The inferior surface is narrow, rough, uneven, wider behind than in front and convex from side to side; it is bounded posteriorly by two tubercles separated by a rough depression; the external tubercle (processus lateralis tuberis calcanei), small, prominent, and rounded, gives attachment to part of the Abductor minimi digitii: the internal tubercle (processus medialis tuberis calcanei), broader and larger, for the support of the heel, gives attachment, by its prominent inner margin, to the Abductor hallucis, and in front to the Flexor brevis digitorum muscles and plantar fascia; the depression between the tubercles gives attachment to the Abductor minimi digitii. The rough surface in front of the tubercles gives attachment to the long plantar ligament and to the outer head of the Flexor accessorius muscle; while to a prominent tubercle nearer the anterior part of
this surface, as well as to a transverse groove in front of it, is attached the short plantar ligament.

**External Surface.**—The external surface is broad, flat, and almost subcutaneous; it presents near its centre a tubercle, for the attachment of the middle fasciculus of the external lateral ligament. At its upper and anterior part this surface gives attachment to the external calcaneo-astragaloid ligament; and in front of the tubercle it presents a narrow surface marked by two oblique grooves, separated by an elevated ridge which varies much in size in different bones; it is named the peroneal spine or tubercle (processus trochlearis), and gives attachment to a fibrous process from the external annular ligament. The superior groove transmits the tendon of the Peroneus brevis; the inferior groove the tendon of the Peroneus longus.

**Internal Surface.**—The internal surface is deeply concave; it is directed obliquely downward and forward, and serves for the transmission of the plantar vessels and nerves into the sole of the foot; it affords attachment to part of the Flexor accessorius muscle. At its upper and fore part it presents an eminence of bone, the lesser process of the calcaneum (sustentaculum talus), which projects horizontally inward, and to it a slip of the tendon of the Tibialis posticus is attached. This process is concave above, and supports the anterior articular surface of the astragalus; below, it is grooved for the tendon of the Flexor longus hallucis. Its free margin is rough, for the attachment of part of the internal lateral ligament of the ankle-joint.

**Anterior Surface** (facies articularis cuboidea).—The anterior surface, of a somewhat triangular form, articulates with the cuboid. It is concave from above downward and outward, and convex in the opposite direction. Its inner border gives attachment to the inferior calcaneo-scaphoïd ligament.

**Posterior Surface.**—The posterior surface is rough, prominent, convex, and wider below than above. The posterior extremity is the projection of the heel. It is called the tuberosity (tuber calcanei). Its lower part is rough, for the attachment of the tendo Achillis and the tendon of the Plantaris muscle; its upper part is smooth, and is covered by a bursa which separates the tendons from the bone.

**Articulations.**—With two bones: the astragalus and cuboid.

**Attachment of Muscles.**—To eight: part of the Tibialis posticus, the tendo Achillis, Plantaris, Abductor hallucis, Abductor minimi digiti, Flexor brevis digitorum, Flexor accessorius, and Extensor brevis digitorum.

**The Astragalus, or Ankle Bone (talus)** (Fig. 178).—The astragalus (ἀστραγαλός, a die) is the largest of the tarsal bones, next to the os calcis. It occupies the middle and upper part of the tarsus, supporting the tibia above, articulating with the malleoli on either side, resting below upon the os calcis, and joined in front to the scaphoid. This bone may easily be recognized by its large rounded head, by the broad articular facet on its upper convex surface, and by the two articular facets separated by a deep groove on its under concave surface. It is divided into a body (corpus talii), which supports the trochlear surface; the head (caput talii), which is in front of the body; and the neck (collum talii), the constricted part between the head and body. The astragalus presents six surfaces for examination.

**Superior Surface.**—The superior surface presents, behind, a broad smooth trochlear surface (trochlea talii) for articulation with the tibia. The trochlea is broader in front than behind, convex from before backward, slightly concave from side to side; in front of it is the upper surface of the neck of the astragalus, rough for the attachment of ligaments.

**Inferior Surface.**—The inferior surface presents two articular facets separated by a deep groove (sulcus talii). The groove runs obliquely forward and outward, becoming gradually broader and deeper in front: it corresponds with a similar
groove upon the upper surface of the calcaneus, and forms, when articulated with that bone, a canal (sinus tarsi), filled up in the recent state by the interosseous calcaneo-astragaloid ligament. Of the two articular facets, the **posterior articular facet** (facies articularis calcanea posterior) is the larger, of an oblong form and deeply concave from side to side; the **anterior articular facet** is shorter and narrower, of an elongated oval form, convex longitudinally, and often subdivided into two by an elevated ridge; of these, the **posterior** (facies articularis calcanea media) articulates with the lesser process of the os calcis; the **anterior** (facies articularis calcanea anterior), with the upper surface of the inferior calcaneo-scaphoid ligament.

**Internal Surface.**—The internal surface presents at its upper part a pear-shaped articular facet (facies malleolaris medialis) for the inner malleolus, continuous above with the trochlear surface; below the articular surface is a rough depression, for the attachment of the deep portion of the internal lateral ligament.

**External Surface.**—The external surface presents a large triangular facet (facies malleolaris lateralis), covered with cartilage and concave from above downward for articulation with the external malleolus; it is called the **external process** (processus lateralis tali), and passes outward and downward from the triangular facet. The triangular facet is continuous above with the trochlear surface; and in front of it is a rough depression for the attachment of the anterior fasciculus of the external lateral ligament of the ankle-joint.

**Anterior Surface** (facies articularis navicularis).—The anterior surface of the head of the astragalus is convex and rounded, smooth, of an oval form, and directed obliquely inward and downward; it articulates with the scaphoid. On its under and inner surface is a small facet, continuous in front with the articular surface of the head, and behind with the smaller facet for the os calcis. This rests on the inferior calcaneo-scaphoid ligament, being separated from it by the synovial membrane, which is prolonged from the anterior calcaneo-astragaloid joint to the astragalo-scaphoid joint. The head is surrounded by a constricted portion, the **neck of the astragalus** (collum tali).

**Posterior Surface.**—The posterior surface is narrow, and traversed by a groove (suclus m. flexoris hallucis longi), which runs obliquely downward and inward, and transmits the tendon of the Flexor longus hallucis, external to which is the prominent **external tubercle** (processus posterior tali), to which the posterior fasciculus of the external lateral ligament is attached. This tubercle is sometimes separated from the rest of the astragalus, and is then known as the **os trigonum.** To the inner side of the groove is the less marked **internal tubercle.**

To ascertain to which foot the bone belongs, hold it with the broad articular surface upward, and the rounded head forward; the lateral triangular articular surface for the external malleolus will then point to the side to which the bone belongs.
Articulations.—With four bones: tibia, fibula, os calcis, and scaphoid.

The Cuboid (os cuboideum) (Fig. 179).—The cuboid, from κούβος, a cube; κυβερνός, like, is placed on the outer side of the foot, in front of the os calcis, and behind the fourth and fifth metatarsal bones. It is of a pyramidal shape, its base being directed inward, its apex outward. It may be distinguished from the other tarsal bones by the existence of a deep groove on its under surface, for the tendon of the Peroneus longus muscle. It presents for examination six surfaces: three articular and three non-articular.

Non-articular Surfaces.—The non-articular surfaces are the superior, inferior, and external. The superior or dorsal surface, directed upward and outward, is rough, for the attachment of numerous ligaments. The inferior or plantar surface presents in front a deep groove, the peroneal groove (sulcus m. peronaei longi), which runs obliquely from without, forward and inward; it lodges the tendon of the Peroneus longus, and is bounded behind by a prominent ridge, to which is attached the long calcaneo-cuboid ligament. The ridge terminates externally in an eminence, the tuberosity of the cuboid (tuberositas ossis cuboidei), the surface of which presents a convex facet, for articulation with the sesamoid bone of the tendon contained in the groove. The surface of bone behind the groove is rough, for the attachment of the short plantar ligament, a few fibres of the Flexor brevis hallucis, and a fasciculus from the tendon of the Tibialis posticus. The external surface, the smallest and narrowest of the three, presents a deep notch formed by the commencement of the peroneal groove.

Articular Surfaces.—The articular surfaces are the posterior, anterior, and internal. The posterior surface is smooth, triangular, and concavo-convex, for articulation with the anterior surface of the os calcis. The anterior surface, of smaller size, but also irregularly triangular, is divided by a vertical ridge into two facets; the inner one, quadrilateral in form, articulates with the fourth metatarsal bone; the outer one, larger and more triangular, articulates with the fifth metatarsal. The internal surface is broad, rough, irregularly quadrilateral, presenting at its middle and upper part a smooth oval facet, for articulation with the external cuneiform bone; and behind this (occasionally) a smaller facet, for articulation with the navicular; it is rough in the rest of its extent, for the attachment of strong interosseous ligaments.

To ascertain to which foot the bone belongs, hold it so that its under surface, marked by the peroneal groove, looks downward, and the large concavo-convex articular surface backward toward the holder: the narrow non-articular surface, marked by the commencement of the peroneal groove, will point to the side to which the bone belongs.

Articulations.—With four bones: the os calcis, external cuneiform, and the fourth and fifth metatarsal bones; occasionally with the scaphoid.

Attachment of Muscles.—Part of the Flexor brevis hallucis and a slip from the tendon of the Tibialis posticus.
Scaphoid or Navicular Bone (os naviculare pedis) (Fig. 180).—The scaphoid is situated at the inner side of the tarsus, between the astragalus behind and the three cuneiform bones in front. It may be distinguished by its form, being concave behind, convex and subdivided into three facets in front.

Surfaces.—The anterior surface, of an oblong form, is convex from side to side, and subdivided by two ridges into three facets, for articulation with the three cuneiform bones. The posterior surface is oval, concave, broader externally than internally, and articulates with the rounded head of the astragalus. The superior surface is convex from side to side, and rough for the attachment of ligaments. The inferior is irregular, and also rough for the attachment of ligaments. The internal surface presents a rounded tubercular eminence, the tuberosity (tuberositas ossis navicularis), the lower part of which projects, and gives attachment to part of the tendon of the Tibialis posticus. The external surface is rough and irregular, for the attachment of ligamentous fibres, and occasionally presents a small facet for articulation with the cuboid bone.

To ascertain to which foot the bone belongs, hold it with the concave articular surface backward, and the convex dorsal surface upward; the external surface—i.e., the surface opposite the tubercle—will point to the side to which the bone belongs.

Articulations.—With four bones: astragalus and three cuneiform; occasionally also with the cuboid.

Attachment of Muscles.—Part of the Tibialis posticus.

Cuneiform or Wedge Bones.—The cuneiform bones have received their name from their wedge-like shape (cuneus, a wedge; forma, likeness). They form, with the cuboid, the anterior row of the tarsus, being placed between the scaphoid behind, the three innermost metatarsal bones in front, and the cuboid externally. They are called the first, second, and third, counting from the inner to the outer side of the foot, and, from their position, internal, middle, and external.

Internal or First Cuneiform (os cuneiforme primum) (Fig. 181).—The internal cuneiform is the largest of the three. It is situated at the inner side of the foot, between the scaphoid behind and the base of the first metatarsal in front. It may be distinguished from the other two by its large size, and by its not presenting such a distinct wedge-like form. Without the others it may be known by the large, kidney-shaped anterior...
articulating surface and by the prominence on the inferior or plantar surface for the attachment of the Tibialis posticus. It presents for examination six surfaces.

Surfaces.—The internal surface is subcutaneous, and forms part of the inner border of the foot; it is broad, quadrilateral, and presents at its anterior inferior angle a smooth oval facet, into which the tendon of the Tibialis anticus is partially inserted; in the rest of its extent it is rough, for the attachment of ligaments. The external surface is concave, presenting, along its superior and posterior borders, a narrow, reversed, L-shaped surface, for articulation with the middle cuneiform behind and second metatarsal bone in front; in the rest of its extent it is rough, for the attachment of ligaments and part of the tendon of the Peroneus longus. The anterior surface, kidney-shaped, much larger than the posterior, articulates with the metatarsal bone of the great toe. The posterior surface is triangular, concave, and articulates with the innermost and largest of the three facets on the anterior surface of the scaphoid. The inferior or plantar surface is rough, and presents a prominent tuberosity at its back part for the attachment of part of the tendon of the Tibialis posticus. It also gives attachment in front to part of the tendon of the Tibialis anticus. The superior surface is the narrow-pointed end of the wedge, which is directed upward and outward; it is rough for the attachment of ligaments.

To ascertain to which side the bone belongs, hold it so that its superior narrow edge looks upward, and the long, kidney-shaped, articular surface forward; the external surface, marked by its vertical and horizontal articular facets, will point to the side to which it belongs.

Articulations.—With four bones: scaphoid, middle cuneiform, first and second metatarsal bones.

Attachment of Muscles.—To three: the Tibialis anticus and posticus, and Peroneus longus.

Middle or Second Cuneiform (os cuneiforme secundum) (Fig. 182).—The middle cuneiform, the smallest of the three, is of very regular wedge-like form, the broad extremity being placed upward, the narrow end downward. It is situated between the other two bones of the same name, and articulates with the scaphoid behind and the second metatarsal in front. It is smaller than the external cuneiform bone, from which it may be further distinguished by the L-shaped articular facet, which runs round the upper and back part of its inner surface.

![Fig. 182.-The left middle cuneiform. A. Antero-internal view. B. Postero-external view.](image)

Surfaces.—The anterior surface, triangular in form and narrower than the posterior, articulates with the base of the second metatarsal bone. The posterior surface, also triangular, articulates with the scaphoid. The internal surface presents a reversed L-shaped articular facet, running along the superior and posterior borders, for articulation with the internal cuneiform, and is rough in the rest of its extent, for the attachment of ligaments. The external surface presents posteriorly a smooth facet for articulation with the external cuneiform bone. The superior surface forms the base of the wedge; it is quadrilateral, broader behind than in front, and rough for the attachment of ligaments. The inferior
surface, pointed and tubercular, is also rough for ligamentous attachment and for the insertion of a slip from the tendon of the Tibialis posticus.

To ascertain to which foot the bone belongs, hold its superior or dorsal surface upward, the broadest edge being toward the holder: the smooth facet (limited to the posterior border) will then point to the side to which it belongs.

Articulations.—With four bones: scaphoid, internal and external cuneiform, and second matatarsal bone.

Attachment of Muscles.—A slip from the tendon of the Tibialis posticus is attached to this bone.

External or Third Cuneiform (os cuneiforme tertium) (Fig. 183).—The external cuneiform, intermediate in size between the two preceding, is of a very regular wedge-like form, the broad extremity being placed upward, the narrow end downward. It occupies the centre of the front row of the tarsus, between the middle cuneiform internally, the cuboid externally, the scaphoid behind, and the third metatarsal in front. It is distinguished from the internal cuneiform bone by its more regular wedge-like shape and by the absence of the kidney-shaped articular surface: from the middle cuneiform, by the absence of the reversed L-shaped facet, and by the two articular facets which are present on both its inner and outer surfaces. It has six surfaces for examination.

Surfaces.—The anterior surface, triangular in form, articulates with the third metatarsal bone. The posterior surface articulates with the most external facet of the scaphoid, and is rough below for the attachment of ligamentous fibres. The internal surface presents two articular facets, separated by a rough depression; the anterior one, sometimes divided into two, articulates with the outer side of the base of the second metatarsal bone; the posterior one skirts the posterior border and articulates with the middle cuneiform; the rough depression between the two gives attachment to an interosseous ligament. The external surface also presents two articular facets, separated by a rough non-articular surface; the anterior facet, situated at the superior angle of the bone, is small, and articulates with the inner side of the base of the fourth metatarsal; the posterior and larger one articulates with the cuboid; the rough, non-articular surface serves for the attachment of an interosseous ligament. The three facets for articulation with the three metatarsal bones are continuous with one another, and covered by a prolongation of the same cartilage; the facets for articulation with the middle cuneiform and scaphoid are also continuous, but that for articulation with the cuboid is usually separate. The superior or dorsal surface is of an oblong square form, its posterior external angle being prolonged backward. The inferior or plantar surface is an obtuse rounded margin, and serves for the attachment of part of the tendon of the Tibialis posticus, part of the Flexor brevis hallucis, and ligaments.

To ascertain to which side the bone belongs, hold it with the broad dorsal surface upward, the prolonged edge backward; the separate articular facet for the cuboid will point to the proper side.

Articulations.—With six bones: the scaphoid, middle cuneiform, cuboid, and second, third, and fourth metatarsal bones.

Attachment of Muscles.—To two: part of the Tibialis posticus, and Flexor brevis hallucis.

The number of tarsal bones may be reduced owing to congenital ankylosis which may occur between the os calcis and cuboid, the os calcis and scaphoid, the os calcis and astragalus, or the astragalus and scaphoid.
The Metatarsal Bones (Ossa Metatarsalia).

The metatarsal bones are five in number, and are numbered one to five, in accordance with their position from within outward; they are long bones, and present for examination a shaft and two extremities.

**Common Characters.**—The shaft (corpus) is prismoid in form, tapers gradually from the tarsal to the phalangeal extremity, and is slightly curved longitudinally, so as to be concave below, slightly convex above. On the plantar surface of the shaft of each bone is a nutrient foramen corresponding to the nutrient foramen in each metacarpal bone. The posterior or proximal extremity, or base (basis), is wedge-shaped, articulating by its terminal surface with the tarsal bones, and by its lateral surfaces with the contiguous metatarsal bones, its dorsal and plantar surfaces being rough for the attachment of ligaments. The anterior or distal extremity, or head (capitulum), presents a terminal rounded articular surface, oblong from above downward, and extending farther backward below than above. Its sides are flattened and present a depression, surmounted by a tubercle, for ligamentous attachment. Its under surface is grooved in the middle line for the passage of the Flexor tendon, and marked on each side by an articular eminence continuous with the terminal articular surface.

**Peculiar Characters.** First Metatarsal Bone or the Metatarsal Bone of the Great Toe (os metatarsale I).—The first (Fig. 184) is remarkable for its great thickness, but is the shortest of all the metatarsal bones. The shaft is strong and of well-marked prismoid form. The posterior extremity presents, as a rule, no lateral articular facet, but occasionally on the outer side there is an oval facet by which it articulates with the second metatarsal bones. Its terminal articular surface is of large size and kidney-shaped; its circumference is grooved, for the tarso-metatarsal ligaments, and internally gives attachment to part of the tendon of the Tibialis anticus muscle; its inferior angle presents a rough oval prominence, the tuberosity (tuberositas ossis metatarsalis I), for the insertion of the tendon of the Peroneus longus. The head is of large size; on its plantar surface are two grooved facets, over which glide sesamoide bones; the facets are separated by a smooth elevated ridge.

This bone is known by the single kidney-shaped articular surface on its base, the deeply grooved appearance of the plantar surface of its head, and its great thickness relatively to its length. When it is placed in its natural position, the concave border of the kidney-shaped articular surface on its base points to the side to which the bone belongs.

**Attachment of Muscles.**—To three: part of the Tibialis anticus, the Peroneus longus, and the First dorsal intersosseus.

Second Metatarsal (os metatarsale II).—The second (Fig. 185) is the longest and largest of the remaining metatarsal bones, being prolonged backward into the recess formed between the three cuneiform bones. Its tarsal extremity is broad above, narrow and rough below. It presents four articular surfaces: one be-
hind, of a triangular form, for articulation with the middle cuneiform; one at the upper part of its internal lateral surface, for articulation with the internal cuneiform; and two on its external lateral surface—an upper and a lower, separated by a rough non-articular interval. Each of these articular surfaces is divided by a vertical ridge into two facets, thus making four facets; the two anterior of these articulate with the third metatarsal; the two posterior (sometimes continuous) with the external cuneiform. In addition to these articular surfaces there is occasionally a fifth when this bone articulates with the first metatarsal bone. It is oval in shape, and is situated on the inner side of the shaft near the base.

The facets on the tarsal extremity of the second metatarsal bone serve at once to distinguish it from the rest, and to indicate the foot to which it belongs; there being one facet at the upper angle of the internal surface, and two facets, each subdivided into two parts, on the external surface, pointing to the side to which the bone belongs. The fact that the two posterior subdivisions of these external facets sometimes run into one should not be forgotten.

Attachment of Muscles.—To fourth: the Adductor obliquus hallucis, First and Second dorsal interosseous, and a slip from the tendon of the Tibialis posticus; occasionally also a slip from the Peroneus longus.

Third Metatarsal (os metatarsale III).—The third metatarsal (Fig. 186) articulates behind, by means of a triangular smooth surface, with the external cuneiform; on its inner side, by two facets, with the second metatarsal; and on its outer side, by a single facet, with the fourth metatarsal. The latter facet is of circular form and situated at the upper angle of the base.

The third metatarsal is known by its having at its tarsal end two undivided facets on the inner side, and a single facet on the outer. This distinguishes it from the second metatarsal, in which the two facets, found on one side of its tarsal end, are each subdivided into two. The single facet (when the bone is put in its natural position) is on the side to which the bone belongs.

Attachment of Muscles.—To five: Adductor obliquus hallucis, Second and Third dorsal, and First plantar interosseous, and a slip from the tendon of the Tibialis posticus.
Fourth Metatarsal *(os metatarsale IV).*—The fourth metatarsal (Fig. 187) is smaller in size than the preceding; its *tarsal extremity* presents a terminal quad-

![Diagram of Fourth Metatarsal](image)

rilateral surface, for articulation with the cuboid; a smooth facet on the inner side, divided by a ridge into an anterior portion for articulation with the third metatarsal, and a posterior portion for articulation with the external cuneiform; on the outer side a single facet, for articulation with the fifth metatarsal.

The fourth metatarsal is known by its having a single facet on either side of the tarsal extremity, that on the inner side being divided into two parts. If this subdivision be not recognizable, the fact that its tarsal end is bent somewhat outward will indicate the side to which it belongs.

**Attachment of Muscles.**—To five: Adductor obliquus hallucis, Third and Fourth dorsal, and Second plantar interosseous, and a slip from the tendon of the Tibialis posticus.

Fifth Metatarsal Bone, or the Metatarsal Bone of the Little Toe *(os metatarsale V).*—The fifth metatarsal (Fig. 188) is recognized by the *tubercle* *(tuberositas ossis metatarsalis V)* on the outer side of its base. It articulates behind, by a triangular surface cut obliquely from without inward, with the cuboid, and internally with the fourth metatarsal.

The projection on the outer side of this bone at its tarsal end at once distinguishes it from the others, and points to the side to which it belongs.

**Attachment of Muscles.**—To six: the Peroneus brevis, Peroneus tertius, Flexor brevis minimi digiti, Adductor transversus hallucis, Fourth dorsal, and Third plantar interossei.

**Articulations.**—Each bone articulates with the tarsal bones by one extremity, and by the other with the first row of phalanges. The number of tarsal bones with which each metatarsal articulates is one for the first, three for the second, one for the third, two for the fourth, and one for the fifth.
**The Phalanges of the Foot (Phalanges Digitorum Pedis).**

The phalanges of the foot, both in number and general arrangement, resemble those in the hand; there being two in the great toe and three in each of the other toes. The nutritive foramina correspond to those in the phalanges of the hand.

The first or proximal phalanx (phalanx prima) resembles closely the corresponding bone of the hand. The shaft also is compressed from side to side, convex above, concave below. The posterior extremity is concave; and the anterior extremity presents a trochlear surface, for articulation with the second phalanx.

The second phalanx (phalanx secunda) is remarkably small and short, but rather broader than the first phalanx.

The ungual or distal phalanx (phalanx tertia) in form resembles the bone of the corresponding finger, but is smaller, flattened from above downward, presenting a broad base for articulation with the second phalanx, and an expanded extremity for the support of the nail and end of the toe.

**Articulation.**—The first row, with the metatarsal bones behind and second phalanges in front; the second row of the four outer toes, with the first and third phalanges; of the great toe, with the first phalanx; the third row of the four outer toes, with the second phalanges.


**Development of the Foot (Fig. 189).**

The Tarsal Bones are each developed by a single centre, excepting the os calcis which has an epiphysis for its posterior extremity. The centres make their appearance in the following order: os calcis, at the sixth month of fetal life; astragalus, about the seventh month; cuboid, at the ninth month; external cuneiform, during the first year; internal cuneiform in the third year; middle cuneiform and scaphoid in the fourth year. The epiphysis for the posterior tuberosity of the os calcis appears at the tenth year, and unites with the rest of the bone soon after puberty.

The Metatarsal Bones are each developed by two centres: one for the shaft and one for the digital extremity in the four outer metatarsals; one for the shaft and one for the base in the metatarsal bone of the great toe.2 Ossification commences in the centre of the shaft about the ninth week, and extends toward either extremity. The centre in the proximal end of the first metatarsal bone appears about the third year, the centre in the distal end of the other bones

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1 Except the second phalanx of the fifth toe, which receives no slip from the Extensor brevis digitorum.—En. of 15th English Edition.

2 As was noted in the first metacarpal bone, so in the first metatarsal, there is often to be observed a tendency to the formation of a second epiphysis in the distal extremity.—En. of 15th English Edition.
between the fifth and eighth years; they become joined between the eighteenth and twentieth years.

The Phalanges are developed by two centres for each bone: one for the shaft and one for the metatarsal extremity. The centre for the shaft appears about the tenth week, that for the epiphysis between the fourth and tenth years; they join the shaft about the eighteenth year.

**Construction of the Foot as a Whole** (Figs. 190, 191).

The foot is constructed on the same principles as the hand, but modified to form a firm basis of support for the rest of the body when in the erect position. It is more solidly constructed, and its component parts are less movable on each other than in the hand. This is especially the case with the great toe, which has to assist in supporting the body, and is therefore constructed with greater solidity; it lies parallel with the other toes, and has a very limited degree of mobility, whereas the thumb, which is occupied in numerous and varied movements, is constructed in such a manner as to permit of great mobility. Its metacarpal bone is directed away from the others, so as to form an acute angle with the second, and it enjoys a considerable range of motion at its articulation with the carpus. The foot is placed at right angles to the leg—a position which is almost peculiar to man, and has relation to the erect position which he maintains. In order to
allow of its supporting the weight of the whole body in this position with the least expenditure of material, it is constructed in the form of an arch. This antero-posterior or longitudinal arch is made up of two unequal limbs. The hinder one, which is made up of the os calcis and the posterior part of the astragalus, is about half the length of the anterior limb, and measures about three inches. The anterior limb consists of the rest of the tarsal and the metatarsal bones, and measures about seven inches. It may be said to consist of two parts, an inner segment made up of the head of the astragalus, the scaphoid, the three cuneiform, and the three inner metatarsal bones; and an outer segment composed of the os calcis, the cuboid, and the two outer metatarsal bones. The summit of the arch is at the superior articular surface of the astragalus; and its two extremities—that is to say, the two piers on which the arch rests in standing—are the tubercles on the under surface of the os calcis posteriorly, and the heads of the metatarsal bones anteriorly. The weakest part of the arch is the joint between the astragalus and scaphoid, and here it is more liable to yield in those who are overweighted, and in those in whom the ligaments which complete and preserve the arch are relaxed. This weak point in the arch is braced on its concave surface by the inferior calcaneo-scaphoid ligament, which is more elastic than most other ligaments, and thus allows the arch to yield from jars or shocks applied to the anterior portion of the foot and quickly restores it to its pristine condition. This ligament is supported internally by blending with the Deltoïd ligament, and inferiorly by the tendon of the Tibialis posticus muscle, which is spread out into a fan-shaped insertion, and prevents undue tension of the ligament or such an amount of stretching as would permanently elongate it.

In addition to this longitudinal arch the foot presents a transverse arch, at the anterior part of the tarsus and hinder part of the metatarsus. This, however, can scarcely be described as a true arch, but presents more the character of a half-dome. The inner border of the central portion of the longitudinal arch is elevated
from the ground, and from this point the bones arch over to the outer border, which is in contact with the ground, and, assisted by the longitudinal arch, produce a sort of rounded niche on the inner side of the foot, which gives the appearance of a transverse as well as a longitudinal arch.

The line of the foot, from the point of the heel to the toes, is not quite straight, but is directed a little outward, so that the inner border is a little convex and the outer border concave. This disposition of the bones becomes more marked when the longitudinal arch of the foot is lost, as in the disease known under the name of "flat-foot."

**Surface Form.**—On the dorsum of the foot the individual bones are not to be distinguished with the exception of the head of the astragalus, which forms a rounded projection in front of the ankle-joint when the foot is forcibly extended. The whole surface forms a smooth convex outline, the summit of which is the ridge formed by the head of the astragalus, the scaphoid, the middle cuneiform, and the second metatarsal bones; from this it gradually inclines outward and more rapidly inward. On the inner side of the foot, the _internal tuberosity of the os calcis_ and the ridge separating the inner from the posterior surface of the bone may be felt most posteriorly. In front of this, and below the internal malleolus, may be felt the projection of the _sustentaculum tali_. Passing forward is the well-marked tuberosity of the scaphoid bone, situated about an inch or an inch and a quarter in front of the internal malleolus. Further toward the front, the ridge formed by the base of the first metatarsal bone can be obscurely felt, and from this the shaft of the bone can be traced to the expanded head articulating with the base of the first phalanx of the great toe. Immediately beneath the base of this phalanx, the internal sesamoid bone is to be felt. Lastly, the expanded ends of the bones forming the last joint of the great toe are to be felt. On the outer side of the foot the most posterior bony point is the outer tuberosity of the os calcis, with the ridge separating the posterior from the outer surface of the bone. In front of this the greater part of the external surface of the os calcis is subcutaneous; on it, below and in front of the external malleolus, may be felt the peroneal ridge, when this process is present. Farther forward, the base of the fifth metatarsal bone forms a prominent and well-defined landmark, and in front of this the shaft of the bone, with its expanded head, and the base of the first phalanx may be defined. The sole of the foot is almost entirely covered by soft parts, so that but few bony parts are to be made out, and these somewhat obscurely. The hinder part of the under surface of the os calcis and the heads of the metatarsal bones, with the exception of the first, which is concealed by the sesamoid bones, may be recognized.

**Surgical Anatomy.**—Considering the injuries to which the foot is subjected, it is surprising how seldom the tarsal bones are fractured. This is no doubt due to the fact that the tarsus is composed of a number of bones, articulated by a considerable extent of surface and joined together by very strong ligaments, which serve to mitigate the intensity of violence applied to this part of the body. When fracture does occur, these bones, being composed for the most part of a soft cancellous structure, covered only by a thin shell of compact tissue, are often extensively comminuted, especially as most of the fractures are produced by direct violence. As the bones have only a very scanty amount of soft parts over them, fractures are very often compound, and amputation is frequently necessary.

When fracture occurs in the _anterior group of tarsal bones_, it is almost invariably the result of direct violence; but fractures of the posterior group, that is, of the calcaneum and astragalus, are most frequently produced by falls from a height on to the feet; though fracture of the _os calcis_ may be caused by direct violence or by muscular action. The posterior part of the bone, that is, the part behind the articular surfaces, is almost always the seat of the fracture, though some few cases of fracture of the _sustentaculum tali_ and of vertical fracture between the two articulating facets have been recorded. The neck of the astragalus, being the weakest part of the bone, is most frequently fractured, though fractures may occur in any part and almost in any direction, either associated or not with fracture of other bones.

In cases of _club-foot_, especially in congenital cases, the bones of the tarsus become altered in shape and size, and displaced from their proper positions. This is especially the case in _congenital equino-varus_, in which the astragalus, particularly about the head, becomes twisted and atrophied, and a similar condition may be present in the other bones, more especially the _scaphoid_. The tarsal bones are peculiarly liable to become the seat of _tuberculous caries_, and this condition may arise after comparatively trivial injuries. There are several reasons to account for this. They are composed of a delicate cancellous structure, surrounded by intricate synovial membranes. They are situated at the farthest point from the central organ of the circulation and exposed to vicissitudes of temperature; and, moreover, on their dorsal surface are thinly clad with soft parts which have but a scanty blood-supply. And finally, after slight injuries, they are not maintained in a condition of rest to the same extent as structures suffering from
similar injuries in some other parts of the body. Caries of the calcaneus or astragalus may remain limited to the one bone for a long period, but when one of the other bones is affected, the remainder frequently become involved, in consequence of the disease spreading through the large and complicated synovial membrane which is more or less common to these bones.

Amputation of the whole or a part of the foot is frequently required either for injury or disease. The principal amputations are as follows: (1) Syme's: amputation at the ankle-joint by a heel-flap, with removal of the malleoli and a thin slice from the lower end of the tibia. (2) Roux's: amputation at the ankle-joint by a large internal flap. (3) Piragoff's amputation: removal of the whole of the tarsal bones, except the posterior part of the os calcis. A thin slice is sawn from the tibia and fibula, including the two malleoli. The sawn surface of the os calcis is then turned up and united to the similar surface of the tibia. (4) Subastragaloid amputation: removal of the foot below the astragalus through the joint between it and the os calcis. This operation has been modified by Hancock, who leaves the posterior third of the os calcis and turns it up against the denuded surface of the astragalus. This latter operation is of doubtful utility and is rarely performed. (5) Chopart's or medio-tarsal: removal of the anterior part of the foot with all the tarsal bones except the os calcis and astragalus; disarticulation being effected through the astragalo-scaphoid and calcaneo-cuboid joints. (6) Lisfranc's: amputation of the anterior part of the foot through the tarso-metatarsal joints. This was modified by Hey, who disarticulated through the joints of the four outer metatarsal bones with the tarsus, and sawed off the projecting internal cuneiform; and by Skye, who sawed off the base of the second metatarsal bone and disarticulated the others.

The bones of the tarsus occasionally require removal individually. This is especially the case with the astragalus and os calcis for disease limited to the one bone, or again the astragalus may require excision in cases of subastragaloid dislocation, or, as recommended by M. r Lund, in cases of inveterate talipes. The cuboid has been removed for the same reason by Mr. Solly. But the latter two operations have fallen into disuse, and have been superseded by resection of a wedge-shaped piece of bone from the outer side of the tarsus. Finally, Mickulicz and Watson have devised operations for the removal of more extensive portions of the tarsus. Mickulicz's operation consists in the removal of the os calcis and astragalus, along with the articular surfaces of the tibia and fibula, and also of the scaphoid and cuboid. The remaining portion of the tarsus is then brought into contact with the sawn surfaces of the tibia and fibula, and fixed there. The result is a position of the shortened foot resembling talipes equinus. Watson's operation is adapted to those cases where the disease is confined to the anterior tarsal bones. By two lateral incisions he saws through the bases of the metatarsal bones in front and opens up the joints between the scaphoid and astragalus, and the cuboid and os calcis, and removes the intervening bones.

Fractures of the metatarsal bones and phalanges are nearly always due to direct violence, and in many cases the injury is the result of severe crushing accidents, necessitating amputation. The metatarsal bones, and especially the metatarsal bone of the great toe, are frequently diseased, either in tuberculous subjects or in perforating ulcer of the foot.

**Sesamoid Bones (Ossa Sesamoidea)** (Figs. 192, 193).

These are small rounded masses, cartilaginous in early life, osseous in the adult, which are developed in those tendons which exert a great amount of pressure upon the parts over which they glide. It is said that they are more commonly found in the male than in the female, and in persons of an active muscular habit than in those who are weak and debilitated. They are invested throughout their whole surface by the fibrous tissue of the tendon in which they are found, excepting upon that side which lies in contact with the part over which they play, where they present a free articular facet. They may be divided into two kinds: those which glide over the articular surfaces of the joints, and those which play over the cartilaginous facets found on the surfaces of certain bones.

The sesamoid bones of the joints in the upper extremity are two on the palmar surface of the metacarpo-phalangeal joint in the thumb, developed in the tendons of the Flexor brevis pollicis; one on the palmar surface of the interphalangeal joint of the thumb; occasionally one or two opposite the metacarpo-phalangeal articulations of the fore and little fingers; and, still more rarely, one opposite the same joints of the third and fourth fingers. In the lower extremity, the patella, which is developed in the tendon of the Quadriceps extensor; two small sesamoid bones, found in the tendons of the flexor brevis hallucis, opposite
the metatarso-phalangeal joint of the great toe; one sometimes over the interphalangeal joint of the great toe; and occasionally one in the metatarso-phalangeal joint of the second toe, the little toe, and, still more rarely, the third and fourth toes.

Those found in the tendons which glide over certain bones occupy the following situations: one sometimes found in the tendon of the Biceps cubiti, opposite the tuberosity of the radius: one in the tendon of the Peroneus longus, where it glides through the groove in the cuboid bone; one appears late in life in the tendon of the Tibialis anticus, opposite the smooth facet of the internal cuneiform bone; one is found in the tendon of the Tibialis posticus, opposite the inner side of the head of the astragalus; one in the outer head of the Gastrocnemius, behind the outer condyle of the femur; and one in the conjoined tendon of the Psoas and Iliacus, where it glides over the os pubis. Sesamoid bones are found occasionally in the tendon of the Gluteus maximus, as it passes over the great trochanter, and in the tendons which wind round the inner and outer malleoli.
THE ARTICULATIONS OR JOINTS.

The various bones of which the Skeleton consists are connected together at different parts of their surfaces, and such a connection is designated by the name of joint or articulation. Arthrology is the branch of anatomy which treats of the joints. Certain joints are immovable, as those between the cranial bones and most of those between the facial bones. In an immovable joint the adjacent margins of the bones are applied in almost close contact, a thin layer of fibrous membrane, the sutural ligament, or, as at the base of the skull, in certain situations, a thin layer of cartilage, being interposed. Where slight movement is required, combined with great strength, the osseous surfaces are united by tough and elastic fibro-cartilages, as in the joints between the vertebral bodies and in the interpubic articulation; but in the movable joints the bones forming the articulation are generally expanded for greater convenience of mutual connection, covered by cartilage, held together by strong bands or capsules of fibrous tissue called ligaments, and partially lined by a membrane, the synovial membrane, which secretes a fluid to lubricate the various parts of which the joint is formed; so that the structures which enter into the formation of a joint are bone, cartilage, fibro-cartilage, ligament, and synovial membrane.

Bone.—Bone constitutes the fundamental element of all the joints. In the long bones the extremities are the parts which form the articulations; they are generally somewhat enlarged and consist of spongy, cancellous tissue, with a thin coating of compact substance. The layer of compact bone which forms the articular surface, and to which the cartilage is attached, is called the articular lamella. It is of a white color, extremely dense, and varies in thickness. Its structure differs from ordinary bone-tissue in this respect, that it contains no Haversian canals, and its lacunae are much larger than in ordinary bone and have no canaliculi. The vessels of the cancellous tissue, as they approach the articular lamella, turn back in loops, and do not perforate it; this layer is consequently more dense and firmer than ordinary bone, and is evidently designed to form a firm and unyielding support for the articular cartilage. In the flat bones the articulations usually take place at the edges, and, in the short bones, at various parts of their surface.

Cartilage.—Cartilage is material which is a transition stage of connective tissue into bone. When boiled it yields chondrin. Cartilage is not vascular and is found in various parts of the body; in adult life chiefly in the joints, in the parietes of the thorax, and in various tubes, which are to be kept permanently open, such as the air passages, nostrils, and ears. In the foetus at an early period the greater part of the skeleton is cartilaginous. Because this cartilage is replaced by bone, it is called temporary in contradistinction to that which remains unossified during life, and which is called permanent. Unless active growth is in progress or calcification is going on, cartilage does not contain blood-vessels; if there is either active growth or calcification it may contain them. The investing membrane of cartilage is called the perichondrium. It consists of connective-tissue fibres and a few elastic fibres. The perichondrium carries blood-vessels, which may grow into the cartilage during active growth or ossification. Cartilage is divided into:

1. Hyaline cartilage.
2. Elastic cartilage.
3. Fibro-cartilage.

The cells of these three varieties of cartilage are similar.
Hyaline Cartilage.—This structure is found in embryos in regions where bone is to be formed, in the nose, larynx, trachea, bronchi, and in symphyses, epiphyses, and synchondroses. Costal cartilage and epiphyseal cartilage are composed of it, and as articular cartilage (cartilago articularis) it covers joint surfaces. It is a bluish or pearly hued substance, in reality a modified connective tissue, but much harder than most connective tissues. The investing membrane, the perichondrium, is composed chiefly of connective-tissue fibres, although a few elastic fibres are present. The peripheral layers of the cartilage pass into the perichondrium. The perichondrium carries blood-vessels which may, if there be active growth or ossification in progress, grow down into the cartilage. During growth the fibres of connective tissue may become the ground substance of cartilage and the cells of connective tissue may become cartilage cells; hence, the connective-tissue cells of the perichondrium are called chondroblasts.

Hyaline cartilage is composed of round or oval cells and intercellular substance. Each cell contains granular protoplasm and a nucleus, and the nucleus contains one or two nucleoli. The cells are placed in the so-called cartilage spaces of the ground substance, and the ground substance immediately surrounding a space is called a cartilage capsule. The cells are placed in groups and near the surface are arranged in rows, and in some regions are flattened by pressure. The intercellular or ground substance (matrix) is an apparently homogeneous and structureless material between the cartilage spaces. By certain methods, however, fibrils can be demonstrated in it. These fibrils in general are parallel. In some of the lower animals canals have been demonstrated. In man it has not been proved that canals exist, and it has been suggested that the fibrils act as paths for the conduction of nutritive fluid.

Articular cartilage forms a thin incrustation upon the joint-surfaces of the bones, and its elasticity enables it to break the force of any concussion, while its smoothness affords ease and freedom of movement. It varies in thickness according to the shape of the articular surface on which it lies; where this is convex the cartilage is thickest at the centre, where the greatest pressure is received; and the reverse is the case on the concave articular surfaces. Articular cartilage appears to derive its nutriment partly from the vessels of the neighboring synovial membrane and partly from those of the bone upon which it is implanted. Toynbee has shown that the minute vessels of the cancellous tissue as they approach the articular lamella dilate and form arches, and then return into the substance of the bone.

The hyaline cartilages, especially in adult and advanced life, are prone to calcify—that is to say, to have their matrix permeated by the salts of lime without any appearance of true bone. The process of calcification occurs also, and still more frequently, according to Rollett, in such cartilages as those of the trachea and in the costal cartilages, which are prone afterward to conversion into true bone. The ossification may occur in old age.

Elastic Cartilage.—In this structure there are elastic fibres in the matrix, which fibres at the periphery of the cartilage enter into the perichondrium. Such cartilage is not blue-white in color, but is a very light yellow, and is not to be regarded as identical with elastic fibrous tissue. Elastic cartilage is found in the epiglottis, the external ear, the Eustachian tube, the vocal processes of the arytenoid cartilages, the corniculate and cuneiform cartilages, and the cartilages of the larynx.

Fibro-cartilage is composed of white fibrous tissue and cartilage in varying proportions; it is to the first of these two constituents that its flexibility and toughness are chiefly owing, and to the latter its elasticity; the cells are fewer in number, but are possessed of more definite capsules than are those of hyaline cartilage, and they are usually arranged in groups surrounded by small islands of hyaline matrix, which may be concentrically striated. The hyaline islands are separated from
one another by bundles of white fibrous tissue that pursue a markedly wavy course.

Fibro-cartilage is found at the point of insertion of the ligamentum teres into the head of the femur, in the intervertebral disks, in the pubic symphysis, and in the interarticular cartilages.

The fibro-cartilages admit of arrangement into four groups: interarticular, connecting, circumferential, and stratiform.

1. The **interarticular fibro-cartilages** (*menisci interarticulares*) are flattened, fibro-cartilaginous plates, of a round, oval, triangular, or sickle-like form, interposed between the articular cartilages of certain joints. They are free on both surfaces, thinner toward their centre than at their circumference, and held in position by the attachment of their margins and extremities to the surrounding ligaments. The synovial membrane of the joint is prolonged over them a short distance from their attached margins. They are found in the temporo-mandibular, sterno-clavicular, acromio-clavicular, wrist- and knee-joints. These cartilages are usually found in those joints which are most exposed to violent concussion and subject to frequent movement. Their use is to maintain the apposition of the opposed surfaces in their various motions; to increase the depth of the articular surfaces and give ease to the gliding movement; to moderate the effects of great pressure and deaden the intensity of the shocks to which the parts may be subjected. Humphry has pointed out that these interarticular fibro-cartilages serve an important purpose in increasing the variety of movements in a joint. Thus, in the knee-joint there are two kinds of motion—viz., angular movement and rotation—although it is a hinge-joint, in which, as a rule, only one variety of motion is permitted; the former movement takes place between the condyles of the femur and the interarticular cartilage, the latter between the cartilage and the head of the tibia. So, also, in the temporo-mandibular joint, the upward and downward movement of opening and shutting the mouth takes place between the fibro-cartilage and the jaw-bone, the grinding movement between the glenoid cavity and the fibro-cartilage, the latter moving with the jaw-bone.

Interarticular cartilages may divide the joint into two distinct cavities, as in the temporo-maxillary articulation. The periphery of an articular cartilage is attached particularly to the capsule and may also be attached to the non-articular portion of the bone. The semilunar cartilages of the knee resemble tendon more than they do cartilage. The fibres are arranged in dense, more or less parallel bundles, separated by small, scattered hyaline cells, and the disks are attached to the bone by thin layers of hyaline cartilage.

2. The **connecting fibro-cartilages** are interposed between the bony surfaces of those joints which admit of only slight mobility, as between the bodies of the vertebrae and between the pubic bones. They form disks which adhere closely to both of the opposed surfaces, and are composed of concentric rings of fibrous tissue, with cartilaginous laminae interposed, the former tissue predominating toward the circumference, the latter toward the centre.

3. The **circumferential fibro-cartilages** consist of a rim of fibro-cartilage, which surrounds the margin of some of the articular cavities, as the cotyloid cavity of the hip and the glenoid cavity of the shoulder; they serve to deepen the articular surface, and to protect its edges.

4. The **stratiform fibro-cartilages** are those which form a thin coating to ossous grooves through which the tendons of certain muscles glide. Small masses of fibro-cartilages are developed also in the tendons of some muscles, where they glide over bones, as in tendons of the Peroneus longus and the Tibialis posticus.

**Ligaments.**—Ligaments consist of bands of various forms, serving to connect together the articular extremities of bones, and are composed mainly of coarse bundles of very dense white fibrous tissue placed parallel with, or closely inter-
laced with, one another, and presenting a white, shining, silvery aspect. These bundles are called fasciculi. They are held together by a cement substance containing cells which resemble those of tendon. A ligament is pliant and flexible, so as to allow of the most perfect freedom of movement, but it is strong, tough, and inextensible, so as not readily to yield under the most severely applied force; it is consequently well adapted to serve as the connecting medium between the bones. Some ligaments consist entirely of yellow elastic tissue (elastic fibrous tissue), the elastic fibres branching considerably, but maintaining in general a parallel course. The fibres are in bundles, between which areolar connective tissue lies. The ligamenta subflava, which connect together the adjacent arches of the vertebrae in man and the ligamentum nuchae in the lower animals are composed of yellow elastic tissue. In these cases it will be observed that the elasticity of the ligament is intended to act as a substitute for muscular power.

**Synovial Membranes.**—These membranes are serous in character. A synovial membrane consists of loose connective tissue (subendothelial tissue), containing fat, vessels, and nerves, its inner surface being lined with a single layer of flat endothelial cells. The endothelial cells are polyhedral, and each cell possesses a flattened oval nucleus. The cells are held together by intercellular cement. It is believed by some that little openings occur at intervals in the intercellular cement, but it is held by many that the supposed openings are artifacts. Synovial cavities contain a little fluid. A non-articular synovial membrane does not actually secrete fluid, but it is moistened by lymph which passes through the membrane and into the cavity by osmosis.

Joint cavities and bursae communicating with joints contain a characteristic fluid which is a secretion of the membrane. It is yellowish-white or slightly reddish, somewhat cloudy, viscid like the white of an egg, having a strongly alkaline reaction and a slightly saline taste. It consists of fats, salts, albumins, extractives from lymph, a mucinous body known as synovin, and another mucin-like body, which is rich in phosphorus (Simon). The synovial membranes found in the body admit of subdivision into three kinds—articular, bursal, and vaginal.

**Articular Synovial Membrane.**—Articular synovial membrane is found in every freely movable joint. It lines the capsule of the joint and is reflected upon the non-articular intracapsular portion of the bones which enter into the formation of the joint. In the fetus this membrane is said, by Toynbee, to be continued over the surface of the cartilages; but in the adult it merely encroaches for a short distance upon the margins of the cartilages, to which it is firmly attached; it then invests the inner surface of the capsular or other ligaments enclosing the joint, and is reflected over the surface of any tendons passing through its cavity, as the tendon of the Popliteus in the knee and the tendon of the Biceps in the shoulder. Hence the articular synovial membrane may be regarded as a short wide tube, attached by its open ends to the margins of the articular cartilages, and covering the inner surface of the various ligaments which connect the articular surfaces, so that along with the cartilages it completely encloses the joint-cavity. In some of the joints the synovial membrane is thrown into folds, which pass across the cavity. They are called synovial ligaments, and are especially distinct in the knee. These folds, when large, frequently contain considerable quantities of fat, which acts as a cushion between the two articular surfaces and which serves a valuable purpose in filling up gaps. In some joints there are flattened folds, subdivided at their margins into fringe-like processes (synovial villi), the vessels of which have a convoluted arrangement. These latter generally project from the synovial membrane near the margin of the cartilage and lie flat upon its surface. They consist of connective tissue covered with endothelium, and contain fat-cells in variable quantities, and, more rarely, isolated cartilage-cells. They were described

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1 Simon's Physiological Chemistry.
by Clopton Havers as mucilaginous glands, and as the source of the synovial secretion. Under certain diseased conditions similar processes are found covering the entire surface of the synovial membrane, forming a mass of pedunculated fibro-fatty growths which project into the joint. Similar structures are also found in some of the bursal and vaginal synovial membranes.

**Bursal Synovial Membrane.**—The bursal synovial membranes are sacs interposed between surfaces which move upon each other, producing friction, as in the gliding of a tendon or of the integument over projecting bony surfaces. There are two groups of synovial bursae designated according to situation: (1) Those situated between the integument and a prominent process of bone. Such a bursa is called a subcutaneous synovial bursa (*bursa mucosa subcutanea*) (Fig. 246). Subcutaneous bursae are found between the integument and the front of the patella, over the olecranon, the malleoli, and other prominent parts. (2) Those situated between tendons or muscles and the bony or cartilaginous surfaces over which the tendons or muscles glide (Fig. 194). Such a bursa is called a subtendinous synovial bursa (*bursa mucosa subtendinea*).

**Vaginal Synovial Membrane** (Figs. 232 and 324).—A vaginal synovial membrane which is the synovial sheath or the thecal synovial bursa (*vagina mucosa tendinis*) serves to facilitate the gliding of a tendon in the osseo-fibrous canal through which it passes. The membrane is here arranged in the form of a sheath, one layer of which adheres to the wall of the canal, and the other is reflected upon the surface of the contained tendon, the space between the two free surfaces of the membrane containing synovia. These sheaths are chiefly found surrounding the tendons of the Flexor and Extensor muscles of the fingers and toes as they pass through the osseo-fibrous canals in the hand or foot. A vaginal sheath covers the long head of the Biceps muscle from its origin to the surgical neck of the humerus (Fig. 222).

**Pads of adipose tissue** (*synovial fat pads*) are found in certain joints between folds of the synovial membrane or between the synovial membrane and the surface beneath it. These pads fill up certain joint intervals, and by adapting themselves to changes of position maintain the form of the joint during movement.

The articulations are divided into three classes: synarthrosis, or immovable; amphiarthrosis, or mixed; and diarthrosis, or movable joints.
Synarthrosis (Immovable Articulation).

Synarthrosis includes all those articulations in which the surfaces of the bones are in almost direct contact, being fastened together by an intervening mass of connective tissue, and in which there is no joint cavity and no appreciable motion. Examples of synarthrosis are the joints between the bones of the cranium and of the face, excepting those of the lower jaw. The varieties of synarthrosis are four in number: sutura, schindylesis, gomphosis, and synchondrosis.

Sutura.—Sutura (a seam) is that form of articulation met with only in the skull, where the contiguous margins of flat bones are apparently but not really in immediate contact, a thin layer of fibrous tissue, sutural membrane, being interposed. This membrane is continuous externally with the pericranium and internally with the dura. In some of the sutures the sutural membrane gradually disappears as age advances and the two bones form an osseous fusion. Where the articulating surfaces are connected by a series of processes and indentations interlocked together, it is termed a true suture or sutura vera, of which there are three varieties: sutura dentata, serrata, and limboa. The sutura dentata (dens, a tooth) is so called from the tooth-like form of the projecting articular processes, as in the suture between the parietal bones. In the sutura serrata (serra, a saw) the edges of the two bones forming the articulation are serrated like the teeth of a fine saw, as between the two portions of the frontal bone. In the sutura limboa (limbus, a selavage), besides the dentated processes, there is a certain degree of bevelling of the articular surfaces, so that the bones overlap one another, as in the suture between the parietal and frontal bones. When the articulation is formed by roughened surfaces placed in apposition with one another, it is termed the false suture (sutura notha), of which there are two kinds: the sutura squamosa (squama, a scale), formed by the overlapping of two contiguous bones by broad bevelled margins, as in the squamo-parietal (squamous) suture; and the sutura harmonia (ἀρμονία, a joining together), where there is simple apposition of two contiguous, rough, bony surfaces, as in the articulation between the two superior maxillary bones or of the horizontal plates of the palate bones.

Schindylesis.—Schindylesis (σχινδυλησίς, a fissure) is that form of articulation in which a thin plate of bone is received into a cleft or fissure formed by the separation of two laminae in another bone, as in the articulation of the rostrum of the sphenoid and perpendicular plate of the ethmoid with the vomer, or in the reception of the latter in the fissure between the superior maxillary and palate bones.

Gomphosis.—Gomphosis (γόμφος, a nail) is an articulation formed by the insertion of a conical process into a socket, as a nail is driven into a board; this is not illustrated by any articulation between bones, properly so called, but is seen in the articulation of the teeth with the alveoli of the maxillary bones.

Synchondrosis.—Where the connecting medium is cartilage the joint is termed a synchondrosis. This is a temporary form of joint, because the hyaline cartilage becomes converted into bone before adult life. Such a joint is found between the epiphyses and shafts of long bones. Another example of a synchondrosis is the occipito-sphenoid articulation.

Amphiarthrosis (Mixed Articulation).

In this form of articulation the contiguous osseous surfaces may be connected together by broad flattened disks of fibro-cartilage, of a more or less complex structure, which adhere to the end of each bone, as in the articulation between the bodies of two vertebrae and that between the pubic bones at the symphysis. This is termed symphysis. In a symphysis there is a partial joint-cavity which may exhibit an incomplete synovial membrane. Each constituent bone is coated with hyaline cartilage and the bones are held together by ligaments and intervening
Diarthrosis. The bony surfaces of an amphiarthrodial joint may be united by an interosseous ligament, as in the inferior fibio-fibular articulation. To such an articulation the term syndesmosis is applied. A mixed articulation permits limited motion.

**Diarthrosis (Movable Articulation).**

This form of articulation includes the greater number of the joints in the body, mobility being their distinguishing character. They are formed by the approximation of two contiguous bony surfaces covered with cartilage, connected by ligaments and lined by synovial membrane. The varieties of joints in this class have been determined by the kind of motion permitted in each. There are two varieties in which the movement is uniaxial; that is to say, all movements take place around one axis. In one form, the ginglymus or hinge-joint, this axis is, practically speaking, transverse; in the other, the trochoïd or pivot-joint, it is longitudinal. There are two varieties where the movement is biaxial or around two horizontal axes at right angles to each other or at any intervening axis between the two. These are the condyloid-joint and the saddle-joint. There is one form of joint where the movement is polyaxial, the enarthrosis or ball-and-socket joint. And finally there are the arthrodia or gliding joints. In a diarthrosis there is always a joint cavity lined with synovial membrane—the articular surfaces of the bones are covered with hyaline cartilage and the bones are held in contact by ligaments.

**Ginglymus or Hinge-joint** (γίγλιμος, a hinge).—In this form of joint the articular surfaces are moulded to each other in such a manner as to permit motion only in one plane, forward and backward; the extent of motion at the same time being considerable. The direction which the distal bone takes in this motion is never in the same plane as that of the axis of the proximal bone, and there is always a certain amount of alteration from the straight line during flexion. The articular surfaces are connected together by strong lateral ligaments, which form their chief bond of union. The most perfect forms of ginglymus are the interphalangeal joints and the joint between the humerus and ulna; the knee and ankle are less perfect, as they allow a slight degree of rotation or lateral movement in certain positions of the limb.

**Trochoïd or Pivot-joint or Rotary-joint.**—Where the movement is limited to rotation, the joint is formed by a pivot-like process turning within a ring, or the ring on the pivot, the ring being formed partly of bone, partly of ligament. In the superior radio-ulnar articulation the ring is formed partly by the lesser sigmoid cavity of the ulna; in the rest of its extent, by the orbicular ligament; here the head of the radius rotates within the ring. In the articulation of the odontoid process of the axis with the atlas the ring is formed in front by the anterior arch of the atlas; behind, by the transverse ligament; here the ring rotates round the odontoid process.

**Condyloid or Biaxial Articulation.**—In this form of joint an ovoid articular head, or condyle, is received into an elliptical cavity in such a manner as to permit of flexion and extension, adduction and abduction and circumduction, but no axial rotation. The articular surfaces are connected together by anterior, posterior, and lateral ligaments. An example of this form of joint is found in the wrist.

**Articulation by Reciprocal Reception or Saddle-joint.**—In this variety the articular surfaces are concavo-convex; that is to say, they are inversely convex in one direction and concave in the other. The movements are the same as in the preceding form; that is to say, there is flexion, extension, adduction, abduction, and circumduction, but no axial rotation. The articular surfaces are connected
by a capsular ligament. The best example of this form of joint is the carpo-
metacarpal joint of the thumb.

**Enarthrosis**, or **Ball-and-socket-joint**, is that form of joint in which the distal 
bone is capable of motion around an indefinite number of axes which have one 
common centre. It is formed by the reception of a globular head into a deep 
cup-like cavity (hence the name "ball-and-socket"), the parts being kept in 
apposition by a capsular ligament strengthened by accessory ligamentous bands. 
Examples of this form of articulation are found in the hip and shoulder.

**Arthrodia.**—Arthrodia is that form of joint which admits of a gliding move-
ment; it is formed by the approximation of plane surfaces or of one slightly con-
cave to one slightly convex, the amount of motion between them being limited 
by the ligaments, or osseous processes, surrounding the articulation; as in the 
articular processes of the vertebrae, the carpal joint, except that of the os magnum 
with the scaphoid and semilunar bones, and the tarsal joints with the exception 
of the joint between the astragalus and the scaphoid.

Below, in tabular form, are the names, distinctive characters, and examples 
of the different kinds of articulations.

### The Kinds of Movement Admitted in Joints.

The movements admissible in joints may be divided into four kinds: gliding, 
angular movement, circumduction, and rotation. These movements are often, 
however, more or less combined in the various joints, so as to produce an infinite 
variety, and it is seldom that we find only one kind of motion in any particular joint.

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<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sutura</strong></td>
<td>Articulation by processes and indentations interlocked together.</td>
</tr>
<tr>
<td><strong>Sutura vera</strong></td>
<td>(true), articulate by indented borders.</td>
</tr>
<tr>
<td><strong>Sutura notha</strong></td>
<td>(false), articulate by rough surfaces.</td>
</tr>
<tr>
<td><strong>Sutura vera</strong></td>
<td>Having tooth-like processes.</td>
</tr>
<tr>
<td><strong>Sutura notha</strong></td>
<td>Having bevelled margins and dentated processes.</td>
</tr>
<tr>
<td><strong>Limbosa</strong></td>
<td>Having bevelled margins, overlapping each other.</td>
</tr>
<tr>
<td><strong>Squamosa</strong></td>
<td>Formed by the apposition of contiguous rough surfaces.</td>
</tr>
<tr>
<td><strong>Schindylesis</strong></td>
<td>Articulation formed by the reception of a thin plate of one bone into a fissure of another.</td>
</tr>
<tr>
<td><strong>Gomphosis</strong></td>
<td>Articulation formed by the insertion of a conical process into a socket: the teeth.</td>
</tr>
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**Synarthrosis**, or **Immovable Joint.** Surfaces separated by fibrous mem-
brane or by line of cartilage, without any intervening synovial cavity, and immo-
avably connected with each other.

As in joints of cranium and face (except lower jaw).
THE KINDS OF MOVEMENT ADMITTED IN JOINTS

Amphiarthrosis, Mixed Articulation.

Symphysis.—Surfaces connected by fibro-cartilage. There is a partial joint cavity and may be an incomplete synovial membrane. Has limited motion. As in joints between bodies of vertebrae.

Syndesmosis.—Surfaces united by an intersosseous liga-

Ginglymus.—Hinge-joint; motion limited to two directions, forward and backward. Articular surfaces fitted together so as to permit of movement in one plane. As in the interphalangeal joints and the joint between the humerus and the ulna.

Trochoides, or Pivot-joint.—Articulation by a pivot process turning within a ring or ring around a pivot. As in superior radio-ulnar articulation and atlanto-axial joint.

Condyloid.—Ovoid head received into elliptical cavity. Movements in every direction except axial rotation. As the wrist-joint.

Reciprocal Reception (saddle-joint).—Articular surfaces inversely convex in one direction and concave in the other. Movement in every direction except axial rotation. As in the carpo-metacarpal joint of the thumb.

Enarthrosis.—Ball-and-socket joint; capable of motion in all directions. Articulations by a globular head received into a cup-like cavity. As in hip- and shoulder-joints.

Arthrodia.—Gliding joint; articulations by plane surfaces, which glide upon each other. As in carpal and tarsal articulations.

Diarthrosis, Movable Joint.

Gliding movement is the most simple kind of motion that can take place in a joint, one surface gliding or moving over another without any angular or rotatory movement. It is common to all movable joints, but in some, as in the articulations of the carpus and tarsus, it is the only motion permitted. This movement is not confined to plane surfaces, but may exist between any two contiguous surfaces, of whatever form, limited by the ligaments which enclose the articulation. Gliding over a wide range, as is seen in the sliding of the patella over the femur, is called coaptation.

Angular movement occurs only between the long bones, and by it the angle between the two bones is increased or diminished. It may take place in four directions: forward and backward, constituting flexion or bending and extension or straightening, or inward toward and outward from the medial line of the body, constituting adduction and abduction. Abduction of a limb is movement away from the medial line of the body. Adduction of a limb is movement toward the medial line of the body. In the fingers and toes the significance of the terms are different; abduction means movement of the fingers away from the middle finger or of the toe away from the second toe; adduction means movement of fingers toward the middle finger or of the toes toward the second toe. The strictly ginglymo-

oid or hinge-joints admit of flexion and extension only. Abduction and adduc-

tion, combined with flexion and extension, are met with in the more movable joints; as in the hip-, shoulder-, and metacarpal-joint of the thumb, and partially in the wrist. When two anterior surfaces are brought nearer together, as by bending the elbow or wrist, we speak of the movement as ventral or anterior flexion. Ventral flexion of the wrist is also called volar or palmar flexion. If two posterior surfaces are brought nearer together, as by bending the knee or extending the wrist, we speak of the movement as posterior or dorsal flexion.
At the wrist-joint the bending of the ulnar margin of the hand toward the ulnar side of the forearm is **ulnar flexion**; the bending of the radial margin of the hand toward the radial side of the forearm is **radial flexion**.

**Circumduction** is that limited degree of motion which takes place between the head of the bone and its articular cavity, whilst the extremity and sides of the limb are made to circumscribe a conical space, the base of which corresponds with the inferior extremity of the limb, the apex with the articular cavity; this kind of motion is best seen in the shoulder- and hip-joints.

**Rotation** is the movement of a bone upon an axis, which is the axis of the pivot on which the bone turns, as in the articulation between the atlas and axis, when the odontoid process serves as a pivot around which the atlas turns; or else is the axis of a pivot-like process which turns within a ring, as in the rotation of the radius upon the humerus.

**Ligamentous Action of Muscles.**—The movements of the different joints of a limb are combined by means of the long muscles which pass over more than one joint, and which, when relaxed and stretched to their greatest extent, act as elastic ligaments in restraining certain movements of one joint, except when combined with corresponding movements of the other, these latter movements being usually in the opposite direction. Thus the shortness of the hamstring muscles prevents complete flexion of the hip, unless the knee-joint is also flexed, so as to bring their attachments nearer together. The uses of this arrangement are threefold: 1. It co-ordinates the kinds of movement which are the most habitual and necessary, and enables them to be performed with the least expenditure of power. “Thus in the usual gesture of the arms, whether in grasping or rejecting, the shoulder and the elbow are flexed simultaneously, and simultaneously extended,” in consequence of the passage of the Biceps and Triceps cubiti over both joints. 2. It enables the short muscles which pass over only one joint to act upon more than one. “Thus, if the Rectus femoris remain tonically of such length that, when stretched over the extended hip, it compels extension of the knee, then the Gluteus maximus becomes not only an extensor of the hip, but an extensor of the knee as well.” 3. It provides the joints with ligaments which, while they are of very great power in resisting movements to an extent incompatible with the mechanism of the joint, at the same time spontaneously yield when necessary. “Taxed beyond its strength, a ligament will be ruptured, whereas a contracted muscle is easily relaxed; also, if neighboring joints be united by ligaments, the amount of flexion or extension of each must remain in constant proportion to that of the other; while, if the union be by muscles, the separation of the points of attachment of those muscles may vary considerably in different varieties of movement, the muscles adapting themselves tonically to the length required.” The quotations are from a very interesting paper by Dr. Cleland in the *Journal of Anatomy and Physiology*, No. 1, 1866, p. 85; by whom I believe this important fact in the mechanism of joints was first clearly pointed out, though it has been independently observed afterward by other anatomists. Dr. W. W. Keen points out how important it is “that the surgeon should remember this ligamentous action of muscles in making passive motion—for instance, at the wrist after Colles’s fracture. If the fingers be extended, the wrist can be flexed to a right angle. If, however, they be first flexed, as in ‘making a fist,’ flexion at the wrist is strictly limited to from 40 to 50 degrees in different persons, and is very painful beyond that point. Hence passive motion here should be made with the fingers extended. In the leg, when flexing the hip, the knee should be flexed.” Dr. Keen further points out that “a beautiful illustration of this is seen in the perching of birds, whose toes are forced to clasp the perch by just such a passive ligamentous action so soon as they stoop. Hence they can go to sleep and not fall off the perch.”
The articular processes may be arranged into those of the trunk, those of the upper extremity, and those of the lower extremity.

**ARTICULATIONS OF THE TRUNK.**

These may be divided into the following groups, viz.:

I. Of the vertebral column.  
II. Of the atlas with the axis.  
III. Of the atlas with the occipital bone.  
IV. Of the axis with the occipital bone.  
V. Of the lower jaw.  
VI. Of the ribs with the vertebrae.  
VII. Of the cartilages of the ribs with the sternum and with each other.  
VIII. Of the sternum.  
IX. Of the vertebral column with the pelvis.  
X. Of the pelvis.

**I. Articulations of the Vertebral Column.**

The different segments of the spine are connected together by **spinal ligaments** (*ligamenta columnar vertebralis*), which may be divided into five sets: 1. Those connecting the **bodies** of the vertebrae. 2. Those connecting the **lamineae**. 3. Those connecting the **articular processes**. 4. Those connecting the **spinous processes**. 5. Those of the **transverse processes**.

The articulations of the bodies of the vertebrae with each other form a series of amphiarthrodial joints; those between the articular processes form a series of arthrodial joints.

1. **The Ligaments of the Vertebral Bodies or Centra (Intervertebral Ligaments).**

   Anterior Common Ligament (*anterior longitudinal ligament*).  
   Posterior Common Ligament (*posterior longitudinal ligament*).  
   Intervertebral Substance (*intervertebral disk, fibro-cartilage*).

The **Anterior Common** or **Anterior Longitudinal Ligament** (*ligamentum longitudinale anterius*) (Figs. 197, 199, and 203) is a broad and strong band of longitudinal fibres which extends along the anterior (ventral) surface of the bodies of the vertebrae from the axis to the sacrum. It is broader below than above, thicker in the thoracic than in the cervical or lumbar regions, and somewhat thicker opposite the front of the body of each vertebra than opposite the intervertebral substance. It is attached, above, to the body of the axis by a pointed process, where it is continuous with the anterior atlanto-axial ligament, is connected with the tendon of insertion of the Longus colli muscle, and extends down as far as the upper bone of the sacrum. It consists of dense longitudinal fibres, which are intimately adherent to the intervertebral substance and the prominent margins of the vertebrae, but less closely to the middle of the bodies. In the latter situation the fibres are exceedingly thick, and serve to fill up the concavities on their front surface and to make the anterior surface of the spine more even. This ligament is composed of several layers of fibres, which vary in length, but are closely interlaced with each other. The most superficial or longest fibres extend between four or five vertebrae. A second subjacent set extends between two or three vertebrae, whilst a third set, the shortest and deepest, extends from one vertebra to the next. At the side of the bodies the ligament consists of a few short fibres, which pass from one vertebra to the next, separated from the median portion by large oval apertures for the passage of vessels.
The Posterior Common or Posterior Longitudinal Ligament (ligamentum longitudinale posterius) (Figs. 195, 197, 202, and 203) is situated within the spinal canal, and extends along the posterior (dorsal) surface of the bodies of the vertebrae from the body of the axis above, where it is continuous with the posterior occipito-axial ligament, to the sacrum below. It can be separated from the posterior occipito-axial ligament, as is shown in Fig. 203, and may be regarded as really arising from the clivus. It is broader above than below, and thicker in the thoracic than in the cervical or lumbar regions. In the situation of the intervertebral substance and contiguous margins of the vertebrae, where the ligament is more intimately adherent, it is broad, and presents a series of dentations with intervening concave margins; but it is narrow and thick over the centre of the bodies, from which it is separated by the venæ basis vertebrae. This ligament is composed of smooth, shining, longitudinal fibres, denser and more compact than those of the anterior ligament, and formed of a superficial layer occupying the interval between three or four vertebrae, and of a deeper layer which extends between one vertebra and the next adjacent to it. It is separated from the dura of the spinal cord by some loose connective tissue, which is very liable to serous infiltration.

The Intervertebral Fibro-cartilages, Disks, or Substances (fibrocartilagines intervertebrales) (Figs. 196 and 197).—Each fibro-cartilaginous disk is of lenticular form and of composite structure. The disks are interposed between the adjacent surfaces of the bodies of the vertebrae from the axis to the sacrum, and form the chief bonds of connection between those bones. In young children intervertebral substance exists in the coccyx. These disks vary in shape, size, and thickness in different parts of the spine. In shape they accurately correspond with the surfaces of the bodies between which they are placed, being oval in the cervical and lumbar regions, and circular in the thoracic. Their size is greatest in the lumbar region. In thickness they vary not only in the different regions of the spine, but in different parts of the same disk; thus, they are thicker in front than behind in the cervical and lumbar regions, while they are uniformly thick in the thoracic region. The intervertebral disks form about one-fourth of the spinal column, exclusive of the first two vertebrae; they are not equally distributed, however, between the various bones; the thoracic portion of the spine
having, in proportion to its length, a much smaller quantity than in the cervical and lumbar regions, which necessarily gives to the latter parts greater pliancy and freedom of movement. The intervertebral disks are adherent, by their surfaces, to a thin layer of hyaline cartilage which covers the upper and under surfaces of the bodies of the vertebrae, and in which, in early life, the epiphysial plate develops, and by their circumference are closely connected in front to the anterior, and behind to the posterior common ligament; whilst in the thoracic region they are connected laterally, by means of the interarticular ligament, to the heads of those ribs which articulate with two vertebrae; they, consequently, form part of the articular cavities in which the heads of these bones are received.

**Structure of the Intervertebral Substance.**—The outer portion of the intervertebral substance is composed of many layers of fibrous connective tissue. This enveloping portion is called the *annulus fibrosus*. The central portion of the disk is composed of soft, pulpy, highly elastic fibro-cartilage, containing some bands of connective tissue. It is called the *nucleus pulposus*, is of a yellowish color, and rises up considerably above the surrounding level when the disk is divided horizontally. This pulpy substance, which is especially well developed in the lumbar region, is the remains of the chorda dorsalis, and, according to Luschka, contains a small synovial cavity in its centre. The outer layers of the disk are arranged concentrically one within the other, the outermost consisting of ordinary fibrous tissue, but the others and more numerous consisting of white fibro-cartilage. These plates are not quite vertical in their direction, those near the circumference being curved outward and closely approximated; whilst those nearest the centre curve in the opposite direction, and are somewhat more widely separated. The fibres of which each plate is composed are directed, for the most part, obliquely from above downward, the fibres of adjacent plates passing in opposite directions and varying in every layer; so that the fibres of one layer are directed across those of another, like the limbs of the letter X. This laminar arrangement belongs to about the outer half of each disk. The pulpy substance presents no concentric arrangement, and consists of a fine fibrous matrix, containing angular cells, united to form a

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*Fig. 197.—Median section of a piece of the lumbar spinal column, right half of sections viewed from the left. (Spalteholz.)*
reticular structure. J. Bland Sutton\(^1\) calls attention to the fact that in the human foetus a transverse ligamentous band crosses the dorsal aspect of the intervertebral disk and is continuous with the interosseous ligaments of the heads of the ribs; and also that a foetal ligamentous band exists in the ventral surface of the intervertebral disk which, after development, becomes the middle fasciculus of the stellate ligament. These bands are named by Sutton the \textit{posterior conjugal ligaments} and the \textit{anterior conjugal ligaments}.

\textbf{Interneural Articulations} include the ligaments of the \textit{laminæ}; articular processes, spinous processes, and transverse processes.

\section*{2. Ligaments connecting the Laminae.}

\textbf{Ligamenta Subflava.}

The \textbf{Ligamenta Subflava} (\textit{ligamenta flava, ligamenta intereruralia}) (Figs. 197 and 198) are interposed between the \textit{laminæ} of the vertebrae, from the axis to the sacrum. They are most distinct when seen from the interior of the spinal canal; when viewed from the outer surface they appear short, being overlapped by the \textit{laminæ}. Each ligamentum subflavum consists of two lateral portions, which commence on each side at the root of either articular process, and pass backward to the point where the \textit{laminæ} converge to form the spinous process, where their \textit{margins} are in contact and to a certain extent united; slight intervals being left for the passage of small vessels. These ligaments consist of yellow elastic tissue, the fibres of which, almost perpendicular in direction, are attached to the anterior surface of the \textit{laminæ} above, some distance from its inferior margin, and to the posterior surface, as well as to the margin of the lamina below. In the cervical region they are thin in texture, but very broad and long; they become thicker in the thoracic region, and in the lumbar acquire very considerable thickness. Their highly elastic property serves to preserve the upright posture and to assist in resuming it after the spine has been flexed. These ligaments do not exist between the occiput and atlas or between the atlas and axis.

\section*{3. Ligaments connecting the Articular Processes.}

\textbf{Capsular Ligaments.}

The \textbf{Capsular Ligaments} \textit{(capsulae articulares)} (Fig. 199) are thin and loose ligamentous sacs, attached to the contiguous margins of the articulating processes of each vertebra through the greater part of their circumference, and completed internally by the ligamenta

\footnote{1 J. Bland Sutton. \textit{Ligaments: Their Nature and Morphology}.}
ARTICULATIONS OF THE VERTEBRAL COLUMN

subflava. They are longer and looser in the cervical than in the thoracic or lumbar regions. The capsular ligaments are lined on their inner surface by synovial membrane.

4. Ligaments connecting the Spinous Processes.

Supraspinous Ligament. Interspinous Ligaments.

The Supraspinous Ligament (ligamentum supraspinale) (Fig. 197) is a strong fibrous cord, which connects together the apices of the spinous processes from the seventh cervical to the spinous processes of the sacrum. It is thicker and broader in the lumbar than in the thoracic region, and intimately blended, in both situations, with the neighboring aponeurosis. The most superficial fibres of this ligament connects three or four vertebrae; those deeper-seated pass between two or three vertebrae; whilst the deepest connect the contiguous extremities of neighboring vertebrae. It is continued upward to the external occipital protuberance as the ligamentum nuchae, which, in the human subject, is thin and forms merely an intermuscular septum.

The Interspinous Ligaments (ligamenta interspinalia) (Fig. 197), thin and membranous, are interposed between the spinous processes. Each ligament extends from the root to the summit of each spinous process and connects together their adjacent margins. They meet the ligamenta subflava in front and the supraspinous ligament behind. They are narrow and elongated in the thoracic region; broader, quadrilateral in form, and thicker in the lumbar region; and only slightly developed in the neck.

5. Ligaments connecting the Transverse Processes.

Intertransverse Ligaments.

The Intertransverse Ligaments (ligamenta intertransversaria) (Fig. 210) consist of bundles of fibres interposed between the transverse processes. In the cervical region they consist of a few irregular, scattered fibres; in the thoracic, they are rounded cords intimately connected with the deep muscles of the back; in the lumbar region they are thin and membranous.

Actions.—The movements permitted in the spinal column are, flexion, extension, lateral movement, circumduction, and rotation.

In flexion (forward flexion), or movement of the spine forward, the anterior common ligament is relaxed, and the intervertebral substances are compressed in front, while the posterior common ligament, the ligamenta subflava, and the inter- and supra-spinous ligaments are stretched, as well as the posterior fibres of the intervertebral disks. The interspaces between the laminae are widened, and the inferior articular processes of the vertebrae above glide upward upon the articular processes of the vertebrae below. Flexion is the most extensive of all the movements of the spine.

In extension (backward flexion), or movement of the spine backward, an exactly opposite disposition of the parts takes place. This movement is not extensive, being limited by the anterior common ligament and by the approximation of the spinous processes.

Flexion and extension are free in the lower part of the lumbar region between the third and fourth and fourth and fifth lumbar vertebrae; above the third they are much diminished, and reach their minimum in the middle and upper part of the back. They increase again in the neck, the capability of motion backward from the upright position being in this region greater than that of the motion forward, whereas in the lumbar region the reverse is the case.

In lateral flexion, the sides of the intervertebral disks are compressed, the extent of motion being limited by the resistance offered by the surrounding liga-
ments and by the approximation of the transverse processes. This movement may take place in any part of the spine, but is most free in the neck and loins.

Circumduction is very limited, and is produced merely by a succession of the preceding movements.

Rotation is produced by the twisting of the intervertebral substances; this, although only slight between any two vertebrae, produces a considerable extent of movement when it takes place in the whole length of the spine, the front of the upper part of the column being turned to one or the other side. This movement takes place only to a slight extent in the neck, but is freer in the upper part of the thoracic region, and is altogether absent in the lumbar region.

It is thus seen that the cervical region enjoys the greatest extent of each variety of movement, flexion and extension, especially being very free. In the thoracic region the three movements of flexion, extension, and circumduction are permitted only to a slight extent, while rotation is very free in the upper part and ceases below. In the lumbar region there is free flexion, extension, and lateral movement, but no rotation.

As Sir George Humphry has pointed out, the movements permitted are mainly due to the shape and position of the articulating processes. In the loins the inferior articulating processes are turned outward and are embraced by the superior; this renders rotation in this region of the spine impossible, while there is nothing to prevent a sliding upward and downward of the surfaces on each other, so as to allow of flexion and extension. In the thoracic region, on the other hand, the articulating processes, by their direction and mutual adaptation, especially at the upper part of the series, permit of rotation, but prevent extension and flexion, while in the cervical region the greater obliquity and lateral slant of the articular processes allow not only flexion and extension, but also rotation.

The principal muscles which produce flexion are the Sterno-mastoid, Rectus capitis anticus major, and Longus colli; the Scaleni; the abdominal muscles and the Psoas magnus. Extension is produced by the fourth layer of the muscles of the back, assisted in the neck by the Splenius, Semispinalis dorsi et colli, and the Multifidus spinae. Lateral motion is produced by the fourth layer of the muscles of the back, by the Splenius and the Scaleni, the muscles of one side only acting; and rotation by the action of the following muscles of one side only—viz. the Sterno-mastoid, the Rectus capitis anticus major, the Scaleni, the Multifidus spinae, the Complexus, and the abdominal muscles.

II. Articulation of the Atlas with the Axis (Articulatio Atlantoepistrophica).

The articulation of the atlas with the axis is of a complicated nature, comprising no fewer than four distinct joints. There is a pivot articulation between the odontoid process of the axis and the ring formed between the anterior arch of the atlas and the transverse ligament (see Fig. 201). Here there are two joints: one in front between the posterior surface of the anterior arch of the atlas and the front of the odontoid process, the atlanto-odontoid joint of Cruveilhier; the other between the anterior surface of the transverse ligament and the back of the process, the syndesmo-odontoid joint. Between the articular processes of the two bones there is a double arthrodia or gliding joint. The ligaments which connect these bones are the

Anterior Atlanto-axial. Transverse.
Posterior Atlanto-axial. Two Capsular.

The Anterior Atlanto-axial or the Anterior Atlo-axoid Ligament (Figs. 199 and 203) is a strong, membranous layer, attached, above, to the lower border of the anterior arch of the atlas; below, to the base of the odontoid process and to the front of
the body of the axis. It is strengthened in the middle line by a rounded cord, which is attached, above, to the tubercle on the anterior arch of the atlas, and below to the body of the axis, being a continuation upward of the anterior common ligament of the spine. Some anatomists regard this ligament as being a part of the anterior common ligament. The ligament is in relation, in front, with the Recti antici majores.

The Posterior Atlanto-axial or the Posterior Atlo-axoid Ligament (Figs. 200 and 203) is a broad and thin membranous layer, attached, above, to the lower border of the posterior arch of the atlas; below, to the upper edge of the laminae of the axis. This ligament supplies the place of the ligamenta subflava, and is in relation, behind, with the Inferior oblique muscles.

The Transverse Ligament of the Atlas1 (ligamentum transversum atlantis) (Figs. 201, 202, and 203) is a thick, strong band, which arches across the ring of the atlas, and serves to retain the odontoid process in firm connection with its anterior arch. This ligament is flattened from before backward, broader and thicker in the middle than at either extremity, and firmly attached on each side to a small tubercle on the inner surface of the lateral mass of the atlas. As it crosses the odontoid process, a small fasciculus is derived from its upper, and another from its lower, border; the former passing upward, to be inserted into the anterior sur-

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1 It has been found necessary to describe the transverse ligament with those of the atlas and axis; but the student must remember that it is really a portion of the mechanism by which the movements of the head on the spine are regulated; so that the connections between the atlas and axis ought always to be studied together with those between the latter bones and the skull.—Ed. of 16th English Edition.
ring of the atlas into two unequal parts: of these, the posterior and larger serves for the transmission of the cord and its membranes and the accessory nerves; the anterior and smaller contains the odontoid process. Since the space between the anterior arch of the atlas and the transverse ligament is smaller at the lower part than the upper (because the transverse ligament embraces tightly the narrow neck of the odontoid process), this process is retained in firm connection with the atlas after all the other ligaments have been divided.

The Capsular Ligaments (capsulae articulares) (Figs. 199, 200, and 202) are two thin and loose capsules, connecting the lateral masses of the atlas with the superior articular surfaces of the axis, the fibres being strengthened at the posterior and inner part of each articulation by an accessory ligament, which is attached below to the body of the axis near the base of the odontoid process.

Synovial Membranes (Fig. 201).—There are four synovial membranes in this articulation: one lining the inner surface of each of the capsular ligaments; one between the anterior surface of the odontoid process and the anterior arch of the atlas, the atlanto-odontoid joint; and one between the posterior surface of the odontoid process and the transverse ligament, the syndesmo-odontoid joint. The latter often communicates with those between the condyles of the occipital bone and the articular surfaces of the atlas.

Actions.—This joint allows the rotation of the atlas (and, with it, of the cranium) upon the axis, the extent of rotation being limited by the odontoid ligaments.

The principal muscles by which this action is produced are the Sterno-mastoid and Complexus of one side, acting with the Rectus capitis anticus major, Sple-nius, Trachelo-mastoid, Rectus capitis posticus major, and Inferior oblique of the other side.

ARTICULATIONS OF THE SPINE WITH THE CRANIUM.

The ligaments connecting the spine with the cranium may be divided into two sets—those connecting the occipital bone with the atlas, and those connecting the occipital bone with the axis.

III. Articulation of the Atlas with the Occipital Bone (Articulatio Atlantooccipitalis).

This articulation is a double condyloid joint. Its ligaments are the

Anterior Occipito-atlantal. Posterior Occipito-atlantal.

Two Capsular.

The Anterior Occipito-atlantal Ligament or Membrane (membrana atlantooccipitalis anterior, anterior occipito-atloid ligament) (Figs. 199 and 203) is a broad membranous layer, composed of densely woven fibres, which passes between the anterior margin of the foramen magnum above, and the whole length of the upper border of the anterior arch of the atlas below. Laterally, it is continuous with the capsular ligaments. In the middle line in front it is strengthened by a strong, narrow, rounded cord, which is attached, above, to the basilar process of the occiput, and, below, to the tubercle on the anterior arch of the atlas, and which is a continuation of the anterior common ligament. This ligament is in relation, in front, with the Recti anteci minores; behind, with the odontoid ligaments.

The Posterior Occipito-atlantal Ligament or Membrane (membrana atlantooccipitalis posterior, posterior occipito-atloid ligament) (Figs. 200 and 203) is a very broad but thin membranous lamina intimately blended with the dura. It is connected, above, to the posterior margin of the foramen magnum; below, to the upper border
ARTICULATION OF THE ATLAS WITH THE OCCIPITAL BONE

of the posterior arch of the atlas. This ligament is incomplete at each side, and forms, with the superior intervertebral notch, an opening for the passage of the vertebral artery and suboccipital nerve. The fibrous band which arches over the artery and nerve sometimes becomes ossified. The ligaments are in relation, behind, with the Recti postici minores and Obliqui superiores; in front, with the dura of the spinal canal, to which they are intimately adherent.

The Capsular Ligaments \(\text{(capsulae articulares)}\) (Fig. 202) surround the condyles of the occipital bone, and connect them with the articular processes of the atlas; they consist of thin and loose capsules, which enclose the synovial membranes of the articulations.

Synovial Membranes.—There are two synovial membranes in this articulation, one lining the inner surface of each of the capsular ligaments. These occasionally communicate with that between the posterior surface of the odontoid process and the transverse ligament.

Actions.—The movements permitted in this joint are flexion and extension, which give rise to the ordinary forward and backward nodding of the head. Slight lateral motion to one or the other side may also take place. When either of these actions is carried beyond a slight extent, the whole of the cervical portion of the spine assists in its production. *Flexion* is mainly produced by the action of the Rectus capitis anticus major et minor and the Sterno-mastoid muscles; *extension* by the
Rectus capitis posticus major et minor, the Superior oblique, the Complexus, Speleni us, and upper fibres of the Trapezius. The Recti laterales are concerned in the lateral movement, assisted by the Trapezius, Spelenius, Complexus, and the Sternomastoid of the same side, all acting together. According to Cruveilhier, there is a slight motion of rotation in this joint.

IV. Articulation of the Axis with the Occipital Bone.

The ligaments of this articulation are the

Occipito-axial. Three Odontoid.

To expose these ligaments the spinal canal should be laid open by removing the posterior arch of the atlas, the laminae and spinal process of the axis, and the portion of the occipital bone behind the foramen magnum, as seen in Fig. 193.

The Posterior Occipito-axial Ligament (posterior occipito-axoid ligament, membrana tectoria, apparatus ligamentosus colli) (Figs. 202 and 203) is situated within the spinal canal. It is a broad, strong band, which covers the odontoid process and its ligaments, and appears to be a prolongation upward of or a membrane due to fusion with the posterior common ligament of the spine. It is attached, below, to the posterior surface of the body of the axis, and, becoming expanded as it ascends, is inserted into the basilar groove of the occipital bone, in front of the foramen magnum, where it becomes blended with the dura of the skull.

**Fig. 202.**—Occipito-axial and atlanto-axial ligaments. Posterior view, obtained by removing the arches of the vertebrae and the posterior part of the skull.

**Relations.**—By its anterior surface with the transverse ligament; by its posterior surface with the posterior common ligament.

The Lateral Odontoid or Check Ligaments (ligamenta alaria) (Figs. 202 and 203) are strong, rounded, fibrous cords, which arise one on either side of the upper part of the odontoid process, and, passing obliquely upward and outward, are inserted into the rough depressions on the inner side of the condyles of the
ARTICULATION OF THE AXIS WITH THE OCCIPITAL BONE 281

occipital bone. In the triangular interval left between these ligaments another strong fibrous cord, ligamentum suspensorium, or middle odontoid ligament (ligamentum apicis dentis), may be seen, which passes almost perpendicularly from the apex of the odontoid process to the anterior margin of the foramen magnum, being intimately blended with the deep portion of the anterior occipito-atlantal ligament and upper fasciculus of the transverse ligament of the atlas.

Actions.—The odontoid ligaments serve to limit the extent to which rotation of the cranium may be carried; hence, they have received the name of check ligaments.

In addition to these ligaments, which connect the atlas and axis to the skull, the ligamentum nuchae must be regarded as one of the ligaments by which the spine is connected with the cranium. It is described on page 275.

Surgical Anatomy.—The ligaments which unite the component parts of the vertebrae together are so strong, and these bones are so interlocked by the arrangement of their articulating processes, that dislocation is very uncommon, and, indeed, unless accompanied by fracture, seldom occurs, except in the upper part of the neck. Dislocation of the occiput from the atlas has only been recorded in one or two cases; but dislocation of the atlas from the axis, with rupture of the transverse ligament, is much more common; it is the mode in which death is produced in many cases of execution by hanging. Occipito-atloid dislocation is certainly fatal. Recoveries are on record after atlo-axoid dislocation. Immediate death occurs if the transverse ligament is torn or the odontoid process is broken. In the lower part of the neck—that is, below the third cervical vertebra—dislocation unattended by fracture occasionally takes place.

Fig. 203.—Median section through the occipital bone and first three cervical vertebrae with ligaments. (Spalteholz.)
V. Articulation of the Lower Jaw, or the Temporo-mandibular Articulation (Articulatio Mandibularis).

This is a ginglymo-arthrodial joint: the parts entering into its formation on each side are, above, the anterior part of the glenoid cavity of the temporal bone and the eminentia articularis; and, below, the condyle of the lower jaw. The ligaments are the following:

- External Lateral
- Internal Lateral
- Stylo-mandibular
- Capsular
- Interarticular Fibro-cartilage

The External Lateral Ligament (ligamentum temporomandibulare) (Fig. 204) is a short, thin, and narrow fasciculus, attached, above, to the outer surface of the zygoma and to the tubercle on its lower border; below, to the outer surface and posterior border of the neck of the lower jaw. It is broader above than below; its fibres are placed parallel with one another, and directed obliquely downward and backward. Externally, it is covered by the parotid gland and by the integument. Internally it is in relation with the capsular ligament, of which it is an accessory band, and from which it is not separable.

The Internal Lateral Ligament (ligamentum sphenomandibulare) (Fig. 205) is a flat, thin band which is attached above to the spinous process of the sphenoid bone, and, becoming broader as it descends, is inserted into the margin of the mandibular or dental foramen and the portion of bone, the lingula, which overhangs the foramen in front. Its outer surface is in relation, above, with the External pterygoid muscle; lower down it is separated from the neck of the condyle by the internal maxillary artery; and still more inferiorly, the inferior dental vessels and nerve separate it from the ramus of the jaw. The inner surface is in relation with the Internal pterygoid. It is really the fibrous covering of a part of Meckel’s cartilage.
The **Stylo-mandibular** or **Stylo-maxillary Ligament** (*ligamentum stylomandibulare*) (Fig. 205) is a specialized band of the cervical fascia, which extends from near the apex of the styloid process of the temporal bone to the angle and posterior border of the ramus of the lower jaw, between the Masseter and Internal pterygoid muscles. This ligament separates the parotid from the submaxillary gland, and has attached to its inner side part of the fibres of origin of the Styloglossus muscle. Although usually classed among the ligaments of the jaw, it can be considered only as an accessory to the articulation.

The **Capsular Ligament** (*capsula articularis*) (Figs. 204 and 205) forms a thin and loose capsule, passing from the circumference of the glenoid cavity and the articular surface immediately in front to the upper margin of the articular disk, and from the lower margin of the articular disk to the neck of the condyle of the lower jaw. It consists of very thin fibres, and is complete. It forms two joint cavities, distinct from each other, and separated by the articular disk. So thin is it that it is hardly to be considered as a distinct ligament; it is thickest at the back part, and thinnest on the inner side of the articulation.1

The **Interarticular Fibro-cartilage** or **Meniscus** (*discus articularis*) (Fig. 206) is a thin plate of an oval form, placed horizontally between the condyle of the jaw and the glenoid cavity. Its upper surface is concavo-convex from before backward, and a little convex transversely, to accommodate itself to the form of the glenoid cavity. Its under surface, where it is in contact with the condyle, is concave. Its circumference is connected to the capsular ligament, and in front to the tendon of the External pterygoid muscle. It is thicker at its circumference, especially behind, than at its centre. The fibres of which it is composed have a concentric arrangement, more apparent at the circumference than at the centre. Its surfaces are smooth. It divides the joint into two cavities, each of which is furnished with a separate synovial membrane from the capsular ligament.

**Synovial Membranes** (Fig. 206).—The synovial membranes, two in number, are placed, one above, and the other below, the fibro-cartilage. The upper one, the larger and looser of the two, is continued from the margin of the cartilage covering

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1 Sir G. Humphry describes the internal portion of the capsular ligament separately as the short internal lateral ligament; and it certainly seems as deserving of a separate description as is the external lateral ligament.—Bo. of 15th English Edition.
the glenoid cavity and eminentia articularis on to the upper surface of the fibro-cartilage. The lower one passes from the under surface of the fibro-cartilage to the neck of the condyle of the jaw, being prolonged downward a little farther behind than in front. The interarticular cartilage is sometimes perforated in its centre; the two synovial sacs then communicate with each other.

The nerves of this joint are derived from the auriculo-temporal and masseteric branches of the inferior maxillary. The arteries are derived from the temporal branch of the external carotid.

Actions.—The movements possible in this articulation are very extensive. Thus, the jaw may be depressed or elevated, or it may be carried forward or backward. It must be borne in mind that there are two distinct joints in this articulation—that is to say, one between the condyle of the jaw and the interarticular fibro-cartilage, and another between the fibro-cartilage and the glenoid fossa; when the jaw is depressed, as in opening the mouth, the movements which take place in these two joints are not the same. In the lower compartment, that between the condyle and the fibro-cartilage, the movement is of a ginglymoid or hinge-like character, the condyle rotating on a transverse axis on the fibro-cartilage; while in the upper compartment the movement is of a gliding character, the fibro-cartilage, together with the condyle, gliding forward on to the eminentia articularis. These two movements take place simultaneously—the condyle and fibro-cartilage move forward on the eminence, and at the same time the condyle revolves on the fibro-cartilage. In the opposite movement of shutting the mouth the reverse action takes place; the fibro-cartilage glides back, carrying the condyle with it, and this at the same time revolves back to its former position. When the jaw is carried horizontally forward, as in protruding the lower incisors in front of the upper, the movement takes place principally in the upper compartment of the joint: the fibro-cartilage, carrying with it the condyle, glides forward on the glenoid fossa. This is because this movement is mainly effected by the External pterygoid muscles, which are inserted into both condyle and interarticular fibro-cartilage. The grinding or chewing movement is produced by the alternate movement of one condyle, with its fibro-cartilage, forward and backward, while the other condyle moves simultaneously in the opposite direction; at the same time the condyle undergoes a vertical rotation on its own axis on the fibro-cartilage in the lower compartment. One condyle advances and rotates, the other condyle recedes and rotates, in alternate succession.

The lower jaw is depressed by its own weight, assisted by the Platysma, the Digastric, the Mylo-hyoid, and the Genio-hyoid muscles. It is elevated by the anterior part of the Temporal, Masseter, and Internal pterygoid. It is drawn forward by the simultaneous action of the External pterygoid and the superficial fibres of the Masseter; and it is drawn backward by the deep fibres of the Masseter and the posterior fibres of the Temporal muscle. The grinding movement is caused by the alternate action of the two External pterygoids.

Surface Form.—The temporo-mandibular articulation is quite superficial, situated below the base of the zygoma, in front of the tragus and external auditory meatus, and behind the posterior border of the upper part of the Masseter muscle. Its exact position can be at once ascertained by feeling for the condyle of the jaw, the working of which can be distinctly felt in the movements of the lower jaw in opening and shutting the mouth. When the mouth is opened wide, the condyle advances out of the glenoid fossa on to the eminentia articularis, and a depression is felt in the situation of the joint.

Surgical Anatomy.—Genuine dislocation of the lower jaw is almost always forward. Croker King and Theim, however, have reported posterior displacement. Dislocation is caused by violence or muscular action. When the mouth is open, the condyle is situated on the eminentia articularis, and any sudden violence, or even a sudden muscular spasm, as during a convulsive yawn, may displace the condyle forward into the zygomatic fossa. The displacement may be unilateral or bilateral, according as one or both of the condyles is displaced. The latter of
the two is the more common. The interarticular fibro-cartilage adheres to the condyle till it passes over the eminentia articularis, but at this point remains behind.

Sir Astley Cooper described a condition which he termed "subluxation." It occurs principally in delicate women, and is believed by some to be due to the relaxation of the ligaments, permitting too free movement of the bone. Others believe it is due to displacement of the interarticular fibro-cartilage. Still others attribute the symptoms to gouty or rheumatic changes in the joint. In close relation to the condyle of the jaw is the external auditory meatus and the tympanum; any force, therefore, applied to the bone is liable to be attended with damage to these parts, or inflammation in the joint may extend to the ear, or on the other hand inflammation of the middle ear may involve the articulation and cause its destruction, thus leading to ankylosis of the joint. In children, arthritis of this joint may follow the exanthema, and in adults it occurs as the result of some constitutional conditions, as rheumatism or gout. The temporomandibular joint is also occasionally the seat of osteo-arthritis, leading to great suffering during efforts of mastication. A peculiar affection sometimes attacks the neck and condyle of the lower jaw, consisting in hypertrophy and elongation of these parts and consequent protrusion of the chin to the opposite side.

VI. Articulations of the Ribs with the Vertebrae or the Costco-vertebral Articulations (Articulationes Costovertebrales).

The articulations of the ribs with the vertebral column may be divided into two sets: 1. Those which connect the heads of the ribs with the bodies of the vertebrae; costo-central. 2. Those which connect the necks and tubercles of the ribs with the transverse processes; costo-transverse.

1. Articulations between the Heads of the Ribs and the Bodies of the Vertebrae or the Costco-central Articulations (Articulationes Capitulorum) (Figs. 207 and 208).

These constitute a series of arthrodial joints, formed by the articulation of the heads of the ribs with the cavities on the contiguous margins of the bodies of the
thoracic vertebrae and the intervertebral substance between them, except in the case of the first, tenth, eleventh, and twelfth ribs, where the cavity is formed by a single vertebra. The bones are connected by the following ligaments:

Anterior Costo-vertebral or Stellate.
Capsular.
Interarticular.

The Anterior Costo-vertebral or Stellate Ligament (ligamentum capituli costae radiatum) (Figs. 207 and 210) connects the anterior part of the head of each rib with the sides of the bodies of two vertebrae and the intervertebral disk between them. It consists of three flat bundles of ligamentous fibres, which are attached to the anterior part of the head of the rib, just beyond the articular surface. The superior fibres pass upward to be connected with the body of the vertebra above; the inferior one descends to the body of the vertebra below; and the middle one, the smallest and least distinct, passes horizontally inward, to be attached to the intervertebral substance.

Relations.—In front, with the thoracic ganglia of the sympathetic, the pleura, and, on the right side, with the vena azygos major; behind, with the interarticular ligament and synovial membranes.

On the first rib, which articulates with a single vertebra, this ligament does not present a distinct division into three fasciculi; its fibres, however, radiate, and are attached to the body of the last cervical vertebra, as well as to the body of the vertebra with which the rib articulates. In the tenth, eleventh, and twelfth ribs also, which likewise articulate with a single vertebra, the division does not exist; but the fibres of the ligament in each case radiate and are connected with the vertebra above, as well as that with which the ribs articulate.

The Capsular Ligament (capsula articularis) is a thin and loose ligamentous bag, which surrounds the joint between the head of the rib and the articular cavity formed by the intervertebral disk and the adjacent vertebra. It is very thin, firmly connected with the anterior ligament, and most distinct at the upper and lower parts of the articularation. Behind, some of its fibres pass through the intervertebral foramen to the back of the intervertebral disk. This is the analogue of the ligamentum conjugale of some mammals, which unites the heads of opposite ribs across the back of the intervertebral disk.

The Interarticular Ligament (ligamentum capituli costae interarticulare) (Figs. 208 and 209) is situated in the interior of the joint. It consists of a short band of fibres, flattened from above downward, attached by one extremity to the sharp crest which separates the two articular facets on the head of the rib, and by the other to the intervertebral disk. It divides the joint into two cavities, which have no communication with each other. In the first, tenth, eleventh, and
twelfth ribs the interarticular ligament does not exist; consequently there is but one synovial membrane.

**Synovial Membranes** (Figs. 208 and 209).—There are two synovial membranes in each of the articulations in which there is an interarticular ligament, one on each side of this structure.

**2. Articulations of the Necks and Tubercles of the Ribs with the Transverse Processes or the C**osto-transverse **Articulations** (Articulationes costotransversariae) (Fig. 209).

The articular portion of the tubercle of the rib and adjacent transverse process form an arthrodial joint.

In the eleventh and twelfth ribs this articulation is wanting.

The ligaments connecting these parts are the

Anterior Superior Costa-transverse. Posterior Costa-transverse

Middle Costa-transverse (Interosseous). Capsular.

The **Anterior Superior or Long Costa-transverse Ligament** (ligamentum costotransversarium anterius) (Figs. 207, 208, 209, and 210) consists of two sets of fibres: the one (anterior) is attached below to the sharp crest on the upper border

![Fig. 209.---Costo-transverse articulation. Seen from above.](image)

of the neck of each rib, and passes obliquely upward and outward to the lower border of the transverse process immediately above; the other (posterior) is attached below to the neck of the rib, and passes upward and inward to the base of the transverse process and outer border of the lower articular process of the vertebra above. This ligament is in relation, in front, with the intercostal vessels and nerves; behind, with the Longissimus dorsi muscle. Its internal border is thickened and free, and bounds an aperture through which pass the posterior branches of the intercostal vessels and nerves. Its external border is continuous with a thin aponeurosis which covers the External intercostal muscle.

The **first rib** has no anterior costo-transverse ligament. In the twelfth rib the ligament is absent or is a mere vestige.
The Middle Costo-transverse or Interosseous Ligament (ligamentum colli costae) (Fig. 209) consists of short but strong fibres which pass between the rough surface on the posterior part of the neck of each rib and the anterior surface of the adjacent transverse process. In order fully to expose this ligament, a horizontal section should be made across the transverse process and corresponding part of the rib; or the rib may be forcibly separated from the transverse process and the fibres of the ligament put on the stretch.

In the eleventh and twelfth ribs this ligament is quite rudimentary or wanting.

The Posterior Costo-transverse Ligament (ligamentum costotransversarium posteriorius) (Fig. 209) is a short but thick and strong fasciculus which passes obliquely from the summit of the transverse process to the rough non-articular portion of the tubercle of the rib. This ligament is shorter and more oblique in the upper than in the lower ribs. Those corresponding to the superior ribs ascend, while those of the inferior ribs descend slightly.

In the eleventh and twelfth ribs this ligament is wanting.

The Capsular Ligament (capsula articularis) is a thin, membranous sac attached to the circumference of the articular surfaces, and enclosing a small synovial membrane.

In the eleventh and twelfth ribs this ligament is absent.

Actions.—The heads of the ribs are so closely connected to the bodies of the vertebrae by the stellate and interarticular ligaments, and the necks and tubercles of the ribs to the transverse processes, that only a slight sliding movement of the articular surfaces on each other can take place in these articulations. The result of this gliding movement with respect to the six upper ribs consists in an elevation of the front and middle portion of the rib, the hinder part being prevented from performing any upward movement by its close connection with the spine. In this gliding movement the rib rotates on an axis corresponding with a line drawn through the two articulations, costo-central and costo-transverse, which the rib forms with the spine. With respect to the seventh, eighth, ninth, and tenth ribs, each one, besides rotating in a similar manner to the upper six, also rotates on an axis corresponding with a line drawn from the head of the rib to the sternum. By the first movement—that of rotation of the rib on an axis corresponding with a line drawn through the two articulations which this bone forms with the spine—an elevation of the anterior part of the rib takes place, and a consequent enlargement of the antero-posterior diameter of the chest. None of the ribs lie in
ARTICULATION OF CARTILAGES OF RIBS WITH STERNUM 289

a truly horizontal plane; they are all directed more or less obliquely, so that their anterior extremities lie on a lower level than their posterior, and this obliquity increases from the first to the seventh, and then again decreases. If we examine any one rib—say, that in which there is the greatest obliquity—we shall see that it is obvious that as its sternal extremity is carried upward, it must also be thrown forward; so that the rib may be regarded as a radius moving on the vertebral joint as a centre, and causing the sternal attachment to describe an arc of a circle in the vertical plane of the body. Since all the ribs are oblique and connected in front to the sternum by the elastic costal cartilages, they must have a tendency to thrust the sternum forward, and so increase the antero-posterior diameter of the chest. By the second movement—that of the rotation of the rib on an axis corresponding with a line drawn from the head of the rib to the sternum—an elevation of the middle portion of the rib takes place, and consequently an increase in the transverse diameter of the chest. For the ribs not only slant downward and forward from their vertebral attachment, but they are also oblique in relation to their transverse plane—that is to say, their middle is on a lower level than either their vertebral or sternal extremities. It results from this that when the ribs are raised, the centre portion is thrust outward, somewhat after the fashion in which the handle of a bucket is thrust away from the side when raised to a horizontal position, and the lateral diameter of the chest is increased (see Fig. 211). The mobility of the different ribs varies very much. The first rib is more fixed than the others, on account of the weight of the upper extremity and the strain of the ribs beneath; but on the freshly dissected thorax it moves as freely as the others. From the same causes the movement of the second rib is also not very extensive. In the other ribs this mobility increases successively down to the last two, which are very movable. The ribs are generally more movable in the female than in the male.

VII. Articulation of the Cartilages of the Ribs with the Sternum, etc., or the Costco-sternal Articulations (Articulationes Sternocostales) (Fig. 212).

The articulations of the cartilages of the true ribs with the sternum are arthrodial joints, with the exception of the first, in which the cartilage is almost always
directly united with the sternum, and which must therefore be regarded as a synarthrodial articulation. The ligaments connecting them are the

Anterior Chondro-sternal. Capsular.
Posterior Chondro-sternal. Interarticular Chondro-sternal.
Chondro-xiphoïd.

The **Anterior Chondro-sternal** or **Sterno-costal Ligament** (ligamentum sternocostale radiatum) (Fig. 212) is a broad and thin membranous band that radiates from the front of the inner extremity of the cartilages of the true ribs to the anterior surface of the sternum. It is composed of fasciculi which pass in different directions. The **superior fasciculi** ascend obliquely, the **inferior fasciculi** pass obliquely downward, and the **middle fasciculi** pass horizontally. The superficial fibres of this ligament are the longest: they intermingle with the fibres of the ligaments above and below them, with those of the opposite side, and with the tendinous fibres of origin of the Pectoralis major, forming a thick fibrous membrane which covers the surface of the sternum (membrana sterni). This is more distinct at the lower than at the upper part. According to the modern nomenclature, this ligament and the posterior chondro-sternal ligament are called **ligamenta sternocostalia radiata**. The two chondro-sternal ligaments form a sheath for the sternum anteriorly and posteriorly, the **membrana sterni**.

The **Posterior Chondro-sternal** or **Sterno-costal Ligament** (ligamentum sternocostale radiatum), less thick and distinct than the anterior, is composed of fibres which radiate from the posterior surface of the sternal end of the cartilages of the true ribs to the posterior surface of the sternum, becoming blended with the periosteum.

The **Capsular Ligament** (capsula articularis) surrounds the joint formed between the cartilage of a true rib and the sternum. It is very thin, intimately blended with the anterior and posterior ligaments, and strengthened at the upper and lower part of the articulation by a few fibres which pass from the cartilage to the side of the sternum. These ligaments protect the synovial membranes.

The **Interarticular Chondro-sternal** or **Sterno-costal Ligament** (ligamentum sternocostale interarticulare) (Fig. 212).—This is found between the second costal cartilage and the sternum. The cartilage of the second rib is connected with the sternum by means of an interarticular ligament attached by one extremity to the cartilage of the second rib, and by the other extremity to the cartilage which unites the first and second pieces of the sternum. This articulation is provided with two synovial membranes. The cartilage of the third rib is also connected with the sternum by means of an interarticular ligament which is attached by one extremity to the cartilage of the third rib, and by the other extremity to the point of junction of the second and third pieces of the sternum. This articulation may be provided with two synovial membranes. In the other joints interarticular ligaments may exist, but they rarely completely divide the joint into two cavities.

The **Anterior Chondro-xiphoïd** or **Costo-xiphoïd Ligament** (ligamentum costo-xiphoïdes) (Fig. 212).—This is a band of ligamentous fibres which connects the anterior surface of the seventh costal cartilage, and occasionally also that of the sixth, to the anterior surface of the ensiform appendix. It varies in length and breadth in different subjects. A similar band of fibres on the internal or posterior surface, though less thick and distinct, may be demonstrated. It is spoken of as the **posterior chondro-xiphoïd** or **costo-xiphoïd ligament**.

**Synovial Membranes** (Fig. 212).—There is no synovial membrane between the first costal cartilage and the sternum, as this cartilage is directly continuous with the sternum. There are two synovial membranes, both in the articulation of the second and third costal cartilages to the sternum. There is generally one synovial membrane in each of the joints between the fourth, fifth, sixth, and seventh
ARTICULATION OF CARTILAGES OF RIBS WITH STERNUM

Costal cartilages to the sternum; but it is sometimes absent in the sixth and seventh chondro-sternal joints. Thus there are usually eight synovial cavities on each side in the articulations between the costal cartilages of the true ribs and the sternum. After middle life the articular surfaces lose their polish, become

roughened, and the synovial membranes appear to be wanting. In old age the articulations do not exist, the cartilages of most of the ribs becoming continuous with the sternum.

Actions.—The movements which are permitted in the chondro-sternal articulations are limited to elevation and depression, and these only to a slight extent.

Articulations of the Cartilages of the Ribs with Each Other or the Interchondral Articulations (articulationes interchondrales) (Fig. 212).—The con-
tiguous borders of the sixth, seventh, and eighth, and sometimes the ninth and tenth, costal cartilages articulate with each other by small, smooth, oblong-shaped facets. Each articulation is enclosed in a thin capsular ligament lined by synovial membrane, and strengthened externally and internally by ligamentous fibres, external and internal interchondral ligaments (ligamenta intercostalia externa et interna), which pass from one cartilage to the other. Sometimes the fifth costal cartilage, more rarely that of the ninth, articulates, by its lower border, with the adjoining cartilage by a small oval facet; more frequently they are connected together by a few ligamentous fibres. Occasionally the articular surfaces above mentioned are wanting.

Articulations of the Ribs with their Cartilages or the Costo-chondral Articulations (Fig. 212).—The outer extremity of each costal cartilage is received into a depression in the sternal ends of the ribs, and the two are held together by the periosteum. There is no real joint. Occasionally a synovial membrane exists between the first rib and the corresponding cartilage.

VIII. Articulations of the Sternum (Fig. 212).

The first piece of the sternum is united to the second either by an amphiarthrodial joint—a single piece of true fibro-cartilage uniting the segments—or by a diarthrodial joint, in which each bone is clothed with a distinct lamina of cartilage, adherent on one side, free and lined with synovial membrane on the other. In the latter case the cartilage covering the gladiolus is continued without interruption on to the cartilages of the second ribs. Mr. Rivington has found the diarthrodial form of joint in about one-third of the specimens examined by him; Mr. Maisonneuve more frequently. It appears to be rare in childhood, and is formed, in Mr. Rivington's opinion, from the amphiarthrodial form by absorption. The diarthrodial joint seems to have no tendency to ossify at any age, while the amphiarthrodial is more liable to do so, and has been found ossified as early as thirty-four years of age. Professor Cunningham¹ says: "It is not usual to find the manubri-gladiolar joint obliterated by the ossification of the two bony segments. Even in advanced life it remains open, and the joint partakes of the nature of an amphiarthrosis, although a joint cavity is not found under any circumstances in the plate of fibro-cartilage which intervenes between the manubrium and the gladiolus." The two segments are further connected by an

Anterior Intersternal Ligament. Posterior Intersternal Ligament.

The Anterior Intersternal Ligament consists of a layer of fibres, having a longitudinal direction; it blends with the fibres of the anterior chondro-sternal ligaments on both sides (membrani sternalii), and with the tendinous fibres of origin of the Pectoralis major muscle. This ligament is rough, irregular, and much thicker below than above.

The Posterior Intersternal Ligament is disposed in a somewhat similar manner on the posterior surface of the articulation.

IX. Articulation of the Vertebral Column with the Pelvis.

The ligaments connecting the last lumbar vertebra with the sacrum are similar to those which connect the segments of the spine with each other—viz.: 1. The continuation downward of the anterior and posterior common ligaments. 2. The intervertebral substance connecting the flattened oval surfaces of the two bones.

¹ Text-book of Anatomy, p. 264.
and forming an amphiarthrodial joint. 3. Ligamenta subflava, connecting the arch of the last lumbar vertebra with the posterior border of the sacral canal. 4. Capsular ligaments connecting the articulating processes and forming a double arthrodia. 5. Inter- and supraspinous ligaments.

The two proper ligaments connecting the pelvis with the spine are the lumbo-sacral and ilio-lumbar.

The **Lumbo-sacral Ligament** (Fig. 213) is a short, thick, triangular fasciculus, which is connected above to the lower and front part of the transverse process of the last lumbar vertebra, passes obliquely outward, and is attached below to the lateral surface of the base of the sacrum. It is closely blended with the anterior sacro-iliac ligament and with the ilio-lumbar ligament, and is to be regarded as a portion of the ilio-lumbar ligament. This ligament is in relation, in front, with the Psoas muscle. The internal border of the lumbo-sacral ligament margins the foramen of the last lumbar nerve.

The **Ilio-lumbar Ligament** (ligamentum iliolumbale) (Fig. 213) passes horizontally outward from the apex of the transverse process of the last lumbar vertebra to the crest of the ilium immediately in front of the sacro-iliac articulation. It is of a triangular form, thick and narrow internally, broad and thinner externally. It is in relation, in front, with the Psoas muscle; behind, with the muscles occupying the vertebral groove; above, with the Quadratus lumborum. It blends in places with the lumbo-sacral ligament, and its crescentic inner margin marks the limit of the foramen for the fourth lumbar nerve. These ligaments are thick prolongations from the anterior layer of the lumbar fascia.
X. Articulations of the Pelvis.

The ligaments connecting the bones of the pelvis with each other may be divided into four groups: 1. Those connecting the sacrum and ilium. 2. Those passing between the sacrum and ischium. 3. Those connecting the sacrum and coccyx. 4. Those between the two pubic bones.

1. Articulation of the Sacrum and Ilium (Articulatio sacroiliaca.)

The sacro-iliac articulation is an amphiarthrodial joint, formed between the lateral surfaces of the sacrum and ilium. The anterior or auricular portion of each articular surface is covered with a thin plate of cartilage, thicker on the sacrum than on the ilium. These are in close contact with each other, and to a certain extent united together by irregular patches of softer fibro-cartilage, and at their upper and posterior part by fine fibres of interosseous fibrous tissue. Throughout a considerable part of their extent, especially in advanced life, they are not connected together, but are separated by a space containing a synovial-like fluid, and hence the joint presents the characters of a diarthrosis.

The ligaments connecting these surfaces are the


The Anterior Sacro-iliac Ligaments (ligamenta sacroiliaca anteriors) (Fig. 213) consists of numerous thin bands which connect the anterior surfaces of the sacrum and ilium.

The Posterior Sacro-iliac Ligament (ligamentum sacroiliacum posterius) (Fig. 214) is a strong interosseous ligament, situated in a deep depression between the sacrum and ilium behind, and forming the chief bond of connection between those bones. It consists of numerous strong fasciculi which pass between the bones in various directions. Three of these are of large size: the two superior fasciculi constitute the short sacro-iliac ligament (ligamentum sacroiliacum posterius breve). They are nearly horizontal in direction, arise from the first and second transverse tubercles on the posterior surface of the sacrum, and are inserted into the rough, uneven surface at the posterior part of the inner surface of the ilium. The third fasciculus, oblique in direction, is attached by one extremity to the third transverse tubercle on the posterior surface of the sacrum, and by the other to the posterior superior spine of the ilium; it is sometimes called the long or oblique sacro-iliac ligament (ligamentum sacroiliacum posterius longum).

The Interosseous Ligaments (ligamenta sacroiliaca interossea) are completely covered by the posterior sacro-iliac ligament, and are not visible when the joint is unopened. The fibres are short and run obliquely and completely fill the hollow which exists posterior to the joint.

The position of the sacro-iliac joint is indicated by the posterior superior spine of the ilium. This process is immediately behind the centre of the articulation.

2. Ligaments passing between the Sacrum and Ischium (Fig. 214).


The Great or Posterior Sacro-scatic Ligament (ligamentum sacrotuberosum) (Figs. 214 and 215) is situated at the lower and back part of the pelvis. It is flat, and triangular in form; narrower in the middle than at the extremities; attached by its broad base to the posterior inferior spine of the ilium, to the fourth and fifth trans-
verse tubercles of the sacrum, and to the lower part of the lateral margin of that bone and the coccyx. Passing obliquely downward, outward, and forward, it becomes narrow and thick, and at its insertion into the inner margin of the tuberosity of the ischium it increases in breadth, and is prolonged forward along the inner margin of the ramus, forming what is known as the falciform process of the great sacro-sciatic ligament or the falciform ligament (processus falciformis). The free concave edge of this prolongation has attached to it the obturator fascia, with which it forms a kind of groove, protecting the internal pudic vessels and nerve. One of its surfaces is turned toward the perinaeum, the other toward the Obturator internus muscle.

Fig. 214.—Articulations of pelvis and hip. Posterior view.

The posterior surface of this ligament gives origin, by its whole extent, to fibres of the Gluteus maximus muscle. Its anterior surface is united to the lesser sacro-sciatic ligament. Its external border forms, above, the posterior boundary of the great sacro-sciatic foramen, and, below, the posterior boundary of the lesser sacro-sciatic foramen. Its lower border forms part of the boundary of the perinaeum. It is pierced by the coccygeal branch of the sciatic artery and the coccygeal nerve.

The Lesser or Anterior Sacro-sciatic Ligament (ligamentum sacrospinosum) (Figs. 214 and 215), much shorter and smaller than the preceding, is thin, triangular in form, attached by its apex to the spine of the ischium, and internally, by its broad base, to the lateral margin of the sacrum and coccyx, anterior to the attachment of the great sacro-sciatic ligament, with which its fibres are intermingled.

It is in relation, anteriorly, with the Coccygeus muscle; posteriorly, it is covered by the great sacro-sciatic ligament and crossed by the internal pudic vessels and nerve. Its superior border forms the lower boundary of the great sacro-sciatic foramen; its inferior border, part of the lesser sacro-sciatic foramen.
These two ligaments convert the sacro-sciatic notches into foramina. The superior or great sacro-sciatic foramen (foramen ischiadicum majus) (Figs. 214 and 215) is bounded, in front and above, by the posterior border of the os innominatum; behind, by the great sacro-sciatic ligament; and below, by the lesser sacro-sciatic ligament. It is partially filled up, in the recent state, by the Pyriformis muscle, which passes through it. Above this muscle the gluteal vessels and superior gluteal nerve emerge from the pelvis, and, below it, the sciatic vessels and nerves, the internal pudic vessels and nerve, the inferior gluteal nerve, and the nerves to the obturator internus and quadratus femoris. The inferior or lesser sacro-sciatic foramen (foramen ischiadicum minus) (Figs. 214 and 215) is bounded, in front, by the

tuber ischi; above, by the spine and lesser sacro-sciatic ligament; behind, by the greater sacro-sciatic ligament. It transmits the tendon of the Obturator internus muscle, its nerve, and the internal pudic vessels and nerve.

3. Articulation of the Sacrum and Coccyx (Symphysi Sacrococcygea).

This articulation is an amphiarthrodial joint, formed between the oval surface at the apex of the sacrum and the base of the coccyx. It is analogous to the joints between the bodies of the vertebrae. The ligaments are the

Anterior Sacro-coccygeal. Lateral Sacro-coccygeal.

The Anterior Sacro-coccygeal Ligament (ligamentum sacrococcygeum anterius) consists of a few irregular fibres which descend from the anterior surface of the sacrum to the front of the coccyx, becoming blended with the periosteum. It is a continuation of the anterior common ligament.

The Posterior Sacro-coccygeal Ligament (ligamentum sacrococcygeum posterius) (Fig. 216) is divided into two portions, the deep and the superficial. The deep
Portion of the posterior sacro-coccygeal ligament (ligamentum sacro-coccygeum posterius profundum), which is a continuation of the posterior common ligament, is a flat band of a pearly tint, which arises from the margin of the lower orifice of the sacral canal, and descends to be inserted into the posterior surface of the coccyx. This ligament completes the lower and back part of the sacral canal. Its superficial fibres are much longer than the more deeply seated. This ligament is in relation, behind, with the Gluteus maximus.

The superficial portion of the posterior sacro-coccygeal ligament (ligamentum sacro-coccygeum posterius superficiale) is composed of longitudinal fibrous bands which extend from the lower portion of the middle sacral ridge to the posterior surface of the coccyx and closes partly the hiatus sacralis; and of fibrous bands which extend from the sacral cornua to the coccygeal cornua. A portion of this ligament corresponds to the ligamenta subflava and the balance to the capsular ligament.

A Lateral Sacro-coccygeal or Intertransverse Ligament (ligamentum sacro-coccygeum laterale) (Fig. 216) connects the transverse process of the coccyx to the lower lateral angle of the sacrum on each side.

A Fibro-cartilage is interposed between the contiguous surfaces of the sacrum and coccyx; it differs from that interposed between the bodies of the vertebrae in being thinner, and its central part firmer in texture. It is somewhat thicker in front and behind than at the sides. Occasionally, a synovial membrane is found and the coccyx is freely movable. This is especially the case during pregnancy. The different segments of the coccyx are connected together by an extension downward of the anterior and posterior sacro-coccygeal ligaments, a thin annular disk of fibro-cartilage being interposed between each of the bones. In the adult male all the pieces become ossified, but in the female this does not commonly occur until a later period of life. The separate segments of the coccyx are first united, and at a more advanced age the joint between the sacrum and coccyx is obliterated.

Actions.—The movements which take place between the sacrum and coccyx, and between the different pieces of the latter bone, are forward and backward, and are very limited. Their extent increases during pregnancy.
4. Articulation of the Ossa Pubis (Symphysis Ossium Pubis) (Figs. 213, 217).

The articulation between the pubic bones is an amphiarthrodial joint, formed by the junction of the two oval articular surfaces of the ossa pubis. The ligaments of this articulation are the


The Anterior Pubic Ligament (ligamentum pubicum anterius) (Fig. 213) consists of several superimposed layers which pass across the front of the articulation. The superficial fibres pass obliquely from one bone to the other, decussating and forming an interlacement with the fibres of the aponeurosis of the External oblique and the tendon of the Rectus muscles. The deep fibres pass transversely across the symphysis, and are blended with the fibro-cartilage.

The Posterior Pubic Ligament (ligamentum pubicum posterius) consists of a few thin, scattered fibres which unite the two pubic bones posteriorly.

The Superior Pubic Ligament (ligamentum pubicum superius) (Fig. 213) is a band of fibres which connects together the two pubic bones superiorly.

The Inferior Pubic or Subpubic Ligament (ligamentum areatuum pubis) (Fig. 213) is a thick, triangular arch of ligamentous fibres, connecting together the two pubic bones below and forming the upper boundary of the pubic arch. Above, it is blended with the interarticular fibro-cartilage; laterally it is united with the descending rami of the pubis. Its fibres are closely connected and have an arched direction. Its lower margin is separated from the triangular ligament of the penmeum by a gap, through which runs the dorsal vein of the penis.

The Interpubic Disk (lamina fibrocartilaginea interpubica) (Fig. 217) consists of a disk of cartilage and fibro-cartilage connecting the surfaces of the pubic bones in front. Each of the two surfaces is covered by a thin layer of hyaline cartilage which is firmly connected to the bone by a series of nipple-like processes which accurately fit within corresponding depressions on the osseous surfaces. These opposed cartilaginous surfaces are connected together by an intermediate stratum of fibrous tissue and fibro-cartilage which varies in thickness in different subjects. It often contains a cavity (cavum articulare) in its centre, probably formed by the softening and absorption of the fibro-cartilage, since it rarely appears before the tenth year of life, and is not lined by synovial membrane. It is larger in the female than in the male, but it is very questionable whether it enlarges, as was formerly supposed, during pregnancy. It is most frequently limited to the upper and back part of the joint, but it occasionally reaches to the front, and may extend the entire length of the cartilage. This cavity may be easily demonstrated by making a vertical section of the symphysis pubis near its posterior surface (Fig. 217).

The Obturator Ligament is more properly regarded as analogous to the muscular fasciae, with which it will be described.
ARTICULATIONS OF THE UPPER EXTREMIT Y.

The articulations of the upper extremity may be arranged in the following groups:

I. Sterno-clavicular Articulation. 
II. Acromio-clavicular Articulation. 
III. Ligaments of the Scapula. 
IV. Shoulder-joint. 
V. Elbow-joint. 
VI. Radio-ulnar Articulations. 
VII. Wrist-joint. 
VIII. Articulations of the Carpal Bones. 
IX. Carpo-metacarpal Articulations. 
X. Metacarpo-phalangeal Articulations. 
XI. Articulations of the Phalanges.

I. Sterno-clavicular Articulation (Articulatio Sternoclavicularis) (Fig. 218).

The sterno-clavicular is regarded by most anatomists as an arthrodial joint, but Cruveilhier considers it to be an articulation by reciprocal reception. Probably the former opinion is the correct one, the varied movement which the joint enjoys being due to the interposition of an interarticular fibro-cartilage between the joint surfaces. The parts entering into its formation are the sternal end of the clavicle, the upper and lateral part of the first piece of the sternum, and the cartilage of the first rib. The articular surface of the sternum is covered with cartilage. The articular surface of the clavicle is much larger than that of the sternum, and invested with a layer of cartilage which is considerably thicker than that on the latter bone. The ligaments of this joint are the

Capsular. Interclavicular.

The Capsular Ligament (capsula articularis) completely surrounds the articulation, consisting of fibres of varying degrees of thickness and strength. Those in front and behind are of considerable thickness, and form the anterior and posterior sterno-clavicular ligaments; but those above and below, especially in the latter situation, are thin and scanty, and partake more of the character of connective tissue than true fibrous tissue.

1 According to Bruch, the sternal end of the clavicle is covered by a tissue which is rather fibrous than cartilaginous in structure. — Ed. of 15th English Edition.
The Anterior Sterno-clavicular Ligament (ligamentum sternoclavulare) (Fig. 218) is a part of the capsule. It is a broad band of fibres which covers the anterior surface of the articulation, being attached, above, to the upper and front part of the inner extremity of the clavicle, and, passing obliquely downward and inward, is attached, below, to the upper and front part of the first piece of the sternum. This ligament is covered, in front, by the sternal portion of the Sterno-cleido-mastoid and the integument; behind, it is in relation with the interarticular fibro-cartilage and the two synovial membranes.

The Posterior Sterno-clavicular Ligament, also a part of the capsule, is a band of fibres which covers the posterior surface of the articulation, being attached, above, to the upper and back part of the inner extremity of the clavicle, and, passing obliquely downward and inward, is attached, below, to the upper and back part of the first piece of the sternum. It is in relation, in front, with the interarticular fibro-cartilage and synovial membranes; behind, with the Sterno-hyoid and Sterno-thyroid muscles.

The Interclavicular Ligament (ligamentum interclaviculare) (Fig. 218) is a flattened band which varies considerably in form and size in different individuals; it passes in a curved direction from the upper part of the inner extremity of one clavicle to the other, and is also attached to the upper margin of the sternum. It is in relation, in front, with the integument; behind, with the Sterno-thyroid muscles.

The Costo-clavicular or Rhomboid Ligament (ligamentum costoclavulare) (Fig. 218) is short, flat, and strong; it is of a rhomboid form, attached, below, to the upper and inner part of the cartilage of the first rib: it ascends obliquely backward and outward, and is attached, above, to the rhomboid depression on the under surface of the clavicle. It is in relation, in front, with the tendon of origin of the Subclavius; behind, with the subclavian vein.

The Interarticular Fibro-cartilage (discus articularis) (Fig. 218) is a flat and nearly circular meniscus, interposed between the articulating surfaces of the sternum and clavicle. It is attached, above, to the upper and posterior border of the articular surface of the clavicle; below, to the cartilage of the first rib, at its junction with the sternum; and by its circumference, to the anterior and posterior sterno-clavicular and the interclavicular ligaments. It is thicker at the circumference, especially its upper and back part, than at its centre or below. It divides the joint into two cavities, each of which is furnished with a separate synovial membrane.

Synovial Membrane.—Of the two synovial membranes found in this articulation, one is reflected from the sternal end of the clavicle over the adjacent surface of the fibro-cartilage and cartilage of the first rib; the other is placed between the articular surface of the sternum and adjacent surface of the fibro-cartilage; the latter is the larger of the two.

Actions.—This articulation is the centre of the movements of the shoulder, and admits of a limited amount of motion in nearly every direction—upward, downward, backward, forward—as well as circumduction. When these movements take place in the joint, the clavicle in its motion carries the scapula with it, this bone gliding on the outer surface of the chest. This joint therefore forms the centre from which all movements of the supporting arch of the shoulder originate, and is the only point of articulation of this part of the skeleton with the trunk. “The movements attendant on elevation and depression of the shoulder take place between the clavicle and the interarticular fibro-cartilage, the bone rotating upon the ligament on an axis drawn from before backward through its own articular facet. When the shoulder is moved forward and backward, the clavicle, with the interarticular fibro-cartilage, rolls to and fro on the articular surface of the sternum, revolving, with a sliding movement, round an axis drawn nearly vertically through the sternum. In the circumduction of the shoulder, which is compounded
of these two movements, the clavicle revolves upon the interarticular fibro-cartilage, and the latter, with the clavicle, rolls upon the sternum.\footnote{Humphry. On the Human Skeleton, p. 402.} Elevation of the clavicle is principally limited by the costo-clavicular ligament; depression by the interclavicular. The muscles which raise the clavicle, as in shrugging the shoulder, are the upper fibres of the Trapezius, the Levator anguli scapulae, the clavicular head of the Sterno-mastoid, assisted to a certain extent by the two Rhomboids, which pull the vertebral border of the Scapula backward and upward, and so raise the clavicle. The depression of the clavicle is principally effected by gravity, assisted by the Subclavius, Pectoralis minor, and lower fibres of the Trapezius. It is drawn backward by the Rhomboids and the middle and lower fibres of the Trapezius; and forward by the Serratus magnus and Pectoralis minor.

Surface Form.—The position of the sterno-clavicular joint may be easily ascertained by feeling the enlarged sternal end of the collar-bone just external to the long, cord-like, sternal origin of the Sterno-mastoid muscle. If this muscle is relaxed by bending the head forward, a depression just internal to the end of the clavicle, and between it and the sternum, can be felt, indicating the exact position of the joint, which is subcutaneous. When the arm hangs by the side, the cavity of the joint is V-shaped. If the arm is raised, the bones become more closely approximated, and the cavity becomes a mere slit.

Surgical Anatomy.—The strength of this joint mainly depends upon its ligaments, and it is because of the ligaments and because the force of a blow is generally transmitted along the long axis of the clavicle, that dislocation so rarely occurs, and that the bone is generally broken rather than displaced. When dislocation does occur, the course which the displaced bone takes depends more upon the direction in which the violence was applied than upon the anatomical construction of the joint; it may be either forward, backward, or upward. A complete upward dislocation is also inward. A complete forward or backward dislocation is also inward and downward. The chief joint worthy of note, as regards the construction of the joint, in regard to dislocations, is the fact that, owing to the shape of the articular surfaces being so little adapted to each other, and that the strength of the joint mainly depends upon the ligaments, the displacement when reduced is very liable to recur, and hence it is extremely difficult to keep the end of the bone in its proper place, and it may be necessary to incise the soft parts and wire the bone in place.

II. Acromio-clavicular Articulation or Scapulo-clavicular Articulation (Articulatio Acromioclavicularis) (Fig. 219).

The acromio-clavicular is an arthrodial joint formed between the outer extremity of the clavicle and the inner margin of the acromion process of the scapula. The ligaments which surround the joint form a capsule. The ligaments of this articulation are the

- Superior Acromio-clavicular.
- Inferior Acromio-clavicular.
- Interarticular Fibro-cartilage.

The Superior Acromio-clavicular Ligament (ligamentum acromioclavicularare) (Figs. 219 and 220) is a portion of the joint capsule. It is a quadrilateral band which covers the superior part of the articulation, extending between the upper part of the outer end of the clavicle and the adjoining part of the upper surface of the acromion. It is composed of parallel fibres which interlace with the aponeurosis of the Trapezius and Deltoid muscles; below, it is in contact with the interarticular fibro-cartilage (when it exists) and the synovial membranes.

The Inferior Acromio-clavicular Ligament, somewhat thinner than the preceding, and like it a portion of the capsule, covers the under part of the articulation, and is attached to the adjoining surfaces of the two bones. It is in relation, above, with the synovial membranes, and in rare cases with the interarticular fibro-cartilage; below, with the tendon of the Supraspinatus. These two liga-
ments are continuous with each other in front and behind, and form a complete capsule round the joint.

The **Interarticular Fibro-cartilage** (*discus articularis*) is frequently absent in this articulation. When the meniscus exists it is generally incomplete and only partially separates the articular surfaces, and occupies the upper part of the articulation. More rarely it completely separates the joint into two cavities.

![Diagram of the left shoulder-joint, scapulo-clavicular articulations, and proper ligaments of scapula.](image)

**Fig. 219.**—The left shoulder-joint, scapulo-clavicular articulations, and proper ligaments of scapula.

**The Synovial Membrane.**—There is usually only one synovial membrane in this articulation, but when a complete interarticular fibro-cartilage exists there are two synovial membranes.

The **Coraco-clavicular Ligament** (*ligamentum coraco-claviculare*) (Figs. 219 and 220) serves to connect the clavicle with the coracoid process of the scapula. It does not properly belong to this articulation, but as it forms a most efficient means in retaining the clavicle in contact with the acromial process, it is usually described with it. It consists of two fasciculi, called the **trapezoid** and **conoid ligaments**.

The **trapezoid ligament** (*ligamentum trapezoideum*), the anterior and external fasciculus, is broad, thin, and quadrilateral; it is placed obliquely between the coracoid process and the clavicle. It is attached, below, to the upper surface of the coracoid process; above, to the oblique line on the under surface of the clavicle. Its anterior border is free; its posterior border is joined with the conoid ligament, the two forming by their junction a projecting angle.

The **conoid ligament** (*ligamentum conoideum*), the posterior and internal fasciculus, is a dense band of fibres, conical in form, the base being directed upward, the summit downward. It is attached by its apex to a rough impression at the base of the coracoid process, internal to the preceding; above, by its expanded
base, to the conoid tubercle on the under surface of the clavicle, and to a line proceeding internally from it for half an inch. These ligaments are in relation, in front, with the Subclavius and Deltoid; behind, with the Trapezius. They serve to limit rotation of the scapula, the Trapezoid limiting rotation forward, and the Conoid backward.

Actions.—The movements of this articulation are of two kinds: 1. A gliding motion of the articular end of the clavicle on the acromion. 2. Rotation of the scapula forward and backward upon the clavicle, the extent of this rotation being limited by the two portions of the coraco-clavicular ligament.

The acromio-clavicular joint has important functions in the movements of the upper extremity. It has been well pointed out by Sir George Humphry that if there had been no joint between the clavicle and scapula the circular movement of the scapula on the ribs (as in throwing both shoulders backward or forward) would have been attended with a greater alteration in the direction of the shoulder than is consistent with the free use of the arm in such position, and it would have been impossible to give a blow straight forward with the full force of the arm; that is to say, with the combined force of the scapula, arm, and forearm. “This joint,” as he happily says, “is so adjusted as to enable either bone to turn in a hinge-like manner upon a vertical axis drawn through the other, and it permits the surfaces of the scapula, like the baskets in a roundabout swing, to look the same way in every position or nearly so.” Again, when the whole arch formed by the clavicle and scapula rises and falls (in elevation or depression of the shoulders), the joint between these two bones enables the scapula still to maintain its lower part in contact with the ribs.

Surface Form.—The position of the acromio-clavicular joint can generally be ascertained by the slightly enlarged extremity of the outer end of the clavicle, which causes it to project above the level of the acromion process of the scapula. Sometimes this enlargement is so considerable as to form a rounded eminence, which is easily to be felt. The joint lies in the plane of a vertical line passing up the middle of the front of the arm.

Surgical Anatomy.—Owing to the slanting shape of the articular surfaces of this joint, the commonest dislocation is the passing of the acromion process of the scapula under the outer end of the clavicle, but dislocations in the opposite direction have been described. The first form of dislocation is produced by violent force applied to the scapula so as to drive the shoulder forward. The displacement in acromio-clavicular dislocation is often incomplete, on account of the strong coraco-clavicular ligaments which remain untorn. The same difficulty exists, as in the sterno-clavicular dislocation, in maintaining the ends of the bone in apposition after reduction, and it may become necessary to wire them in place after incision of the soft parts.

III. Proper Ligaments of the Scapula (Figs. 219, 220).

The proper ligaments of the scapula pass between portions of that bone, but are not parts of an articulation. They are the

Coraco-acromial. Superior Transverse.
Inferior Transverse.

The Coraco-acromial Ligament (ligamentum coracoacromiale) is a strong triangular band, extending between the coracoid and acromial processes. It is attached, by its apex, to the summit of the acromion just in front of the articular surface for the clavicle, and by its broad base to the whole length of the outer border of the coracoid process. Its posterior fibres are directed inward, its anterior fibres forward and inward. This ligament completes the vault formed by the coracoid and acromion processes for the protection of the head of the humerus. It is in relation, above, with the clavicle and under surface of the Deltoid muscle; below, with the tendon of the Supraspinatus muscle, a bursa being interposed. Its outer border is continuous with a dense lamina that passes beneath the Deltoid upon the tendons
of the Supra- and Infraspinatus muscles. This ligament is sometimes described as consisting of two marginal bands and a thinner intervening portion, the two bands being attached respectively to the apex and base of the coracoid process, and joining together at their attachment into the acromion process. When the Pectoralis minor is inserted, as sometimes is the case, into the capsule of the shoulder-joint instead of into the coracoid process, it passes between these two bands, and the intervening portion is then deficient.

The Superior Transverse, Coracoid or Suprascapular Ligament (ligamentum transversum scapulae superius) (Figs. 219, 220, and 222) converts the suprascapular notch into a foramen. It is a thin and flat fasciculus, narrower at the middle than at the extremities, attached by one end to the base of the coracoid process, and by the other to the inner extremity of the scapular notch. The suprascapular nerve passes through the foramen; the suprascapular vessels pass over the ligament.

An additional ligament, the Inferior Transverse or Spino-glenoid Ligament (ligamentum transversum scapulae inferius), is sometimes found on the scapula, stretching from the outer border of the spine to the margin of the glenoid cavity. When present, it forms an arch under which the suprascapular vessels and nerve pass as they enter the infraspinous fossa.

 Movements of Scapula.—The scapula is capable of being moved upward and downward, forward and backward, or, by a combination of these movements, circumducted on the wall of the chest. The muscles which raise the scapula are the upper fibres of the Trapezius, the Levator anguli scapulae, and the two Rhomboids; those which depress it are the lower fibres of the Trapezius, the Pectoralis minor, and, through the clavicle, the Subclavius. The scapula is drawn backward by the Rhomboids and the middle and lower fibres of the Trapezius, and forward
by the Serratus magnus and Pectoralis minor, assisted, when the arm is fixed, by the Pectoralis major. The mobility of the scapula is very considerable, and greatly assists the movements of the arm at the shoulder-joint. Thus, in raising the arm from the side the Deltoid and Supraspinatus can only lift it to a right angle with the trunk, the further elevation of the limb being effected by the Trapezius and Serratus magnus moving the scapula on the wall of the chest. This mobility is of special importance in ankylosis of the shoulder-joint, the movement of this bone compensating to a very great extent for the immobility of the joint.

IV. The Shoulder-joint (Articulatio Humeri) (Figs. 219, 220, 221, 222).

The shoulder is an enarthrodial or ball-and-socket joint. The bones entering into its formation are the large globular head of the humerus, which is received into the shallow glenoid cavity of the scapula—an arrangement which permits of very considerable movement, whilst the joint itself is protected against displacement by the tendons which surround it and by atmospheric pressure. The ligaments do not maintain the joint surfaces in apposition, because when they alone remain the humerus can be separated to a considerable extent from the glenoid cavity; their use, therefore, is to limit the amount of movement. Above, the joint is protected by an arched vault, formed by the under surfaces of the coracoid and acromion processes, and the coraco-acromial ligament. The articular surfaces are covered by a layer of cartilage: that on the head of the humerus is thicker at the centre than at the circumference, the reverse being the case in the glenoid cavity. The ligaments of the shoulder are the

- Capsular.
- Coraco-humeral.
- Transverse humeral.
- Glenoid.¹

The Capsular Ligament (capsula articularis) (Figs. 219, 220, and 222) completely encircles the articulation, being attached, above, to the circumference of the glenoid cavity beyond the glenoid ligament, below, to the anatomical neck of the humerus, approaching nearer to the articular cartilage above than in the rest of its extent. It is thicker above and below than elsewhere, and is remarkably loose and lax, and

¹The long tendon of origin of the Biceps muscle also acts as one of the ligaments of this joint. See the observations on p. 270 on the function of the muscles passing over more than one joint.—Ed. of 15th English Edition.
THE ARTICULATIONS OR JOINTS

much larger and longer than is necessary to keep the bones in contact, allowing them to be separated from each other more than an inch—an evident provision for that extreme freedom of movement which is peculiar to this articulation. Its superficial surface is strengthened, above, by the Supraspinatus; below, by the long head of the Triceps; behind, by the tendons of the Infraspinatus and Teres minor; and in front, by the tendon of the Subscapularis. The capsular ligament usually presents three openings: One anteriorly, below the coracoid process, establishes a communication between the synovial membrane of the joint and a bursa beneath the tendon of the Subscapularis muscle. The second, which is not constant, is at the posterior part, where a communication sometimes exists between the joint and a bursal sac belonging to the Infraspinatus muscle. The third is seen between the two tuberosities, for the passage of the long tendon of the Biceps muscle. It transmits a sac-like prolongation of the synovial membrane, which ends as a blind pouch opposite the surgical neck of the bone. This synovial sac is called the vagina mucosa intertubercularis.

The Coraco-humeral Ligament (ligamentum coracohumerale) (Fig. 219) is a broad band which strengthens the upper part of the capsular ligament. It arises from the outer border of the coracoid process, and passes obliquely downward and outward to the front of the great tuberosity of the humerus, being blended with the tendon of the Supraspinatus muscle. This ligament is intimately united to the capsular ligament throughout the greater part of its extent.

Supplemental Bands of the Capsular Ligament.—In addition to the coraco-humeral ligament, the capsular ligament is strengthened by supplemental bands in the interior of the joint. One of these bands is situated on the inner side of the joint, and passes from the inner edge of the glenoid cavity to the lower part of the lesser tuberosity of the humerus. This is sometimes known as Flood's ligament,
and is supposed to correspond with the ligamentum teres of the hip-joint. A second of these bands is situated at the lower part of the joint, and passes from the under edge of the glenoid cavity to the under part of the neck of the humerus, and is known as Schlemm's ligament. A third, called the gleno-humeral ligament, is situated at the upper part of the joint, and projects into its interior, so that it can be seen only when the capsule is opened. It is attached above to the apex of the glenoid cavity, close to the root of the coracoid process, and, passing downward along the inner edge of the tendon of the Biceps, is attached below to the lesser tuberosity of the humerus, where it forms the inner boundary of the upper part of the bicipital groove. It is a thin, ribbon-like band, occasionally quite free from the capsule.

The Transverse Humeral Ligament is a prolongation of the capsular ligament. It is a broad band of fibrous tissue passing from the lesser to the greater tuberosity of the humerus, and always limited to that portion of the bone which lies above the epiphysial line. It converts the bicipital groove into an osseo-aponerotic canal, and is the analogue of the strong process of bone which connects the summits of the two tuberosities in the musk ox.

The Glenoid Ligament (labrum glenoidale) (Figs. 220 and 222) is a fibro-cartilaginous rim, attached round the margin of the glenoid cavity. It is triangular on section, the thickest portion being fixed to the circumference of the cavity, the free edge being thin and sharp. It is continuous above with the long tendon of the Biceps muscle, which bifurcates at the upper part of the cavity into two fasciculi, and becomes continuous with the fibrous tissue of the glenoid ligament. This ligament deepens the cavity for articulation, and protects the edges of the bone. It is lined by the synovial membrane.

Synovial Membrane (Fig. 222).—The synovial membrane is reflected from the margin of the glenoid cavity over the fibro-cartilaginous rim surrounding it: it is then reflected over the internal surface of the capsular ligament, covers the lower part and sides of the anatomical neck of the humerus as far as the cartilage covering the head of the bone. The long tendon of the Biceps muscle which passes through the capsular ligament is enclosed in a tubular sheath of synovial membrane (vagina mucosa intertubercularis), which is reflected upon it at the point where it perforates the capsule, and is continued around it as far as the level of the surgical neck of the humerus. The tendon of the Biceps is thus enabled to traverse the articulation, but it is not contained in the interior of the synovial cavity.

Bursæ.—A large bursa exists between the joint capsule and the tendon of the Subscapularis muscle. It is called the subscapular bursa. This sac communicates with the shoulder-joint by means of an opening at the inner side of the capsular ligament. The subscapular bursa is constant. Occasionally another and smaller bursa exists beneath the tendon of the infraspinatus. It is called the infraspinatus bursa, and communicates with the shoulder-joint by means of an opening in the outer surface of the capsule. The subdeltoïd or subacromial bursa is placed between the under surface of the Deltoid muscle and the outer surface of the capsule. It does not communicate with the joint. The subcutaneous acromial bursa is between the surface and the summit of the acromion process. There is a bursa beneath the Coraco-brachialis muscle—one beneath the teres major—and one beneath the tendinous portion of the latissimus dorsi. There is also a bursa between the tendon of insertion of the Pectoralis major muscle and the long head of the biceps.

The Muscles in relation with the joint are, above, the Supraspinatus; below, the long head of the Triceps; in front, the Subscapularis; behind, the Infraspinatus and Teres minor; within, the long tendon of the Biceps. The Deltoid is placed most externally, and covers the articulation on its outer side, as well as in front and behind.
The Arteries supplying the joint are articular branches of the anterior and posterior circumflex, and the suprascapular. The Nerves are derived from the circumflex and suprascapular.

Actions.—The shoulder-joint is capable of movement in every direction, forward, backward, abduction, adduction, circumduction, and rotation. The humerus is drawn forward by the Pectoralis major, anterior fibres of the Deltoid, Coracobrachialis, and by the Biceps when the forearm is flexed; backward, by the Latsissimus dorsi, Teres major, posterior fibres of the Deltoid, and by the Triceps when the forearm is extended; it is abducted (elevated) by the Deltoid and Supraspinatus; it is adducted (depressed) by the Subscapularis, Pectoralis major, Latsissimus dorsi, and Teres major; it is rotated outward by the Infraspinatus and Teres minor; and it is rotated inward by the Subscapularis, Latsissimus dorsi, Teres major, and Pectoralis major.

The most striking peculiarities in this joint are: 1. The large size of the head of the humerus in comparison with the depth of the glenoid cavity, even when supplemented by the glenoid ligament. 2. The looseness of the capsule of the joint. 3. The intimate connection of the capsule with the muscles attached to the head of the humerus. 4. The peculiar relation of the biceps tendon to the joint.

It is in consequence of the relative size of the two articular surfaces that the joint enjoys such free movement in every possible direction. When these movements of the arm are arrested in the shoulder-joint by the contact of the bony surfaces and by the tension of the corresponding fibres of the capsule, together with that of the muscles acting as accessory ligaments, they can be carried considerably farther by the movements of the scapula, involving, of course, motion at the acromio- and sterno-clavicular joints. These joints are therefore to be regarded as accessory structures to the shoulder-joint. The extent of these movements of the scapula is very considerable, especially in extreme elevation of the arm, which movement is best accomplished when the arm is thrown somewhat forward and outward, because the margin of the head of the humerus is by no means a true circle; its greatest diameter is from the bicipital groove downward, inward, and backward, and the greatest elevation of the arm can be obtained by rolling its articular surface in the direction of the measurement. The great width of the central portion of the humeral head also allows of very free horizontal movement when the arm is raised to a right angle, in which movement the arch formed by the acromion, the coracoid process, and the coraco-acromial ligament constitutes a sort of supplemental articular cavity for the head of the bone.

The looseness of the capsule is so great that the arm will fall about an inch from the scapula when the muscles are dissected from the capsular ligament and an opening made in it to remove the atmospheric pressure. The movements of the joint, therefore, are not regulated by the capsule so much as by the surrounding muscles and by the pressure of the atmosphere—an arrangement which "renders the movements of the joint much more easy than they would otherwise have been, and permits a swinging, pendulum-like vibration of the limb when the muscles are at rest" (Humphry). The fact, also, that in all ordinary positions of the joint the capsule is not put on the stretch enables the arm to move freely in all directions. Extreme movements are checked by the tension of appropriate portions of the capsule, as well as by the interlocking of the bones. Thus it is said that "abduction is checked by the contact of the great tuberosity with the upper edge of the glenoid cavity, adduction by the tension of the coraco-humeral ligament" (Beaunis et Bouchard). Cleland maintains that the limitations of movement at the shoulder-joint are due to the structure of the joint itself, the glenoid ligament fitting, in different positions of the elevated arm, into the anatomical neck of the humerus.

1 See p. 303.
Cathcart\textsuperscript{1} has pointed out that in abducting the arm and raising it above the head, the scapula rotates throughout the whole movement with the exception of a short space at the beginning and at the end; that the humerus moves on the scapula not only from the hanging to the horizontal position, but also in passing upward as it approaches the vertical above; that the clavicle moves not only during the second half of the movement but in the first as well, though to a less extent—\textit{i.e.}, the scapula and clavicle are concerned in the first stage as well as in the second; and that the humerus is partly involved in the second as well as chiefly in the first.

The intimate union of the tendons of the four short muscles with the capsule converts these muscles into elastic and spontaneously acting ligaments of the joint, and it is regarded as being also intended to prevent the folds into which all portions of the capsule would alternately fall in the varying positions of the joint from being driven between the bones by the pressure of the atmosphere.

The peculiar relations of the Biceps tendon to the shoulder-joint appear to subserve various purposes. In the first place, by its connection with both the shoulder and elbow the muscle harmonizes the action of the two joints, and acts as an elastic ligament in all positions, in the manner previously adverted to.\textsuperscript{2} Next, it strengthens the upper part of the articular cavity, and prevents the head of the humerus from being pressed up against the acromion process, when the Deltoid contracts, instead of forming the centre of motion in the glenoid cavity. By its passage along the bicipital groove it assists in rendering the head of the humerus steady in the various movements of the arm. When the arm is raised from the side it assists the Supra- and Infraspinatus in rotating the head of the humerus in the glenoid cavity. It also holds the head of the bone firmly in contact with the glenoid cavity, and prevents its slipping over its lower edge, or being displaced by the action of the Latissimus dorsi and Pectoralis major, as in climbing and many other movements.

\textbf{Surface Form.}—The direction and position of the shoulder-joint may be indicated by a line drawn from the middle of the coraco-acromial ligament, in a curved direction, with its convexity inward, to the innermost part of that portion of the head of the humerus which can be felt in the axilla when the arm is forcibly abducted from the side. When the arm hangs by the side, not more than one-third of the head of the bone is in contact with the glenoid cavity, and three-quarters of its circumference is in front of a vertical line drawn from the anterior border of the acromion process.

\textbf{Surgical Anatomy.}—Owing to the construction of the shoulder-joint and the freedom of movement which it enjoys, as well as in consequence of its exposed situation, it is more frequently dislocated than any other joint in the body. Dislocations of the shoulder contribute about forty per cent. of the cases in tables of dislocations. \textit{Dislocation} occurs when the arm is thrown into extreme abduction, and when, therefore, the head of the humerus presses against the lower and front part of the capsule, which is the thinnest and least supported part of the ligament. The rent in the capsule almost invariably takes place in this situation, between the tendon of the Subscapularis and the Triceps, and through it the head of the bone escapes, so that the dislocation in most instances is primarily subglenoid. The head of the bone does not usually remain in this situation, but generally assumes some other position, which varies according to the direction and amount of force producing the dislocation and the relative strength of the muscles in front and behind the joint. In consequence of the muscles at the back being weaker than those in front, and especially on account of the long head of the Triceps preventing the bone passing backward, dislocation forward is much more common than backward. The most frequent position which the head of the humerus ultimately assumes is on the front of the neck of the scapula, beneath the coracoid process, and hence named subcoracoid dislocation. Occasionally, in consequence of a greater amount of force being brought to bear on the limb, the head is driven farther inward, and rests on the upper part of the front of the chest, beneath the clavicle (sub-clavicular). If the head of the bone passes under the Subscapularis muscle and also under the Teres major or the lower border of the Pectoralis major, the arm remains abducted, or even with the elbow raised above the head (\textit{luxatio erecta}). Sometimes the humerus remains in the position in which it was primarily displaced, resting on the axillary border of the scapula (sub-

\textsuperscript{1} Journal of Anatomy and Physiology, 1884, vol. xviii. \textsuperscript{2} See p. 270.
THE ARTICULATIONS OR JOINTS

glenoid), and rarely it passes backward and remains in the infraspinatus fossa beneath the spine (subspinous). If dislocation frequently recurs the condition may be amended in some cases by exposing the capsule and putting tucks in it by means of sutures.

An old unreduced dislocation is sometimes treated by incising the soft parts and returning the head of the humerus into the glenoid cavity. In other cases the head of the humerus is excised. Dislocation of the long tendon of the Biceps muscle from the bicipital groove is a rare accident. When it occurs the arm is rigid in abduction, but the head of the humerus is found to be in the glenoid cavity. It is reduced by flexion of the elbow and rotation of the arm. Rupture of the long tendon of the biceps is more common than dislocation of the tendon.

After this injury the belly of the muscle is relaxed and is nearer than normal to the elbow; flexion of the forearm is much weakened, and is weaker in supination than it is in pronation. The head of the humerus passes forward and inward, and the condition is often mistaken for dislocation of the bone.

If we desire to aspirate the shoulder-joint, place the arm against the side, flex the forearm at a right angle to the arm, carry the forearm across the front of the chest, and enter the trocar below the acromion (De Vos).

The shoulder-joint is sometimes the seat of all those inflammatory affections, both acute and chronic, which attack joints, though perhaps it suffers less frequently than some other joints of equal size and importance. Acute synovitis may result from injury, rheumatism, or pyaemia, or may follow secondarily on the so-called acute epiphysitis of infants. It is attended with effusion into the joint, and when this occurs the capsule is evenly distended and the contour of the joint rounded. Special projections may occur at the site of the openings in the capsular ligament. Thus a swelling may appear just in front of the joint, internal to the lesser tuberosity, from effusion into the joint, and when this occurs the capsule is evenly distended and the contour of the joint rounded. Special projections may occur at the site of the openings in the capsular ligament. Thus a swelling may appear just in front of the joint, internal to the lesser tuberosity, from effusion into the bursa beneath the Subscapularis muscle; or, again, a swelling which is sometimes bilobed may be seen in the interval between the Deltoïd and Pectoralis major muscles, from effusion into the diverticulum, which runs down the bicipital groove with the tendon of the biceps. The effusion into the synovial membrane can be best ascertained by examination from the axilla, where a soft, elastic, fluctuating swelling can usually be felt. The bursa beneath the deltoïd is sometimes ruptured by violence, and sometimes inflames, suppurates, or becomes tuberculous.

Tuberculous arthritis not unfrequently attacks the shoulder-joint, and may lead to total destruction of the articulation, when ankylosis may result or long-protracted suppuration may necessitate excision. This joint is also one of those which is most liable to be the seat of osteoarthritis, and may also be affected in gout and rheumatism; or in locomotor ataxia, when it occasionally becomes the seat of Charcot's disease.

Excision of the shoulder-joint may be required in cases of arthritis (especially the tuberculous form) which have gone on to destruction of the articulation; in compound dislocations and fractures, particularly those arising from gunshot injuries, in which there has been extensive injury to the head of the bone; in some cases of old unreduced dislocation, where there is much pain; and possibly in some few cases of growth connected with the upper end of the bone. The operation is best performed by making an incision from the middle of the coraco-acromial ligament down the arm for about three inches: this will expose the bicipital groove and the tendon of the Biceps, which may be either divided or hooked out of the way, according as to whether it is implicated in the disease or not. The capsule is then freely opened, and the muscles attached to the greater and lesser tuberosities of the humerus divided. The head of the bone can then be thrust out of the wound and sawn off, or divided with a narrow saw in situ and subsequently removed. The section should be made, if possible, just below the articular surface, so as to leave the bone as long as possible. The glenoid cavity must then be examined, and gouged if carious.

V. The Elbow-joint (Articulatio Cubiti) (Figs. 223, 224, 225, 226).

The elbow is a ginglymus or hinge-joint. The bones entering into its formation are the trochlea of the humerus, which is received into the greater sigmoid cavity of the ulna (articulatio humeroulnaris), and admits of the movements peculiar to this joint—viz., flexion and extension; whilst the capitellum or radial head of the humerus articulates with the cup-shaped depression on the head of the radius (articulatio humeroradialis); the circumference of the head of the radius articulates with the lesser sigmoid cavity of the ulna (articulatio radio-ulnaris proximalis), allowing of the movement of rotation of the radius on the ulna, the chief action of the superior radio-ulnar articulation. The articular surfaces are covered with a thin layer of cartilage, and connected together by a capsular ligament (capsula articularis) (Fig. 225) of unequal thickness, being especially thickened on its two sides and, to a less extent, in front and behind.
These thickened portions are usually described as distinct ligaments under the following names:

- Anterior
- Posterior
- Internal Lateral
- External Lateral

The orbicular ligament of the upper radio-ulnar articulation must also be reckoned among the ligaments of the elbow.

The Anterior Ligament (Fig. 223) is a broad and thin fibrous layer which covers the anterior surface of the joint. It is attached to the front of the internal condyle and to the front of the humerus immediately above the coronoid and radial fossae; below, to the anterior surface of the coronoid process of the ulna and to the orbicular ligament, being continuous on each side with the lateral ligaments. Its superficial fibres pass obliquely from the inner condyle of the humerus outward to the orbicular ligament. The middle fibres, vertical in direction, pass from the upper part of the coronoid depression and become partly blended with the preceding, but are mainly inserted into the anterior surface of the coronoid process. The deep or transverse set intersects these at right angles. This ligament is in relation, in front, with the Brachialis anticus muscle, except at its outermost part; behind, it is in relation with the synovial membrane.

The Posterior Ligament (Fig. 224) is a thin and loose membranous fold, attached, above, to the lower end of the humerus, above and at the sides of the olecranon
fossa; below, to the groove on the upper and outer surfaces of the olecranon. The superficial or transverse fibres pass between the adjacent margins of the olecranon fossa. The deeper portion consists of vertical fibres, some of which, thin and weak, pass from the upper part of the olecranon fossa to the margin of the olecranon; others, thicker and stronger, pass from the back of the capitellum of the humerus to the posterior border of the lesser sigmoid cavity of the ulna. This ligament is in relation, behind, with the tendon of the Triceps muscle and the Anconeus muscle; in front, with the synovial membrane.

The **Internal Lateral Ligament** (ligamentum collaterale ulnare) (Fig. 223) is a thick triangular band consisting of two portions, an anterior and posterior, united by a thinner intermediate portion. The **anterior portion**, directed obliquely forward, is attached, above, by its apex, to the front part of the internal condyle of the humerus; and, below, by its broad base, to the inner margin of the coronoid process. The **posterior portion**, also of triangular form, is attached, above, by its apex, to the lower and back part of the internal condyle; below, to the inner margin of the olecranon. Between these two bands a few intermediate fibres descend from the internal condyle to blend with a transverse band of ligamentous tissue which bridges across the notch between the olecranon and coronoid processes. This ligament is in relation, internally, with the Triceps and Flexor carpi ulnaris muscles and the ulnar nerve, and gives origin to part of the Flexor sublimis digitorum muscle.

The **External Lateral Ligament** (ligamentum collaterale radiale) (Fig. 224) is a short and narrow fibrous band less distinct than the internal, attached, above, to a depression below the external condyle of the humerus; below, to the orbicular ligament, some of its most posterior fibres passing over that ligament, to be inserted into the outer margin of the ulna. This ligament is intimately blended with the tendon of origin of the Supinator brevis muscle.

**Synovial Membrane** (Fig. 225).—The synovial membrane is very extensive. It covers the margin of the articular surface of the humerus, and lines the coronoid and olecranon fossa on that bone; from these points it is reflected over the anterior, posterior, and lateral ligaments, and forms a **pouch** (recessus sacciformis) between the lesser sigmoid cavity, the internal surface of the orbicular ligament, and the
circumference of the head of the radius. Projecting into the cavity is a crescentic fold of synovial membrane, between the radius and ulna, suggesting the division of the joint into two: one the humero-radial, the other the humero-ulnar.

Between the capsular ligament and the synovial membrane are three masses of fat: one, the largest, above the olecranon fossa, which is pressed into the fossa by the Triceps during flexion; a second, over the coronoid fossa; and a third, over the radial fossa. The two last-named pads are pressed into their respective fossae during extension.

The muscles (Fig. 226) in relation with the joint are, in front, the Brachialis anticus; behind, the Triceps and Anconeus; externally, the Supinator brevis and the common tendon of origin of the Extensor muscles; internally, the common tendon of origin of the Flexor muscles, and the Flexor carpi ulnaris, with the ulnar nerve.

The arteries supplying the joint are derived from the anastomosis between the superior profunda, inferior profunda, and anastomotica magna, branches of the brachial, with the anterior, posterior, and interosseous recurrent branches of the ulnar and the recurrent branch of the radial. These vessels form a complete chain of insolution around the joint.

The nerves are derived from the ulnar as it passes between the internal condyle and the olecranon; a filament from the musculo-cutaneous (Rüdinger), and two filaments from the median (Macalister).

Bursae.—The olecranon bursa (bursa subcutaneous olecrani) is placed between the olecranon process and the cutaneous surface. A bursa exists between the tendon of the Biceps and the tubercle of the radius (bursa bicipitoradialis)—another between the Triceps tendon and the olecranon process (bursa subtendinea olecrani)—another between the cutaneous surface and the external condyle (bursa subcutanea epicondylhi humeri lateralis)—another between the cutaneous surface and the internal condyle (bursa subcutanea epicondylhi humeri medialis)—another within the Triceps tendon at its insertion on the olecranon (bursa intratendinea olecrani).

Actions.—The elbow-joint comprises three different portions—viz., the joint between the ulna and humerus, that between the head of the radius and the humerus, and the superior radio-ulnar articulation, described below. All these articular surfaces are invested by a common synovial membrane, and the movements of the whole joint should be studied together. The combination of the movements of flexion and extension of the forearm with those of pronation and supination of the hand, which is ensured by the two being performed at the same joint, is essential to the accuracy of the various minute movements of the hand.

The portion of the joint between the ulna and humerus is a simple hinge-joint, and allows of movements of flexion and extension only. Owing to the obliquity of the trochlear surface of the humerus, this movement does not take
place in a straight line. When the forearm is extended and supinated the axis
of the arm is not in the same line as the axis of the forearm, but the axis of the arm
forms an angle with the axis of the forearm, and the hand, with the forearm, is
directed outward. During flexion, on the other hand, the forearm and the hand
tend to approach the middle line of the body, and thus enable the hand to be easily
carried to the face. The shape of the articular surface of the humerus, with its
prominences and depressions accurately adapted to the opposing surface of the
olecranon, prevents any lateral movement. Flexion is produced by the action of the
Biceps and Brachialis anticus, assisted by the muscles arising from the in-
ternal condyle of the humerus and the Supinator longus; extension, by the Triceps
and Anconeus, assisted by the extensors of the wrist and by the Extensor communis
digitorum and Extensor minimi digiti.

The joint between the head of the radius and the capitellum or radial head of the
humerus is an arthrodial joint. The bony surfaces would of themselves constitute
an enarthrosis, and allow of movement in all directions were it not for the orbicular
ligament by which the head of the radius is bound down firmly to the lesser
sigmoid cavity of the ulna, and which prevents any separation of the two bones
laterally. It is to the same ligament that the head of the radius owes its security
from dislocation, which would otherwise constantly occur as a consequence of the
shallowness of the cup-like surface on the head of the radius. In fact, but for
this ligament the tendon of the biceps would be liable to pull the head of the
radius out of the joint. In complete extension the head of the radius glides so
far back on the outer condyle that its edge is plainly felt at the back of the articu-
lation. Flexion and extension of the elbow-joint are limited by the tension of
the structures on the front and back of the joint, the limitation of flexion being
also aided by the soft structures of the arm and forearm coming in contact.

In combination with any position of flexion or extension the head of the radius
can be rotated in the upper radio-ulnar joint, carrying the hand with it. The
hand is directly articulated to the lower surface of the radius only, and the concave
or sigmoid surface on the lower end of the radius travels round the lower end of
the ulna. The latter bone is excluded from the wrist-joint (as will be seen in
the sequel) by the interarticular fibro-cartilage. Thus, rotation of the head of the
radius round an axis which passes through the centre of the radial head of the
humerus imparts circular movement to the hand through a very considerable
arc.

Surface Form.—If the forearm be slightly flexed on the arm, a curved crease or fold with
its convexity downward may be seen running across the front of the elbow, extending from one
condyle to the other. The centre of this fold is some slight distance above the line of the joint.
The position of the radio-humeral portion of the joint can be at once ascertained by feeling for a
slight groove or depression between the head of the radius and the capitellum of the humerus at
the back of the articulation.

Surgical Anatomy.—From the great breadth of the joint, and the manner in which the
articular surfaces are interlocked, and also on account of the strong lateral ligaments and the
support which the joint derives from the mass of muscles attached to each condyle of the
humerus, lateral displacement of the bones is very uncommon, whereas antero-posterior disloca-
tion, on account of the shortness of the antero-posterior diameter, the weakness of the anterior
and posterior ligaments, and the want of support of muscles, much more frequently takes place,
dislocation backward taking place when the forearm is in a position of extension, and forward
when in a position of flexion. For, in the former position, that of extension, the coronoid process
is not interlocked into the coronoid fossa, and loses its grip to a certain extent, whereas the
olecranon process is in the olecranon fossa, and entirely prevents displacement forward. On
the other hand, during flexion, the coronoid process is in the coronoid fossa, and prevents dis-
location backward, while the olecranon loses its grip and is not so efficient, as during extension,
in preventing a forward displacement. When lateral dislocation does take place, it is generally
incomplete.

1 Humphry, op cit., p. 419.
Dislocation of the elbow-joint is of common occurrence in children, far more common than dislocation of any other articulation, for, as a rule, fracture of a bone more frequently takes place, under the application of any severe violence, in young persons than dislocation. In lesions of this joint there is often very great difficulty in ascertaining the exact nature of the injury. Sprain of the elbow is a very common injury in childhood. Injury to the radio-humeral joint is frequently produced by lifting a child by the hand, as in swinging it over a gutter. The supinator brevis, which under normal circumstances would retain the head of the radius against the capitellum of the humerus, is unable to do so, the radio-humeral articulation receives the force and the orbicular ligament undergoes upward displacement, is caught between the head of the radius and the capitellum and jams the joint. 1 This injury is often called subluxation of the head of the radius.

The elbow-joint is occasionally the seat of acute synovitis. The synovial membrane then becomes distended with fluid, the bulging showing itself principally around the olecranon process; that is to say, on its inner and outer sides and above, in consequence of the laxness of the posterior ligament. Occasionally a well-marked, triangular projection may be seen on the outer side of the olecranon, from bulging of the synovial membrane beneath the Anconeus muscle. Again, there is often some swelling just above the head of the radius, in the line of the radio-humeral joint. There is generally not much swelling at the front of the joint, though sometimes deep-seated fullness beneath the Brachialis anticus may be noted. When suppuration occurs the abscess usually points at one or other border of the Triceps muscle; occasionally the pus discharges itself in front, near the insertion of the Brachialis anticus muscle. Chronic synovitis, usually of tuberculous origin, is of common occurrence in the elbow-joint: under these circumstances the forearm tends to assume the position of semi-flexion, which is that of greatest ease and relaxation of ligaments. It should be borne in mind that should ankylosis occur in this or the extended position, the limb will not be nearly so useful as if it becomes ankylosed in a position of rather less than a right angle. Loose cartilages are sometimes met with in the elbow-joint, not so commonly, however, as in the knee; nor do they, as a rule, give rise to such urgent symptoms. They rarely require operative interference. The elbow-joint is also sometimes affected with osteo-arthritis, but this affection is less common in this articulation than in some other of the larger joints. Bursitis about the elbow is not uncommon. Enlargement of the subcutaneous bursa over the olecranon is known as miners’ elbow. Enlargement of any one of the bursae may occur.

Excision of the elbow is principally required for one of three conditions—viz., tuberculous arthritis, injury and its results, and ankylosis in a position which greatly impairs the usefulness of the limb; but may be necessary for some other rarer conditions, such as disorganizing arthritis after pyaemia, unreduced dislocation, and osteo-arthritis. The results of the operation are, as a rule, more favorable than those of excision of any other joint, and it is one, therefore, that the surgeon should never hesitate to perform, especially in the first three of the conditions mentioned above. The operation is best performed by a single vertical incision down the back of the joint, a transverse incision, over the outer condyle, being added if the parts are much thickened and fixed. A straight incision is made about four inches long, the mid-point of which is on a level with and a little to the inner side of the tip of the olecranon. This incision is made down to the bone, through the substance of the Triceps muscle. The operator with the point of his knife, and guarding the soft parts with his thumb-nail, separates them from the bone. In doing this there are two structures which he should carefully avoid: the ulnar nerve, which lies parallel to his incision, but a little internal, as it courses down between the internal condyle and the olecranon process, and the prolongation of the Triceps into the deep fascia of the forearm over the Anconeus muscle. Having cleared the bones and divided the lateral and posterior ligaments, the forearm is strongly flexed and the ends of the bone turned out and sawn off. The section of the humerus should be through the base of the condyles, that of the ulna and radius should be just below the level of the lesser sigmoid cavity of the ulna and the neck of the radius. In this operation the object is to obtain such fibrous union as shall allow free motion of the bones of the forearm; and, therefore, passive motion must be commenced early, that is to say, about the tenth day.

VI. Radio-ulnar Articulation (Articulatio Radioulnaris).

The articulation of the radius with the ulna is effected by ligaments which connect together both extremities as well as the shafts of these bones. It may, consequently, be subdivided into three articulations: (1) the superior radio-ulnar, which is a portion of the elbow-joint; (2) the middle radio-ulnar; and (3) the inferior radio-ulnar articulations.

1 Mr. Jonathan Hutchinson, Jr., in Annals of Surgery, August, 1885.
THE ARTICULATIONS OR JOINTS

1. Superior or Proximal Radio-ulnar Articulation (Articulatio Radioulnaris Proximalis).

This articulation is a trochoid or pivot-joint. The bones entering into its formation are the inner side of the circumference of the head of the radius rotating within the lesser sigmoid cavity of the ulna. Its only ligament is the annular or orbicular.

The Orbicular or Annular Ligament (ligamentum annulare radii) (Figs. 223, 224, and 227) is a strong, flat band of ligamentous fibres which surrounds the head of the radius and retains it in firm connection with the lesser sigmoid cavity of the ulna. It forms about four-fifths of an osseo-fibrous ring, attached by each end to the extremities of the lesser sigmoid cavity, and is smaller at the lower part of its circumference than above, by which means the head of the radius is more securely held in its position. Its outer surface is strengthened by the external lateral ligament of the elbow, and affords origin to part of the Supinator brevis muscle. Its inner surface is smooth, and lined by synovial membrane. The synovial membrane is continuous with that which lines the elbow-joint.

Actions.—The movement which takes place in this articulation is limited to rotation of the head of the radius within the orbicular ligament, and upon the lesser sigmoid cavity of the ulna, rotation forward being called pronation; rotation backward, supination. Supination is performed by the Biceps and Supinator brevis, assisted to a slight extent by the Extensor muscles of the thumb and, in certain positions, by the Supinator longus. Pronation is performed by the Pronator radii teres and the Pronator quadratus, assisted, in some positions, by the Supinator longus.

Surface Form.—The position of the superior radio-ulnar joint is marked on the surface of the body by the little dimple on the back of the elbow which indicates the position of the head of the radius.

Surgical Anatomy.—Dislocation of the head of the radius alone is not an uncommon accident, and occurs most frequently in young persons from falls on the hand when the forearm is extended and supinated, the head of the bone being displaced forward. It is attended by rupture of the orbicular ligament. Occasionally a peculiar injury, which is supposed to be a subluxation, occurs in young children in lifting them from the ground by the hand or forearm. It is believed that the head of the radius is displaced downward or the orbicular ligament upward, and the upper border of the ligament becomes folded over the head of the radius, between it and the capitellum of the humerus.

2. Middle Radio-ulnar Ligaments.

The interval between the shafts of the radius and ulna is occupied by two ligaments.

Oblique. Interosseous.

The Oblique or Round Ligament (chorda obliqua) (Figs. 223 and 225) is a small, flattened fibrous band which extends obliquely downward and outward from the tubercle of the ulna at the base of the coronoid process to the radius a little below the bicapital tuberosity. Its fibres run in the opposite direction to those of the interosseous ligament, and it appears to be placed as a substitute for it in the upper part of the interosseous interval. This ligament is sometimes wanting.

The Interosseous Membrane (membrana interossea antibrachii) (Fig. 227) is a broad and thin plane of fibrous tissue descending obliquely downward and inward, from the interosseous ridge on the radius to that on the ulna. It is deficient above, commencing about an inch beneath the tubercle of the radius; is broader in the middle than at either extremity; and presents an oval aperture just above its lower margin for the passage of the anterior interosseous vessels to the back of the forearm. This ligament serves to connect the bones and to increase the extent of surface for the attachment of the deep muscles. Between its upper
border and the oblique ligament an interval exists through which the posterior interosseous vessels pass to the dorsum of the forearm. Two or three fibrous bands are occasionally found on the posterior surface of this membrane which descend obliquely from the ulna toward the radius, and which have consequently a direction contrary to that of the other fibres. It is in relation, in front, by its upper three-fourths with the Flexor longus pollicis on the outer side, and with the Flexor profundus digitorum on the inner, lying upon the interval between which are the anterior interosseous vessels and nerve; by its lower fourth, with the Pronator quadratus; behind, with the Supinator brevis, Extensor ossis metacarpi pollicis, Extensor brevis' pollicis, Extensor longus pollicis, Extensor indicis; and, near the wrist, with the anterior interosseous artery and posterior interosseous nerve.

3. Inferior or Distal Radio-ulnar Articulation (Articulatio Radioulnaris Distalis).

This is a pivot-joint, formed by the sigmoid cavity at the inner side of the lower end of the radius receiving the head of the ulna. The articular surfaces are covered by a thin layer of cartilage, and connected together by a capsule (capsula articularis), portions of which are usually described as distinct ligaments. The ligaments of the articulation are:

Anterior Radio-ulnar.
Posterior Radio-ulnar.
Triangular Interarticular Fibro-cartilage.

The Anterior Radio-ulnar Ligament (Fig. 228) is a narrow band of fibres extending from the anterior margin of the sigmoid cavity of the radius to the anterior surface of the head of the ulna.

The Posterior Radio-ulnar Ligament (Fig. 229) extends between similar points on the posterior surface of the articulation.

The Triangular Interarticular Fibro-cartilage (discus articularis) (Figs. 227 and 231) is triangular in shape, and is placed transversely beneath the head of the ulna, binding the lower end of this bone and the radius firmly together. Its periphery
is thicker than its centre, which is thin and occasionally perforated. It is attached by its apex to a depression which separates the styloid process of the ulna from the head of that bone; and by its base, which is thin, to the prominent edge of the radius, which separates the sigmoid cavity from the carpal articulating surface. Its margins are united to the ligaments of the wrist-joint. Its upper surface, smooth and concave, articulates with the head of the ulna, forming an arthrodial joint; its under surface, also concave and smooth, forms part of the wrist-joint and articulates with the cuneiform and inner part of the semilunar bone. Both surfaces are lined by a synovial membrane—the upper surface, by
one peculiar to the radio-ulnar articulation; the under surface, by the synovial membrane of the wrist.

**Synovial Membrane.**—The synovial membrane (Fig. 231) of this articulation has been called, from its extreme looseness, the *membrana sacciformis*. It projects horizontally inward between the head of the ulna and the interarticular fibro-cartilage, and upward between the radius and the ulna, forming a very loose cul-de-sac (*recessus sacciformis*). The quantity of synovia which it contains is usually considerable. The inferior radio-ulnar joint does not communicate with the wrist-joint.

**Actions.**—The movement in the inferior radio-ulnar articulation is just the reverse of that in the superior radio-ulnar joint. It consists of a movement of rotation of the lower end of the radius round an axis which corresponds to the centre of the head of the ulna. When the radius rotates forward, *pronation* of the forearm and hand is the result; and when backward, *supination*. It will thus be seen that in pronation and supination of the forearm and hand the radius describes a segment of a cone, the axis of which extends from the centre of the head of the radius to the middle of the head of the ulna. In this movement, however, the ulna is not quite stationary, but rotates a little in the opposite direction. So that it also describes the segment of a cone, though of smaller size than that described by the radius. The movement which causes this alteration in the position of the head of the ulna takes place principally at the shoulder-joint by a rotation of the humerus, but possibly also to a slight extent at the elbow-joint.1

**Surface Form.**—The position of the inferior radio-ulnar joint may be ascertained by feeling for a slight groove at the back of the wrist, between the prominent head of the ulna and the lower end of the radius, when the forearm is in a state of almost complete pronation.

### VII. Radio-carpal or Wrist-joint (Articulatio Radiocarpea) (Figs. 228, 229, 231).

The wrist is a condyloid articulation. The parts entering into its formation are the lower end of the radius and under surface of the interarticular fibro-cartilage, which form together the receiving cavity, and the scaphoid, semilunar, and the cuneiform bones, which form the condyle. The articular surface of the radius and the under surface of the interarticular fibro-cartilage are the receiving cavity, forming together a transversely elliptical concave surface. The articular surfaces of the scaphoid, semilunar, and cuneiform bones form together a smooth, convex surface, the condyle, which is received into the concavity above mentioned. All the bony surfaces of the articulation are covered with cartilage, and

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1 See Journal of Anatomy and Physiology, vol. xix., parts ii., iii., and iv.
connected together by a loose capsule (capsula articularis), which is divided into
the following ligaments:

- **External Lateral.**
- **Anterior.**
- **Internal Lateral.**
- **Posterior.**

The **External Lateral Ligament** (ligamentum collaterale carpi radiale) (Fig. 228) extends from the summit of the styloid process of the radius to the outer side of
the scaphoid, some of its fibres being prolonged to the trapezium and annular ligament.

The **Internal Lateral Ligament** (ligamentum collaterale carpi ulnare) (Fig. 228) is a rounded cord, attached, above, to the extremity of the styloid process of the ulna, and dividing below into two fasciculi, which are attached, one to the inner side of the cuneiform bone, the other to the pisiform bone and annular ligament.

The **Anterior** or **Volar Ligament** (ligamentum radiocarpeum volare) (Fig. 228) is a broad, membranous band, attached, above, to the anterior margin of the lower end of the radius, its styloid process, and the ulna; its fibres pass downward and inward to be inserted into the palmar surface of the scaphoid, semilunar, and cuneiform bones, some of the fibres being continued to the os magnum. In addition to this broad membrane there is a distinct rounded fasciculus, superficial to the rest, which passes from the base of the styloid process of the ulna to the semilunar and cuneiform bones. This ligament is perforated by numerous apertures for the passage of vessels, and is in relation, in front, with the tendons of the Flexor profundus digitorum and Flexor longus pollicis; behind, with the synovial membrane of the wrist-joint.

The **Posterior** or **Dorsal Ligament** (ligamentum radiocarpeum dorsale) (Fig. 229), less thick and strong than the anterior, is attached, above, to the posterior border of the lower end of the radius; its fibres pass obliquely downward and inward, to be attached to the dorsal surface of the scaphoid, semilunar, and cuneiform bones, being continuous with those of the dorsal carpal ligaments. This ligament is in relation, behind, with the extensor tendons of the fingers; in front, with the synovial membrane of the wrist.

**Synovial Membrane.**—The synovial membrane (Fig. 231) lines the inner surfa-
ces of the ligaments above described, extending from the lower end of the radius and interarticular fibro-cartilage above to the articular surfaces of the carpal bones below. It is loose and lax, and presents numerous folds, especially behind.

**Relations.**—The wrist-joint is covered in front by the flexor and behind by the extensor tendons (Fig. 230); it is also in relation with the radial and ulnar arteries.

The **arteries** supplying the joint are the anterior and posterior carpal branches
of the radial and ulnar, the anterior and posterior interosseous, and some ascending branches from the deep palmar arch.

The **nerves** are derived from the ulnar and posterior interosseous.

**Actions.**—The movements permitted in this joint are flexion, extension, abduction, adduction, and circumduction. Its actions will be further studied with those of the carpus, with which they are combined.

**Surface Form.**—The line of the radio-carpal joint is on a level with the apex of the styloid process of the ulna.

**Surgical Anatomy.**—The wrist-joint is rarely dislocated, its strength depending mainly
upon the numerous strong tendons which surround the articulation. Its security is further pro-
vided for by the number of small bones of which the carpus is made up, and which are united by very strong ligaments. The slight movement which takes place between the several bones serves to break the jars that result from falls or blows on the hand. Dislocation backward, which is the more common dislocation, simulates to a considerable extent Colles’s fracture of the radius, and is liable to be mistaken for it. The diagnosis can be easily made out by observing the relative position of the styloid processes of the radius and the ulna. In the natural condition
the styloid process of the radius is on a lower level—i.e., nearer the ground—when the arm hangs by the side, than that of the ulna, and the same would be the case in dislocation. In Colles's fracture, on the other hand, the styloid process of the radius is on the same or even a higher level than that of the ulna.

The wrist-joint is occasionally the seat of acute synovitis, the result of traumatism or arising in the rheumatic or pyemic state. When the synovial sacs is distended with fluid, the swelling is greatest on the dorsal aspect of the wrist, showing a general fulness, with some bulging between the tendons. The inflammation is prone to extend to the intercarpal joints and to attack also the sheaths of the tendons in the neighborhood. Chronic inflammation of the wrist is generally tuberculous, and often leads to similar disease in the synovial sheaths of adjacent tendons and of the intercarpal joints. The disease, therefore, when progressive, often leads to necrosis of the carpal bones, and the result is often unsatisfactory.

**VIII. Articulations of the Carpus (Articulatio Intercarpea)**

(Figs. 228, 229, 231).

These articulations may be subdivided into three sets:

1. The Articulations of the First Row of Carpal Bones.
2. The Articulations of the Second Row of Carpal Bones.
3. The Articulations of the Two Rows with each other.

1. **Articulations of the First Row of Carpal Bones.**

These are arthrodial joints. The ligaments connecting the scaphoid, semilunar, and cuneiform bones are—

<table>
<thead>
<tr>
<th>Dorsal</th>
<th>Two Interosseous</th>
<th>Palmar</th>
</tr>
</thead>
</table>

The **Dorsal Ligaments** (*ligamenta intercarpea dorsalia*) are placed transversely behind the bones of the first row; they connect the scaphoid and semilunar and the semilunar and cuneiform.

The **Palmar or Volar Ligaments** (*ligamenta intercarpea volaria*) connect the scaphoid and semilunar and the semilunar and cuneiform bones; they are less strong than the dorsal, and placed very deeply below the anterior ligament of the wrist.

The **Interosseous Ligaments** (*ligamenta intercarpea interossea*) (Fig. 231) are two narrow bundles of fibrous tissue connecting the semilunar bone on one side with the scaphoid, and on the other with the cuneiform. They are on a level with the superior surfaces of these bones, and close the upper part of the spaces between them. Their upper surfaces are smooth, and form with the bones the convex articular surfaces of the wrist-joint.

The ligaments connecting the pisiform bone are—

<table>
<thead>
<tr>
<th>Capsular</th>
<th>Two Palmar Ligaments</th>
</tr>
</thead>
</table>

The **Capsular Ligament** (*capsula articularis*) is a thin membrane which connects the pisiform bone to the cuneiform. It is lined with a separate synovial membrane.

The **Two Palmar Ligaments** are two strong fibrous bands which connect the pisiform to the unciform, the **piso-uncinate ligament** (*ligamentum pisohamatum*), and to the base of the fifth metacarpal bone, the **piso-metacarpal ligament** (*ligamentum pisometacarpeum*).

2. **Articulations of the Second Row of Carpal Bones.**

These are also arthrodial joints. The articular surfaces are covered with cartilage, and connected by the following ligaments:

<table>
<thead>
<tr>
<th>Dorsal</th>
<th>Three Interosseous</th>
<th>Palmar</th>
</tr>
</thead>
</table>

21
The **Dorsal Ligaments** (*ligamenta intercarpea dorsalia*) extend transversely from one bone to another on the dorsal surface, connecting the trapezium with the trapezoid, the trapezoid with the os magnum, and the os magnum with the unciform.

The **Palmar or Volar Ligaments** (*ligamenta intercarpea volaria*) have a similar arrangement on the palmar surface.

The **Three Interosseous Ligaments** (*ligamenta intercarpea interossea*) (Fig. 231) much thicker than those of the first row, are placed one between the os magnum and the unciform, a second between the os magnum and the trapezoid, and a third between the trapezium and trapezoid. The first of these is much the strongest, and the third is sometimes wanting.

3. **Articulations of the Two Rows of Carpal Bones with Each Other** (Figs. 228, 229, 231).

The joint between the scaphoid, semilunar, and cuneiform, and the second row of the carpus, or the mid-carpal joint, is made up of three distinct portions; in the centre the head of the os magnum and the superior surface of the unciform articulate with the deep, cup-shaped cavity formed by the scaphoid and semilunar bones, and constitute a sort of ball-and-socket joint. On the outer side the trapezium and trapezoid articulate with the scaphoid, and on the inner side the unciform articulates with the cuneiform, forming gliding joints.

The ligaments are:

- **Anterior.**
- **External Lateral.**
- **Posterior.**
- **Internal Lateral.**

The **Anterior, Palmar, or Volar Ligaments** (*ligamenta intercarpea volaria*) consist of short fibres, which pass, for the most part, from the palmar surface of the bones of the first row to the front of the os magnum.

The **Posterior or Dorsal Ligaments** (*ligamenta intercarpea dorsalia*) consist of short, irregular bundles of fibres passing between the bones of the first and second row on the dorsal surface of the carpus.

The **Lateral Ligaments** are very short: they are placed, one on the radial, the other on the ulnar side of the carpus; the former, the stronger and more distinct, connecting the scaphoid and trapezium bones, the latter the cuneiform and unciform; they are continuous with the lateral ligaments of the wrist-joint. In addition to these ligaments, a slender interosseous band sometimes connects the os magnum and the scaphoid.

**Synovial Membrane** (Fig. 231).—The synovial membrane of the carpus is very extensive: it passes from the under surface of the scaphoid, semilunar, and cuneiform bones to the upper surface of the bones of the second row, sending upward two prolongations—between the scaphoid and semilunar and the semilunar and cuneiform; sending downward three prolongations between the four bones of the second row, which are further continued onward into the carpo-metacarpal joints of the four inner metacarpal bones, and also for a short distance between the metacarpal bones. There is a separate synovial membrane between the pisiform and cuneiform bones.

**Actions.**—The articulation of the hand and wrist, considered as a whole, is divided into three parts: (1) the radius and the interarticular fibro-cartilage; (2) the meniscus, formed by the scaphoid, semilunar, and cuneiform, the pisiform bone having no essential part in the movements of the hand; (3) the hand proper, the metacarpal bones with the four carpal bones on which they are supported—viz., the trapezium, trapezoid, os magnum, and unciform. These three elements form two joints: (1) the superior, **wrist-joint proper**, between the meniscus and bones of the forearm; (2) the inferior, between the hand and meniscus, **transverse** or **mid-carpal joint**.
(1) The articulation between the forearm and carpus is a true condyloid articulation, and therefore all movements but rotation are permitted. Flexion and extension are the most free, and of these a greater amount of extension than flexion is permitted on account of the articulating surfaces extending farther on the dorsal than on the palmar aspect of the carpal bones. In this movement the carpal bones rotate on a transverse axis drawn between the tips of the styloid processes of the radius and ulna. A certain amount of adduction (or ulnar flexion) and abduction (or radial flexion) is also permitted. Of these the former is considerably greater in extent than the latter. In this movement the carpus revolves upon an antero-posterior axis drawn through the centre of the wrist. Finally, circumduction is permitted by the consecutive movements of adduction, extension, abduction, and flexion, with intermediate movements between them. There is no rotation, but this is provided for by the supination and pronation of the radius on the ulna. The movement of flexion is performed by the Flexor carpi radialis, the Flexor carpi ulnaris, and the Palmaris longus; extension, by the Extensor carpi radialis longior et brevior and the Extensor carpi ulnaris; adduction (ulnar flexion), by the Flexor carpi ulnaris and the Extensor carpi ulnaris; and abduction (radial flexion), by the Extensors of the thumb and the Extensor carpi radialis longior et brevior and the Flexor carpi radialis.

(2) The chief movements permitted in the transverse or mid-carpal joint are flexion and extension and a slight amount of rotation. In flexion and extension, which is the movement most freely enjoyed, the trapezium and trapezoid on the radial side and the unciform on the ulnar side glide forward and backward on the scaphoid and cuneiform respectively, while the head of the os magnum and the superior surface of the unciform rotate in the cup-shaped cavity of the scaphoid and semilunar. Flexion at this joint is freer than extension. A very trifling amount of rotation is also permitted, the head of the os magnum rotating round a vertical axis drawn through its own centre, while at the same time a slight gliding movement takes place in the lateral portions of the joint.

IX. Carpo-metacarpal Articulations (Articulationes Carpometacarpeae) (Figs. 228, 229, 231).

1. Articulation of the Metacarpal Bone of the Thumb with the Trapezium (Articulatio Carpometacarpea Pollicis).

This is a joint of reciprocal reception, and enjoys great freedom of movement, on account of the configuration of its articular surfaces, which are saddle-shaped, so that, on section, each bone appears to be received into a cavity in the other, according to the direction in which they are cut. The joint is surrounded by a capsular ligament.

The Capsular Ligament (capsula articularis) is thick and fibrous, but loose, and passes from the circumference of the upper extremity of the metacarpal bone to the rough edge bounding the articular surface of the trapezium; it is thickest externally and behind, and lined by a separate synovial membrane.

Movements.—In the articulation of the metacarpal bone of the thumb with the trapezium the movements permitted are flexion, extension, adduction, abduction, and circumduction. When the joint is flexed the metacarpal bone is brought in front of the palm and the thumb is gradually turned to the fingers. It is by this peculiar movement that the tip of the thumb is opposed to the other digits; for by slightly flexing the fingers the palmar surface of the thumb can be brought in contact with their palmar surfaces one after another.
2. **Articulations of the Metacarpal Bones of the Four Inner Fingers with the Carpus (Articulationes carpometacarpeae).**

The joints formed between the carpus and four inner metacarpal bones are arthrodial joints. The ligaments are—

Dorsal. Interosseous. Palmar.

The **Dorsal Ligaments** (*ligamenta carpometacarpea dorsalia*), the strongest and most distinct, connect the carpal and metacarpal bones on their dorsal surface.

The second metacarpal bone receives two fasciculi—one from the trapezium, the other from the trapezoid; the third metacarpal receives two—one from the trapezoid and one from the os magnum; the fourth two—one from the os magnum and one from the unciform; the fifth receives a single fasciculus from the unciform bone, which is continuous with a similar ligament on the palmar surface, forming an incomplete capsule.

The **Palmar or Volar Ligaments** (*ligamenta carpometacarpea volaria*) have a somewhat similar arrangement on the palmar surface, with the exception of the third metacarpal, which has three ligaments—an external one from the
CARPO-METACARPAL ARTICULATIONS

325

trapezium, situated above the sheath of the tendon of the Flexor carpi radialis; a middle one, from the os magnum; and an internal one, from the unciform.

The **Interosseous Ligaments** consist of short, thick fibres, which are limited to one part of the carpo-metacarpal articulation; they connect the contiguous inferior angles of the os magnum and unciform with the adjacent surfaces of the third and fourth metacarpal bones.

**Synovial Membrane.**—The synovial membrane is a continuation of that between the two rows of carpal bones. Occasionally, the articulation of the unciform with the fourth and fifth metacarpal bones has a separate synovial membrane.

The synovial membranes of the wrist and carpus (Fig. 231) are thus seen to be five in number. The *first*, the **membrana sacciformis** or the **recessus sacciformis** of the inferior radio-ulnar articulation, passes from the lower end of the ulna to

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**Diagram:**

- **Tendon of Flexor Sublimis Digitorum**
- **Tendon of Flexor Profundus Digitorum**
- **Lateral Ligament**
- **Transverse Metacarpal Ligament**
- **Anterior or Vaginal Ligament**
- **Second Lumbrical Muscle**
- **Anterior or Vaginal Ligament**
- **Second Palmar Interosseous Muscle**

**Fig. 232.**—Metacarpal bones and first phalanges of the second to the fifth finger of the right hand, with ligaments, from the volar surface. (Spalteholz.)

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the sigmoid cavity of the radius, and lines the upper surface of the interarticular fibro-cartilage. The *second* passes from the lower end of the radius and interarticular fibro-cartilage above to the bones of the first row below. The *third*, the most extensive, passes between the contiguous margins of the two rows of carpal bones—between the bones of the second row to the carpal extremities of the four inner metacarpal bones. The *fourth*, from the margin of the trapezium to the metacarpal bone of the thumb. The *fifth*, between the adjacent margins of the cuneiform and pisiform bones.

**Actions.**—The movement permitted in the carpo-metacarpal articulations of the four inner fingers is limited to a slight gliding of the articular surfaces upon each other, the extent of which varies in the different joints. Thus the articulation of the metacarpal bone of the little finger is most movable, then that of the ring finger. The metacarpal bones of the index and middle fingers are almost immovable.
3. Articulations of the Metacarpal Bones with Each Other (Articulaciones Intermetacarpeae (Figs. 228, 229, 231)).

The carpal extremities of the four inner metacarpal bones articulate with one another at each side by small surfaces covered with cartilages, and connected together by dorsal, palmar, and interosseous ligaments.

The Dorsal Ligaments (ligamenta basium oss. metacarp. dorsalia) and Palmar Ligaments (ligamenta basium oss. metacarp. volaria) pass transversely from one bone to another on the dorsal and palmar surfaces.

The Interosseous Ligaments (ligamenta basium oss. metacarp. interossea) pass between their contiguous surfaces, just beneath their lateral articular facets.

Synovial Membrane (Fig. 231).—The synovial membrane between the lateral facets is a reflection from that between the two rows of carpal bones.

The Transverse Metacarpal Ligament (ligamentum capitulorum oss. metacarpalium transversum) (Fig. 232) is a narrow, fibrous band which passes transversely across the anterior surfaces of the digital extremities of the four inner metacarpal bones, connecting them together. It is blended anteriorly with the palmar ligaments of the metacarpo-phalangeal articulations. To its posterior border is connected the fascia which covers the Interossei muscles. Its anterior surface is concave where the flexor tendons pass over it. Behind it the tendons of the Interossei muscles pass to their insertion.

X. Metacarpo-phalangeal Articulations (Articulationes Metacarpropalangeae) (Figs. 232, 233).

These articulations are of the condyloid kind, formed by the reception of the rounded head of the metacarpal bone into a shallow cavity in the extremity of the first phalanx. The expansion of the extensor tendon acts as a dorsal ligament. There is a capsular ligament which at certain points has strengthening ligaments. The ligaments are—

Anterior. Two Lateral.

The Anterior, Palmar, or Vaginal Ligament (glenoid ligament of Cruveilhier, ligamentum vaginale) is a thick, dense, fibrous structure, placed on the palmar surface of the joint in the interval between the lateral ligaments, to which it is connected; it is loosely united to the metacarpal bone, but very firmly to the base of the first phalanx. Its palmar surface is intimately blended with the transverse metacarpal ligament, and presents a
groove for the passage of the flexor tendons, the sheath surrounding which is connected to each side of the groove. By its deep surface it forms part of the articular surface for the head of the metacarpal bone, and is lined by a synovial membrane.

The **Lateral or Collateral Ligaments** (**ligamenta collateralia**) are strong, rounded cords placed one on each side of the joint, each being attached by one extremity to the posterior tubercle on the side of the head of the metacarpal bone, and by the other to the contiguous extremity of the phalanx.

**Actions.** — The movements which occur in these joints are **flexion**, **extension**, **adduction**, **abduction**, and **circumduction**; the lateral movements are very limited.

**Surface Form.** — The prominences of the knuckles do not correspond to the position of the joints either of the metacarpo-phalangeal or interphalangeal articulations. These prominences are invariably formed by the distal ends of the proximal bone of each joint, and the line indicating the position of the joint must be sought considerably in front of the middle of the knuckle. The usual rule for finding these joints is to flex the distal phalanx on the proximal one to a right angle; the position of the joint is then indicated by an imaginary line drawn along the middle of the lateral aspect of the proximal phalanx.

**XI. Articulations of the Phalanges (Articulationes Digitorum Manus)** (Fig. 233).

These are ginglymus joints. Each joint has a capsule, and certain accentuated portions are regarded as definite ligaments. These ligaments are—

Anterior or Palmar. Two Lateral (**ligamenta collateralia**).

The arrangement of these ligaments is similar to those in the metacarpo-phalangeal articulations; the extensor tendon supplies the place of a dorsal ligament.

**Actions.** — The only movements permitted in the phalangeal joints are **flexion** and **extension**; these movements are more extensive between the first and second phalanges than between the second and third. The movement of flexion is very considerable, but extension is limited by the anterior and lateral ligaments.

**ARTICULATIONS OF THE LOWER EXTREMITY.**

The articulations of the Lower Extremity comprise the following groups:

I. The Hip-joint.  
II. The Knee-joint.  
III. The Articulations between the Tibia and Fibula.  
IV. The Ankle-joint.  
V. The Articulations of the Tarsus.  
VI. The Tarso-metatarsal Articulations.  
VII. Articulations of the Metatarsal Bones with each other.  
VIII. The Metatarso-phalangeal Articulations.  
IX. The Articulations of the Phalanges.

I. The Hip-joint (**Articulatio Coxae**) (Figs. 234, 235, 236, 237, 238, 239).

This articulation is an enarthrodial or ball-and-socket joint, formed by the reception of the head of the femur into the cup-shaped cavity of the acetabulum. The articulating surfaces are covered with cartilage, that on the head of the femur being thicker at the centre than at the circumference, and covering the entire surface, with the exception of a depression just below its centre for the ligamentum teres; that covering the acetabulum is much thinner at the centre than at the circumference. It forms an incomplete cartilaginous ring of a horseshoe shape, being deficient below, where there is a circular depression, which is occu-
pied in the recent state by a mass of fat covered by synovial membrane. The ligaments of the joints are the

Capsular.  
Ilio-femoral.  
Transverse.  
Teres.  
Cotyloid.

The **Capsular Ligament** (*capsula articularis*) (Figs. 234, 235, 237, and 239) is a strong, dense, ligamentous capsule, embracing the margin of the acetabulum above and surrounding the neck of the femur below. Its *upper circumference*

![Diagram of hip joint](image)

Fig. 234.—Right hip-joint, from in front. (Spalteholz.)

is attached to the acetabulum, above and behind, two or three lines external to the cotyloid ligament; but in front it is attached to the outer margin of this ligament, and opposite to the notch, where the margin of this cavity is deficient, it is connected to the transverse ligament, and by a few fibres to the edge of the obturator foramen. Its *lower circumference* surrounds the neck of the femur, being attached, in front, to the spiral or anterior intertrochanteric line; above, to the base of the neck; behind, to the neck of the bone, about half
an inch above the posterior intertrochanteric line. From this insertion the fibres are reflected upward over the neck of the femur, forming a sort of tubular sheath, the **cervical reflection**, which blends with the periosteum and can be traced as far as the articular cartilage. On the surface of the neck of the femur some of these reflected fibres are raised into longitudinal folds, termed **retinacula**. It is much thicker at the upper and forepart of the joint, where the greatest amount of

![Right hip-joint, from behind. (The joint capsule, except for the strengthening ligaments, has been removed.) (Spalteholz.)](image)

resistance is required, than below and internally, where it is thin, loose, and longer than in any other part. It consists of two sets of fibres, circular and longitudinal. The circular fibres, **zona orbicularis** (Fig. 237), are most abundant at the lower and back part of the capsule, and form a sling or collar around the neck of the femur. Anteriorly they blend with the deep surface of the iliio-femoral ligament, and through its medium reach the anterior inferior spine of the ilium. The longitudinal fibres are greatest in amount at the upper and front part of the capsule, where they form distinct bands or accessory ligaments, of which the most important is the **iliio-femoral**. Other accessory bands are known as the pubo-
femoral or pubo-capsular ligament (ligamentum pubocapsulare), passing from the outer portion of the horizontal pubic ramus, the ilio-pectineal eminence, the obturator crest and the obturator membrane, to the front of the capsule; and ischio-capsular ligament or ligament of Bertin (ligamentum ischiocapsulare), passing from the ischium, just below the acetabulum, to blend with the circular fibres at the lower part of the joint. The external surface is rough, covered by numerous muscles, and separated in front from the Psoas and Iliacus muscles by a synovial bursa, which not infrequently communicates, by a circular aperture, with the cavity of the joint. It differs from the capsular ligament of the shoulder in being much less loose and lax, and in not being perforated for the passage of a tendon.

The Ilio-femoral or Y-ligament or Ligament of Bigelow (ligamentum ilio-femorale) (Figs. 234, 235, 237, and 238) is an accessory band of fibres extending obliquely across the front of the joint; it is intimately connected with the capsular ligament, and serves to strengthen it in this situation. It is attached, above, to the lower part of the anterior inferior spine of the ilium and the adjacent rim of the acetabulum; and, diverging below, forms two bands, of which one passes downward to be inserted into the lower part of the anterior intertrochanteric line; the other passes downward and outward to be inserted into the upper part of the same line and the adjacent part of the neck of the femur. Between the two bands is a thinner part of the capsule. Sometimes there is no division, but the ligament spreads out into a flat, triangular band, which is attached below into the whole length of the anterior intertrochanteric line. This ligament is frequently called the Y-shaped ligament of Bigelow; and
the outer or upper of the two bands is sometimes described as a separate ligament, under the name of the ilio-trochanteric ligament.

The Ligamentum Teres, or the Interarticular Ligament (ligamentum teres femoris) (Figs. 236, 237, and 239) is a triangular band implanted by its apex into the depression a little behind and below the centre of the head of the femur, and by its broad base into the margins of the cotyloid notch, becoming blended with the transverse ligament. It is formed of connective tissue, surrounded by a tubular sheath of synovial membrane. Sometimes only the synovial fold exists. Very rarely it is absent. The ligament is made tense when the hip is semiflexed,

and the limb adducted and rotated outward; it is, on the other hand, relaxed when the limb is abducted. It has, however, but little influence as a ligament, though it may to a certain extent limit movement, and would appear to be merely a "vestigial and practically useless ligament." It is probably a modification of the folds which in other joints fringe the margins of reflection of synovial membranes.

The Cotyloid Ligament (labrum glenoidale) (Fig. 239) is a fibro-cartilaginous rim attached to the margin of the acetabulum, the cavity of which it deepens; at the

\[\text{Fig. 237.—The right hip-joint, seen from before. (Toldt.)}\]

same time it protects the edges of the bone and fills up the inequalities on its surface. It bridges over the notch as the **transverse ligament of the acetabulum**, and thus forms a complete circle, which closely surrounds the head of the femur, and assists in holding it in its place, acting as a sort of valve. It is prismatic on section, its base being attached to the margin of the acetabulum and its opposite edge being free and sharp; whilst its two surfaces are invested by synovial membrane, the external one being in contact with the capsular ligament, the internal one being inclined inward, so as to narrow the acetabulum and embrace the cartilaginous surface of the head of the femur. It is much thicker above and behind than below and in front, and consists of close, compact fibres, which arise from different points of the circumference of the acetabulum and interface with each other at very acute angles.

The **transverse ligament of the acetabulum** (ligamentum transversum acetabuli) (Figs. 236 and 239) is in reality a portion of the cotyloid ligament, though differing from it in having no cartilage-cells amongst its fibres. It consists of strong, flattened fibres, which cross the notch at the lower part of the acetabulum and convert it into a foramen. Thus an interval is left beneath the ligament for the passage of nutrient vessels to the joint.

**Synovial Membrane** (Figs. 237 and 239).—The synovial membrane is very extensive. Commencing at the margin of the cartilaginous surface of the head of the femur, it covers all that portion of the neck which is contained within the joint; from the neck it is reflected on the internal surface of the capsular ligament, covers both surfaces of the cotyloid ligament and the mass of fat contained in the depression at the bottom of the acetabulum, and is prolonged in the form of a tubular sheath around the ligamentum teres, as far as the head of the femur. It sometimes communicates through a hole in the capsular ligament between the inner band of the Y-shaped ligament and the pubo-femoral ligament with a bursa situated on the under surface of the Ilio-psoas muscle.

The **muscles** in relation with the joint (Fig. 240) are, in front, the Psoas and Iliacus, separated from the capsular ligament by a synovial bursa; above, the reflected head of the Rectus and Gluteus minimus, the latter being closely adherent to the capsule; internally, the Obturator externus and Pectineus; behind, the Pyriformis, Gemellus superior, Obturator internus, Gemellus inferior, Obturator externus, and Quadratus femoris.

The **arteries** supplying the joint are derived from the obturator, sciatic, internal circumflex, and glutaeal.

The **nerves** are articular branches from the sacral plexus, great sciatic, obturator, accessory obturator, and a filament from the branch of the anterior crural supplying the rectus.

**Bursæ.**—Numerous bursæ exist in the neighborhood of the hip-joint. Some anatomists have counted twenty-one (Synnestredt). The chief ones are: 1. The **ilio-pectineal bursa** (bursa iliopectinea) (Fig. 240), between the ilio-psoas tendon and the capsule of the joint. It often communicates with the hip-joint. 2. The
subtendinous iliac bursa (bursa iliaca subtendinea), between the tendon of the psoas and iliacus and the lesser trochanter. 3. The ischio-gluteal bursa (bursa ischiadica m. glutaei maximi), between the Gluteus maximus muscle and the tuberosity of the ischium (not constant). 4. The bursa of the great trochanter (bursa trochanterica m. glutaei maximi), between the great trochanter and the Gluteus maximus muscle near the muscular insertion. 5. Two or three gluteo-femoral bursae (bursae glutaeofemorales) below. 6. The obturator bursa (bursa m. obturatorii interni), between the margin of the great sacro-sciatic notch and the tendon of the Obturator internus muscle. 7. The subcutaneous trochanteric bursa (bursa tro-

Fig. 239.—Right hip-joint. Frontal section. Posterior half, viewed from in front. (The joint surfaces have been somewhat pulled apart.) (Spalteholz.)

chanterica subcutanea), between the cutaneous surface and the great trochanter. Besides these there is a bursa between the great trochanter and the anterior part of the Gluteus medius—between the great trochanter and the posterior part of the Gluteus medius—between the great trochanter and the Gluteus minimus—beneath the Pyriformis muscle—between the small trochanter and the Quadratus femoris muscle, and there are bursae beneath the Biceps femoris muscle.

Actions.—The movements of the hip are very extensive, and consist of flexion, extension, adduction, abduction, circumduction, and rotation.
The hip-joint presents a very striking contrast to the shoulder-joint in the much more complete mechanical arrangements for its security and for the limitation of its movements. In the shoulder, as we have seen, the head of the humerus is not adapted at all in size to the glenoid cavity, and is hardly restrained in any of its ordinary movements by the capsular ligament. In the hip-joint, on the contrary, the head of the femur is closely fitted to the acetabulum for a distance extending over nearly half a sphere, and at the margin of the bony cup it is still more closely embraced by the cotyloid ligament, so that the head of the femur is held in its place by that ligament even when the fibres of the capsule have been quite divided (Humphry). The anterior portion of the capsule, described as the ilio-femoral ligament, is the strongest of all the ligaments in the body, and is put on the stretch by any attempt to extend the femur beyond a straight line with the trunk. That is to say, this ligament is the chief agent in maintaining the erect position without muscular fatigue; for a vertical line passing through the centre of gravity of the trunk falls behind the centres of rotation in the hip-joints, and therefore the pelvis tends to fall backward, but is prevented by the tension of the ilio-femoral and capsular ligaments. The security of the joint may be also provided for by the two bones being directly united through the ligamentum teres; but it is doubtful whether this so-called ligament can have much influence upon the mechanism of the joint. Flexion of the hip-joint is arrested by the soft parts of the thigh and abdomen being brought into contact when the leg is flexed on the thigh; and by the action of the hamstring muscles when the leg is extended; extension, by the tension of the ilio-femoral ligament and front of the capsule; adduction, by the thighs coming into contact; adduction, with flexion by the outer band of the ilio-femoral ligament, the outer part of the capsular ligament:

\[\text{Fig. 240.—Relation of muscles to hip-joint. (Henle.)}\]

1 The hip-joint cannot be completely flexed, in most persons, without at the same time flexing the knee, on account of the shortness of the hamstring muscles.—Cleland, Jour. of Anat. and Phys., No. 1, Old Series, p. 87.
abduction, by the inner band of the iliopsoas being the pubo-femoral
band; rotation outward, by the outer band of the iliopsoas being the pubo-femoral
band; rotation inward, by the ischio-capsular ligament and the hinder part of the capsu-
le. The muscles which flex the femur on the pelvis are the Psoas, Iliacus, Rectus, Sarktrius, Pectineus, Adductor longus and brevis, and the anterior fibres of the Gluteus medius and minimus. Extension is mainly performed by the Gluteus maximus, assisted by the hamstring muscles. The thigh is adducted by the Adductor magnus, longus, and brevis, the Pectineus, the Gracilis, and lower part of the Gluteus maximus, and adducted by the Gluteus medius and minimus and upper part of the Gluteus maximus. The muscles which rotate the thigh inward are the anterior fibres of the Gluteus medius, the Gluteus minimus, and the Tensor fasciae femoris; while those which rotate it outward are the posterior fibres of the Gluteus medius, the Pyriformis, Obturator externus and internus, Gemellus superior and inferior, Quadratus femoris, Iliacus, Gluteus maximus, the three Adductors, the Pectineus, and the Sartorius.

Surface Form.—A line drawn from the anterior superior spinous process of the ilium to the most prominent part of the tuberosity of the ischium (Nelaton's line) runs through the centre of the acetabulum, and would, therefore, indicate the level of the hip-joint; or, in other words, the upper border of the great trochanter, which lies on Nelaton's line, is on a level with the centre of the hip-joint.

Surgical Anatomy.—Inflammation of bursa about the hip-joint gives rise to confusing symptoms. Inflammation of one of the bursae over the great trochanter is not uncommon. Great pain is produced if any movement of the glutal muscles is permitted.

Enlargement of the bursa over the ischial tuberosity was long called weaver's button. Enlargement of the bursa beneath the iliopsoas may produce a large swelling. Bursal inflammation is not unusually mistaken for hip-joint disease.

In dislocation of the hip "the head of the thigh bone may rest at any point around its socket" (Bryant), but whatever position the head ultimately assumes, the primary displacement is generally downward and inward, the capsule giving way at its weakest—that is, its lower and inner—part. The situation that the head of the bone subsequently assumes is determined by the degree of flexion or extension, and of outward or inward rotation of the thigh at the moment of luxation, influenced, no doubt, by the iliopsoas ligament, which is not easily ruptured. When, for instance, the head is forced backward, this ligament forms a fixed axis, round which the head of the bone rotates, and the head is thus driven on to the dorsum of the ilium. The iliopsoas ligament also influences the position of the thigh in the various dislocations: in the dislocations backward it is tense, and produces inversion of the limb; in the dislocation on to the pubes it is relaxed, and therefore allows the external rotators to evert the thigh; while in the thyroid dislocation it is tense and produces flexion. The muscles inserted into the upper part of the femur, with the exception of the Obturator internus, have very little direct influence in determining the position of the bone. But Bigelow has endeavored to show that the Obitu-
ator internus is the principal agent in determining whether in the backward dislocations the head of the bone shall be ultimately lodged on the dorsum of the ilium or in or near the sciotic notch. In both dislocations the head passes, in the first instance, in the same direction; but, as Bigelow asserts, in the displacement on to the dorsum, the head of the bone travels up behind the acetabulum, in front of the muscle; while in the dislocation into the sciotic notch, the head passes behind the muscle, and is therefore prevented from reaching the dorsum, in consequence of the tendon of the muscle arching over the neck of the bone, and so remains in the neighborhood of the sciotic notch. Bigelow, therefore, distinguishes these two forms of dislocation by describing them as dislocations backward, "above and below," the Obturator internus.

The iliopsoas ligament is rarely torn in dislocations of the hip, and this fact is taken advantage of by the surgeon in reducing these dislocations by manipulation. It is made to act as a fulcrum to a lever, of which the long arm is the shaft of the femur, and the short arm the neck of the bone.

The hip-joint is rarely the seat of acute synovitis from injury, on account of its deep position and its thick covering of soft parts. Acute inflammation may, and does, frequently occur as the result of constitutional conditions, as rheumatism, pyemia, etc. When, in these cases, effusion takes place, and the joint becomes distended with fluid, the swelling is not very easy to detect on account of the thickness of the capsule and the depth of the articulation. It is principally to be found on the front of the joint, just internal to the iliopsoas ligament; or behind, at the lower and back part. In these two places the capsule is thinner than elsewhere.

Disease of the hip-joint is much more frequently of a chronic character and is usually of tuberculous origin. It begins either in the bones or in the synovial membrane, more frequently in the
THE ARTICULATIONS OR JOINTS

former, and probably, in most cases, in the growing, highly vascular tissue in the neighborhood of the epiphyseal cartilage. In this respect it differs very materially from tuberculous arthritis of the knee, where the disease often commences in the synovial membrane. The reasons why hip-disease so frequently begins near the epiphyseal cartilage are twofold: first, this part being the centre of rapid growth, its nutrition is unstable and inflammation is easily awakened; and, secondly, great strain is thrown upon it, from the frequency of falls and blows upon the hip, which causes crushing of the epiphyseal cartilage or the cancellous tissue in its neighborhood, with the results likely to follow such an injury. In addition to these, the depth of the joint protects it from the causes of synovitis.

In chronic hip-disease the affected limb assumes an altered position, the cause of which it is important to understand. In the early stage of a typical case the limb is flexed, abducted, and rotated outward. In this position all the ligaments of the joint are relaxed; the front of the capsule by flexion; the outer band of the ilio-femoral ligament by abduction; and the inner band of this ligament and the back of the capsule by rotation outward. It is, therefore, the position of the greatest ease. The condition is not quite obvious at first upon examining a patient. If the patient is laid in the supine position, the affected limb will be found to be extended and parallel with the other. But it will be found that the pelvis is tilted downward on the diseased side and the limb apparently longer than its fellow, and that the lumbar spine is arched forward (lordosis). If now the thigh is abducted and flexed, the tilting downward and the arching forward of the pelvis disappears. The condition is thus explained. A limb which is flexed and abducted is obviously useless for progression, and, to overcome the difficulty, the patient depresses the affected side of his pelvis in order to produce parallelism of his limbs, and at the same time rotates his pelvis on its transverse horizontal axis, so as to direct the limb downward instead of forward. In the latter stages of the disease the limb becomes flexed, adducted, and inverted. The position probably depends upon muscular action, at all events as regards the adduction. The Adductor muscles are supplied by the obturator nerve, which also largely supplies the joint. These muscles are therefore thrown into reflex action by the irritation of the peripheral terminations of this nerve in the inflamed articulation. Osteo-arthritis is not uncommon in the hip-joint, and it is said to be more common in the male than in the female, in whom the knee-joint is more frequently affected. It is a disease of middle age or more advanced period of life.

Congenital dislocation is more commonly met with in the hip-joint than in any other articulation. The displacement usually takes place on to the dorsum ili. It gives rise to extreme lordosis, and a waddling gait is noticed as soon as the child commences to walk. Excision of the hip may be required for disease or for injury, especially for gunshot wound. It may be performed either by an anterior or an external incision. The former one entails less interference with important structures, especially muscles, than the posterior one, but permits of less efficient drainage. In these days, however, when the surgeon aims at securing healing of his wound without suppuration, this second advantage is not of so much importance. In the operation in front the surgeon makes an incision three or four inches in length, starting immediately below and external to the anterior superior spinous process of the ilium, downward and inward between the Sartorius and Tensor fasciae femoris, to the neck of the bone, dividing the capsule at its upper part. A narrow-bladed saw now divides the neck of the femur, and the head of the bone is extracted with sequestrum forceps. All diseased tissue is carefully removed with a sharp spoon or scissors, and the cavity thoroughly flushed with a hot aseptic fluid.

The external method consists in making an incision three or four inches long, commencing midway between the top of the great trochanter and the anterior superior spine, and ending over the shaft, just below the trochanter. The muscles are detached from the great trochanter, and the capsule opened freely. The head and neck are freed from the soft parts and the bone sawn through just below the top of the trochanter with a narrow saw. The head of the bone is then levered out of the acetabulum. In both operations, if the acetabulum is eroded, it must be freely gouged.

II. The Knee-joint (Articulatio Genu).

The knee-joint was formerly described as a ginglymus or hinge-joint, but is really of a much more complicated character. It must be regarded as consisting of three articulations in one: one between each condyle of the femur and the corresponding tuberosity of the tibia, which are condyloid joints, and one between the patella and the femur, which is partly arthrodial, but not completely so, since the articular surfaces are not mutually adapted to each other, so that the movement is not a simple gliding one. This view of the construction of the knee-joint receives confirmation from the study of the articulation in some of the lower mammals,
where three synovial membranes are sometimes found, corresponding to these three subdivisions, either entirely distinct or only connected together by small communications. This view is further rendered probable by the existence of the two crucial ligaments within the joint, which must be regarded as the external and internal lateral ligaments of the inner and outer joints respectively. The existence of the ligamentum mucosum would further indicate a tendency to separation of the synovial cavity into two minor sacs, one corresponding to each joint.

The bones entering into the formation of the knee-joint are the condyles of the femur above, the head of the tibia below, and the patella in front. The bones are connected together by ligaments, some of which are placed on the exterior of the joint, while others occupy its interior.

**External Ligaments.**

Anterior, or Ligamentum Patellæ.  
Posterior.  
Internal Lateral.  
Two External Lateral. (The long external ligament is constant. The short external ligament is not always present.)  
Capsular.

**Interior Ligaments.**

Anterior, or External Crucial.  
Posterior, or Internal Crucial.  
Two Semilunar Fibro-cartilages.  
Transverse.  
Coronary.  
Ligamentum mucosum.  
Ligamenta alaria.  
Processes of Synovial Membrane.

The **Anterior Ligament**, or **Ligamentum Patellæ** (Figs. 241, 245, and 246), is the central portion of the common tendon of the Extensor muscles of the thigh, which is continued from the patella to the tubercle of the tibia, supplying the place of an anterior ligament. It is a strong, flat, ligamentous band about three inches in length, attached, above, to the apex of the patella and the rough depression on its posterior surface; below, to the lower part of the tubercle of the tibia, its superficial fibres being continuous over the front of the patella with those of the tendon of the Quadriceps extensor. The lateral portions of the tendon of the Extensor muscles pass down on either side of the patella, and are attached to the borders of this bone. The deep fascia and the quadriceps extensor muscle are inserted into the patella. Prolongations from the fascia and from the fibrous expansion of the muscle pass from the edges of the patella and from the ligament of the patella to the upper extremity of the tibia on each side of the tubercle; externally, and to the head of the fibula. They are termed lateral patellar ligaments (*retinacula* *patellae* *mediae* and *retinacula* *patellae* *laterale*), and merge into the capsule. The posterior surface of the ligamentum patellæ is separated from the front of the capsular ligament by a mass of fat.

The **Posterior Ligament** (*ligamentum popliteum obliquum*) (Fig. 241) is a broad, flat, fibrous band, formed of fasciculi separated from one another by apertures for the passage of vessels and nerves. It is attached, above, to the upper margin of the intercondyloid notch of the femur, and, below, to the posterior margin of the head of the tibia. Superficial to the main part of the ligament and forming a portion of it is a strong fasciculus derived from the tendon of the Semi-membranosus, and passing from the back part of the inner tuberosity of the tibia obliquely upward and outward to the back part of the outer condyle of the femur. This expansion from the tendon of the Semimembranosus muscle is called the **posterior ligament of Winslow** (*ligamentum posticum Winslowii*), and it merges with the posterior ligament. The posterior ligament forms part of the floor of the popliteal space, and the popliteal artery rests upon it.

The **Internal Lateral Ligament** (*ligamentum collaterale tibiale*) (Figs. 241 and 242) is a broad, flat, membranous band, thicker behind than in front, and situated
nearer to the back than the front of the joint. It is attached, above, to the inner tuberosity of the femur; below, to the inner tuberosity and inner surface of the shaft of the tibia to the extent of about two inches. It is crossed, at its lower part, by the tendons of the Sartorius, Gracilis, and Semitendinosus muscles, a synovial bursa being interposed. Its *deep surface* covers the anterior portion of the tendon of the Semimembranosus, with which it is connected by a few fibres, the synovial membrane of the joint, and the inferior internal articular vessels and nerve; it is intimately adherent to the internal semilunar fibro-cartilage.

The **External Lateral** or **Long External Lateral Ligament** (*ligamentum collaterale fibulare*) (Figs. 242 and 246) is a strong, rounded, fibrous cord situated nearer to the back than the front of the joint. It is attached, above, to the back part of the outer tuberosity of the femur; below, to the outer part of the head of the fibula. Its *outer surface* is covered by the tendon of the Biceps, which divides at its insertion into two parts, separated by the ligament. The ligament has, passing beneath it, the tendon of the Popliteus muscle and the inferior external articular vessels and nerve.

The **Short External Lateral Ligament** (*ligamentum laterale externum breve seu posticum*) (Fig. 242) is not a constant structure. It is an accessory bundle of fibres placed behind and parallel with the preceding, attached, above, to the lower and back part of the outer tuberosity of the femur; below, to the summit of the styloid process of the fibula. This ligament is intimately connected with the capsular ligament, and has, passing beneath it, the tendon of the Popliteus muscle and the inferior external articular vessels and nerve.
The Capsular Ligament (capsula articularis) (Fig. 241) consists of an exceedingly thin but strong, fibrous membrane which fills in the intervals left between the stronger bands above described, and is inseparably connected with them. In front it blends with and forms part of the lateral patellar ligaments and fills in the interval between the anterior and lateral ligaments of the joints, with which latter structures it is closely connected. It is deficient above the joint and beneath the tendon of the quadriceps extensor. Behind, it is formed chiefly of vertical fibres, which arise above from the condyles and intercondylar notch of the femur, and is connected below with the back part of the head of the tibia, being closely united with the origins of the Gastrocnemius, Plantaris, and Popliteus muscles. It passes in front of, but is inseparably connected with, the posterior ligament.

The Crucial Ligaments (ligamenta cruciata geni) (Figs. 172, 243, and 244) are two interosseous ligaments of considerable strength situated in the interior of the joint, nearer its posterior than its anterior part. They are called crucial because they cross each other somewhat like the lines of the letter X; and have received the names anterior crucial and posterior crucial, from the position of their attachment to the tibia.

The anterior or external crucial ligament (ligamentum cruciatum anterius) (Fig. 243) is attached to the depression in front of the spine of the tibia, being blended with the anterior extremity of the external semilunar fibro-cartilage, and, passing obliquely upward, backward, and outward, is inserted into the inner and back part of the outer condyle of the femur.

The posterior or internal crucial ligament (ligamentum cruciatum posterius) is stronger, but shorter and less oblique in its direction than the anterior. It is attached to the back part of the depression behind the spine of the tibia, to the popliteal notch, and to the posterior extremity of the external semilunar fibro-cartilage; and passes upward, forward, and inward, to be inserted into the outer and forepart of the inner condyle of the femur. It is in relation, in front, with the anterior crucial ligament; behind, with the capsular ligament.

The Semilunar Fibro-cartilages (meniscus) (Figs. 172, 243, 244, 245, and 246) are two crescentic lamellæ which serve to deepen the surface of the head of the tibia, for articulation with the condyles of the femur. The
circumference of each cartilage is thick, convex, and attached to the inside of the capsule of the knee; the inner border is thin, concave, and free. Their upper surfaces are concave, and in relation with the condyles of the femur; their lower surfaces are flat, and rest upon the head of the tibia. Each cartilage covers nearly the outer two-thirds of the corresponding articular surface of the tibia, leaving the inner third uncovered; both surfaces are smooth and invested by synovial membrane.

The internal semilunar fibro-cartilage (meniscus medialis) is nearly semicircular in form, a little elongated from before backward, and broader behind than in front; its anterior extremity, thin and pointed, is attached to a depression on the anterior margin of the head of the tibia, in front of the anterior crucial ligament; its posterior extremity is attached to the depression behind the spine, between the attachments of the external semilunar fibro-cartilage and the posterior crucial ligaments.
The external semilunar fibro-cartilage \((\text{meniscus lateralis})\) forms nearly an entire circle, covering a larger portion of the articular surface than the internal one. It is grooved on its outer side for the tendon of the Popliteus muscle. Its extremities, at their insertion, are interposed between the two extremities of the internal semilunar fibro-cartilage; the anterior extremity being attached in front of the spine of the tibia to the outer side of, and behind, the anterior crucial ligament, with which it blends; the posterior extremity being attached behind the spine of the tibia, in front of the posterior extremity of the internal semilunar fibro-cartilage. Just before its insertion posteriorly it gives off a strong fasciculus, the ligament of Wrisberg, which passes obliquely upward and outward, to be inserted into the inner condyle of the femur, close to the attachment of the posterior crucial ligament. Occasionally a small fasciculus is given off which passes forward to be inserted into the back part of the anterior crucial ligament. The
external semilunar fibro-cartilage gives off from its anterior convex margin a fasciculus which forms the transverse ligament.

The Transverse Ligament (ligamentum transversum genu) (Fig. 244) is a band of fibres which passes transversely from the anterior convex margin of the external semilunar fibro-cartilage to the anterior convex margin of the internal semilunar fibro-cartilage; its thickness varies considerably in different subjects, and it is sometimes absent altogether.

The Coronary Ligaments (ligamenta coronaria) are merely portions of the capsular ligament, which connect the circumference of each of the semilunar fibro-cartilages with the margin of the head of the tibia.

Synovial Membrane (Figs. 245 and 246).—The synovial membrane encloses the articular cavity (cavum articulare) of the knee-joint. It is the largest and most extensive synovial membrane in the body. Commencing above the upper border of the patella, it forms a short cul-de-sac beneath the Quadriceps extensor tendon of the thigh, on the lower part of the front of the shaft of the femur; this communicates, by an orifice of variable size, with a synovial bursa interposed between the tendon and the front of the femur (bursa suprapatellaris). On each side of the patella the synovial membrane extends beneath the aponeurosis of the Vasti muscles, and more especially beneath that of the Vastus internus. Below the patella it is separated from the anterior ligament by the anterior part of the capsule and a considerable quantity of adipose tissue, known as the infrapatellar pad (Fig. 245). In this situation the synovial membrane sends off a triangular prolongation, containing a few ligamentous fibres, which extends from the anterior part of the joint below the patella to the front of the intercondylloid notch. This fold has been termed the ligamentum mucosum (plica synovialis patellaris). It also sends off two fringe-like folds, called the ligamenta alaria (plcae alares) (Fig. 245), which extend from the sides of the ligamentum mucosum, upward and laterally between the patella and femur. On either side of the joint it passes downward from the femur, lining the capsule to its point of attachment to the semilunar cartilages; it may then be traced over the upper surfaces of these cartilages to their free borders, and from thence along their under surfaces to the tibia. At the back part of the external one it forms a cul-de-sac between the groove on its surface and the tendon of the Popliteus; it surrounds the crucial ligaments and lines the inner surface of the ligaments which enclose the joint. The pouch of synovial membrane between the Extensor tendon and front of the femur is supported, during the movements of the knee, by a small muscle, the Suberureus, which is inserted into the upper part of the capsular ligament.

The folds of synovial membrane and the fatty processes contained in them act, as it seems, mainly in padding to fill up interspaces and obviate concussions. Sometimes the bursa beneath the Quadriceps extensor is completely shut off from the rest of the synovial cavity, thus forming a closed sac between the Quadriceps and the lower part of the front of the femur; sometimes it communicates with the synovial cavity by a minute aperture; usually the two cavities are incompletely separated by a synovial fold.

Bursæ.—The bursæ about the knee-joint are the following: In front there are four bursæ: one is interposed between the patella and the skin. It is known as the prepatellar bursa (bursa prepatellaris subcutanea); another, of small size, between the upper part of the tuberosity of the tibia and the ligamentum patellae is called the deep infrapatellar bursa (bursa infrapatellaris profunda); and a third between the lower part of the tuberosity of the tibia and the skin, the subcutaneous tibial bursa (bursa subcutanea tuberositatis tibiae). A fourth bursa exists in front, the suprapatellar bursa (bursa suprapatellaris). It lies between the anterior surface of the lower end of the femur and the posterior surface of the quadriceps femoris. Spalteholz says that the supra-
patellar bursa is closely connected with the quadriceps tendon and is usually incompletely shut off from the cavity of the joint.\(^1\) Occasionally there is a bursa between the expansion of the fascia lata and the Quadriceps and the patella (\textit{bursa prepatellaris subfascialis}), and sometimes one between the tendon of the quadriceps and the anterior surface of the patella (\textit{bursa prepatellaris subcondylica}). On the outer side there are four bursae: (1) one beneath the outer head of the Gastrocnemius (which sometimes communicates with the joint); (2) one above the external lateral ligament between it and the tendon of the Biceps; (3) one beneath the external lateral ligament between it and the tendon of the Popliteus (this is sometimes only an expansion from the next bursa); (4) one beneath the tendon of the Popliteus (\textit{bursa musculi poplites}) between it and the condyle of the femur, which is almost always an extension from the synovial membrane of the joint. On the inner side there are five bursae: (1) one beneath the inner head of the Gastrocnemius, which sends a prolongation between the tendons of the Gastrocnemius and Semimembranosus; this bursa often communicates with the joint; (2) one above the internal lateral ligament between it and the tendons of the Sartorius, Gracilis, and Semitendinosus; (3) one beneath the internal lateral ligament between it and the tendon of the Semimembranosus: this is sometimes only an expansion from the next bursa; (4) one beneath the tendon of the Semimembranosus, between it and the head of the tibia; (5) sometimes there is a bursa between the tendons of the Semimembranosus and of the Semitendinosus.

**Structures around the Joint.**—In front and at the sides, the Quadriceps extensor; on the outer side, the tendons of the Biceps and the Popliteus and the external popliteal nerve; on the inner side, the Sartorius, Gracilis, Semitendinosus, and Semimembranosus; behind, an expansion from the tendon of the Semimembranosus, the popliteal vessels, and the internal popliteal nerve, the Popliteus, the Plantaris, and the inner and outer heads of the Gastrocnemius, some lymphatic glands, and fat.

The arteries supplying the joint are derived from the anastomotica magna branch of the femoral, articular branches of the popliteal, anterior and posterior recurrent branches of the anterior tibial, and a descending branch from the external circumflex of the Profunda.

The nerves are derived from the obturator, anterior crural, and external and internal popliteal.

**Actions.**—The knee-joint permits of movements of flexion and extension, and, in certain positions, of slight rotation inward and outward. The movement of flexion and extension does not, however, take place in a simple, finger-like manner, as in other joints, but is a complicated movement, consisting of a certain amount of gliding and rotation; so that the same part of one articular surface is not always applied to the same part of the other articular surface, and the axis of motion is not a fixed one. If the joint is examined while in a condition of extreme flexion, the posterior part of the articular surfaces of the tibia will be found to be in contact with the posterior rounded extremities of the condyles of the femur; and if a simple hinge-like movement were to take place, the axis, round which the revolving movement of the tibia occurs, would be in the back part of the condyle. If the leg is now brought forward into a position of semi-flexion, the upper surface of the tibia will be seen to glide over the condyles of the femur, so that the middle part of the articular facets are in contact, and the axis of rotation must therefore have shifted forward to nearer the centre of the condyles. If the leg is now brought into the extended position, a still further gliding takes place and a further shifting forward of the axis of rotation. This

\(^1\) Spalteholz's \textit{Hand Atlas of Human Anatomy}. Translated by Lewellys F. Barker.
is not, however, a simple movement, but is accompanied by a certain amount of rotation outward round a vertical axis drawn through the centre of the head of the tibia. This rotation is due to the greater length of the internal condyle, and to the fact that the anterior portion of its articular surface is inclined obliquely outward. In consequence of this it will be seen that toward the close of the movement of extension—that is to say, just before complete extension is effected—the tibia glides obliquely upward and outward over this oblique surface on the inner condyle, and the leg is therefore necessarily rotated outward. In flexion of the joint the converse of these movements takes place: the tibia glides backward round the end of the femur, and at the commencement of the movement the tibia is directed downward and inward along the oblique curve of the inner condyle, thus causing an inward rotation to the leg.

During flexion and extension the patella moves on the lower end of the femur, but this movement is not a simple gliding one; for if the articular surface of this bone is examined, it will be found to present on each side of the central vertical ridge two less marked transverse ridges, which divide the surface, except a small portion along the inner border, which is cut off by a slight vertical ridge into six facets (see Fig. 247), and therefore does not present a uniform curved surface as would be the case if a simple gliding movement took place. These six facets—three on each side of the median vertical ridge—correspond to and denote the parts of the bone respectively in contact with the condyles of the femur during flexion, semiflexion, and extension. In flexion only the upper facets on the patella are in contact with the condyles of the femur; the lower two-thirds of the bone rests upon the mass of fat which occupies the space between the femur and tibia. In the semiflexed position of the joint the middle facets on the patella rest upon the most prominent portion of the condyles, and thus afford greater leverage to the Quadriceps by increasing its distance from the centre of motion. In complete extension the patella is drawn up, so that only the lower facets are in contact with the articular surfaces of the condyles. The narrow strip along the inner border is in contact with the outer aspect of the internal condyle when the leg is fully flexed at the knee-joint. As in the elbow, so it is in the knee—the axis of rotation in flexion and extension is not precisely at right angles to the axis of the bone, but during flexion there is a certain amount of alteration of plane; so that, whereas in flexion the femur and tibia are in the same plane, in extension the one bone forms an angle of about 10 degrees with the other. There is, however, this difference between the two extremities: that in the upper, during extension, the humeri are parallel and the bones of the forearm diverge; in the lower, the femora converge below and the tibia are parallel.

In addition to the slight rotation during flexion and extension, the tibia enjoys an independent rotation on the condyles of the femur in certain positions of the joint. This movement takes place between the interarticular fibro-cartilages and the tibia, whereas the movement of flexion and extension takes place between the interarticular fibro-cartilages and the femur. So that the knee may be said to consist of two joints, separated by the fibro-cartilages: an upper, menisco-femoral, in which flexion and extension take place; and a lower, menisco-tibial, allowing of a certain amount of rotation. This latter movement can only take place in the semiflexed position of the limb, when all the ligaments are relaxed.

During flexion the ligamentum patellae is put upon the stretch, as is also the posterior crucial ligament in extreme flexion. The other ligaments are all relaxed.
by flexion of the joint, though the relaxation of the anterior crucial ligament is very trifling. During life flexion is checked by the contact of the leg with the thigh. In the act of extending the leg upon the thigh the ligamentum patellæ is tightened by the Quadriceps extensor; but when the leg is fully extended, as in the erect posture, the ligament becomes relaxed, so as to allow free lateral movement to the patella, which then rests on the front of the lower end of the femur. The other ligaments, with the exception of the posterior crucial, which is partly relaxed, are all on the stretch. When the limb has been brought into a straight line, extension is checked mainly by the tension of all the ligaments except the posterior crucial and ligamentum patellæ. The movements of rotation of which the knee is capable are permitted in the semiflexed condition by the partial relaxation of both crucial ligaments, as well as of the lateral ligaments. Rotation inward appears to be limited by the tension of the anterior crucial ligament, and by the interlocking of the two ligaments; but rotation outward does not appear to be checked by either crucial ligament, since they uncross during the execution of this movement, but it is checked by the lateral ligaments, especially the internal. The main function of the crucial ligaments is to act as a direct bond of union between the tibia and femur, preventing the former bone from being carried too far backward or forward. Thus the anterior crucial ligament prevents the tibia being carried too far forward by the extensor tendons, and the posterior crucial checks too great movement backward by the flexors. They also assist the lateral ligaments in resisting any lateral bending of the joint. The interarticular cartilages are intended, as it seems, to adapt the surface of the tibia to the shape of the femur to a certain extent, so as to fill up the intervals which would otherwise be felt in the varying positions of the joint, and to interrupt the jars which would be so frequently transmitted up the limb in jumping or falls on the feet; also to permit of the two varieties of motion, flexion and extension, and rotation, as explained above. The patella is a great defence to the knee-joint from any injury inflicted in front, and it distributes upon a large and tolerably even surface during kneeling the pressure which would otherwise fall upon the prominent ridges of the condyles; it also affords leverage to the Quadriceps extensor muscle when it acts upon the tibia; and Mr. Ward has pointed out1 how this leverage varies in the various positions of the joint, so that the action of the muscles produces velocity at the expense of force in the commencement of extension, and, on the contrary, at the close of extension tends to diminish velocity, and therefore the shock to the ligaments at the moment tension of the structures takes place.

Extension of the leg on the thigh is performed by the Quadriceps extensor; flexion by the hamstring muscles, assisted by the Gracilis and Sartorius, and, indirectly, by the Gastrocnemius, Popliteus, and Plantaris; rotation outward, by the Biceps; and rotation inward by the Popliteus, Semitendinosus, and, to a slight extent, the Semimembranosus, the Sartorius, and the Gracilis.

Surface Form.—The interval between the two bones entering into the formation of the knee-joint can always easily be felt. If the limb is extended, it is situated on a slightly higher level than the apex of the patella; but if the limb is slightly flexed, a knife carried horizontally backward immediately below the apex of the patella would pass directly into the joint. When the knee-joint is distended with fluid, the outline of the synovial membrane at the front of the knee may be fairly well mapped out.

Surgical Anatomy.—The bursa about the knee are frequently the seat of inflammation. Enlargement of the prepatellar bursa constitutes housemaid’s knee. The bursa beneath the Semimembranosus may enlarge greatly. It communicates with the knee-joint and can frequently be made to disappear by pressure when the knee is flexed. Treves points out that enlargement of the bursa between the biceps tendon and the external lateral ligament causes great pain because the peroneal nerve crosses the sac.2

From a consideration of the construction of the knee-joint it would at first sight appear to be

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1 Human Osteology, p. 405.  
2 Applied Anatomy.
THE ARTICULATIONS OR JOINTS

one of the least secure of any of the joints in the body. It is formed between the two longest bones, and therefore the amount of leverage which can be brought to bear upon it is very considerable; the articular surfaces are but ill adapted to each other, and the range and variety of motion which it enjoys is great. All these circumstances tend to render the articulation very insecure; but, nevertheless, on account of the very powerful ligaments which bind the bones together, the joint is one of the strongest in the body, and dislocation from traumatism is of very rare occurrence. When, on the other hand, the ligaments have been softened or destroyed by disease, partial displacement is very liable to occur, and is frequently brought about by the mere action of the muscles displacing the articular surfaces from each other. The tibia may be dislocated in any direction from the femur—forward, backward, inward, or outward; or a combination of two of these dislocations may occur—that is, the tibia may be dislocated forward and laterally, or backward and laterally, and any of these dislocations may be complete or incomplete. As a rule, however, the antero-posterior dislocations are complete, the lateral ones incomplete.

One or other of the semilunar cartilages may become displaced and nipped between the femur and tibia. The accident is produced by a twist of the leg when the knee is flexed, and is accompanied by a sudden pain and fixation of the knee in a flexed position. The cartilage may be displaced either inward or outward; that is to say, either inward toward the tibial spine, so that the cartilage becomes lodged in the intercondyloid notch; or outward, so that the cartilage projects beyond the margin of the articular surface. Acute synovitis, the result of traumatism or exposure to cold, is very common in the knee, on account of its superficial position. When distended with fluid, the swelling shows itself above and at the sides of the patella, reaching about an inch or more above the trochlear surface of the femur, and extending a little higher under the Vastus internus than the Vastus externus. Occasionally the swelling may extend two inches or more. At the sides of the patella the swelling extends lower at the inner side than it does on the outer side. The lower level of the synovial membrane is just above the level of the upper part of the head of the fibula. In the middle line it covers the upper third of the ligamentum patellae, being separated from it, however, by the capsule and a pad of fat. Chronic synovitis principally shows itself in the form of pulpy degeneration of the synovial membrane, the result of tuberculous arthritis. The reasons why tuberculous disease of the knee so often commences in the synovial membrane appear to be the complex and extensive nature of this sac; the extensive vascular supply to it; and the fact that injuries are generally diffused and applied to the front of the joint rather than to the ends of the bones. Syphilitic disease not unfrequently attacks the knee-joint. In the hereditary form of the disease it is usually symmetrical, attacking both joints, which become filled with synovial effusion, and is very intractable and difficult to cure. In the tertiary stage of acquired syphils, gummatous infiltration of the synovial membrane may take place. The knee is one of the joints most commonly affected with osteo-arthritis, and is said to be more frequently the seat of this disease in women than in men. The occurrence of the so-called loose cartilage is almost confined to the knee, though loose cartilages are occasionally met with in the elbow, and, rarely, in some other joints. Many of them occur in cases of osteo-arthritis, in which calcareous or cartilaginous material is formed in one of the synovial fringes and constitutes the foreign body, and may or may not become detached, in the former case only meriting the usual term, "loose" cartilage. In other cases they have their origin in the exudation of inflammatory lymph, and possibly, in some rare instances, a portion of the articular cartilage or one of the semilunar cartilages becomes detached and constitutes the foreign body.

Genu valgum, or knock-knee, is a common deformity of childhood, in which, owing to changes in and about the joint, the angle between the outer border of the tibia and femur is diminished, so that as the patient stands the two internal condyles of the femora are in contact, but the two internal malleoli of the tibiae are more or less widely separated from each other. When, however, the knees are flexed to a right angle, the two legs are practically parallel with each other. At the commencement of the disease there is a yielding of the internal lateral ligament and other fibrous structures on the inner side of the joint; as a result of this there is a constant undue pressure of the outer tuberosity of the tibia against the outer condyle of the femur. This extra pressure causes arrest of growth and, possibly, wasting of the outer condyle, and a consequent tendency for the tibia to become separated from the internal condyle. To prevent this the internal condyle becomes depressed; probably, as was first pointed out by Mikulicz, by an increased growth of the lower end of the diaphysis on its inner side, so that the line of the epiphyseal line becomes oblique instead of transverse to the axis of the bone, with a direction downward and inward. It is often said that the deformity is produced by undue length of the inner condyle, but in reality the condyle grows as the deformity progresses.

Excision of the knee-joint is most frequently required for tuberculous disease of this articulation, but is also practised in cases of disorganization of the knee after rheumatic fever, pyemia, etc., in osteo-arthritis, and in ankylosis. It is also occasionally called for in cases of injury, gunshot or otherwise. The operation is best performed either by a horseshoe incision, starting from one condyle, descending as low as the tubercle of the tibia, where it crosses the leg, and is then carried upward to the other condyle; or by a transverse incision across the patella. In this
latter incision the patella is either removed or sawn across, and the halves subsequently sutured together. The bones having been cleared, and in those cases where the operation is performed for tuberculous disease all pulpy tissue having been carefully removed, the section of the femur is first made. This should never include, in children, more than, at the most, two-thirds of the articular surface, otherwise the epiphyseal cartilage will be involved, with disastrous results as regards the growth of the limb. Afterward a thin slice should be removed from the upper end of the tibia, not more than half an inch. If any diseased tissue still appears to be left in the bones, it should be removed with the gouge rather than by making a further section of the bones.

III. Tibio-fibular Articulation (Articulatio Tibiofibularis).

The articulations between the tibia and fibula are effected by ligaments which connect both extremities, as well as the shafts of the bones. It may, consequently, be subdivided into three articulations: 1. The superior tibio-fibular articulation. 2. The middle tibio-fibular ligament or interosseous membrane. 3. The inferior tibio-fibular articulation.

1. Superior Tibio-fibular Articulation (Articulatio Tibiofibularis).

This articulation is an arthrodial joint. The contiguous surfaces of the bones present two flat, oval facets covered with cartilage, and connected together by the following ligaments:

Capsular.
Anterior Superior Tibio-fibular.
Posterior Superior Tibio-fibular.

The Capsular Ligament (capsula articularis) consists of a membranous bag which surrounds the articulation, being attached around the margins of the articular facets on the tibia and fibula, and is much thicker in front than behind. The new nomenclature considers the anterior and posterior ligaments as one ligament (ligamentum capituli fibulae).

The Anterior Superior Ligament (Fig. 248) consists of two or three broad and flat bands which pass obliquely upward and inward from the front of the head of the fibula to the front of the outer tuberosity of the tibia.

The Posterior Superior Ligament (Fig. 241) is a single thick and
broad band which passes upward and inward from the back part of the head of
the fibula to the back part of the outer tuberosity of the tibia. It is covered by
the tendon of the Popliteus muscle.

_Synovial Membrane._—A synovial membrane lines this articulation, which at its
upper and back part is occasionally continuous with that of the knee-joint.

2. **Middle Tibio-fibular Ligament or Interosseous Membrane**
(Membrana Interossea Cruris) (Fig. 248).

An interosseous membrane extends between the contiguous margins of the
tibia, and fibula and separates the muscles on the front from those on the back
of the leg. It consists of a thin, aponeurotic lamina composed of oblique fibres
which for the most part pass downward and outward between the interosseous
ridges on the two bones; some few fibres, however, pass in the opposite direction,
downward and inward. It is broader above than below. Its upper margin does
not quite reach the superior tibio-fibular joint, but presents a free concave border,
above which is a large, oval aperture for the passage of the anterior tibial vessels
forward to the anterior aspect of the leg. At its lower part is an opening for the
passage of the anterior peroneal vessels. It is continuous below with the inferior
interosseous ligament, and is perforated in numerous places for the passage of small
vessels. It is in relation, in front, with the Tibialis anticus, Extensor longus digi-
torum, Extensor proprius hallucis, Peroneus tertius, and the anterior tibial vessels
and nerve; behind, with the Tibialis posticus and Flexor longus hallucis.

3. **Inferior Tibio-fibular Articulation**
(Syndesmosis Tibiofibularis)
(Figs. 250, 251, 252).

This articulation is formed by the rough, convex surface of the inner side of
the lower end of the fibula, connected with a concave rough surface on the outer
side of the tibia. Below, to the extent of about two lines, these surfaces are smooth,
and covered with cartilage, which is continuous with that of the ankle-joint. The
ligaments of this joint are—

- Anterior Inferior Tibio-fibular.
- Posterior Inferior Tibio-fibular.
- Transverse or Inferior.
- Inferior Interosseous.

The _Anterior Inferior Ligament_ (ligamentum malleoli lateralis anterius) (Figs. 248
and 252) is a flat, triangular band of fibres, broader below than above, which extends
obliquely downward and outward, between the adjacent margins of the tibia and
fibula, on the front aspect of the articulation. It is in relation, in front, with the
Peroneus tertius, the aponeurosis of the leg, and the integument; behind, with the
inferior interosseous ligament; and lies in contact with the cartilage covering the
astragalus.

The _Posterior Inferior Ligament_ (ligamentum malleoli lateralis posterius) (Fig.
252), smaller than the preceding, is disposed in a similar manner on the posterior
surface of the articulation.

The _Transverse Ligament_ or _Inferior Ligament_ lies under cover of the posterior
ligament, and is a strong, thick band of yellowish fibres which passes transversely
across the back of the joint, from the external malleolus to the posterior border of
the articular surface of the tibia, almost as far as its malleolar process. This liga-
ment projects below the margin of the bones, and forms part of the articulating
surface for the astragalus.

The _Inferior Interosseous Ligament_ (Fig. 250) consists of numerous short, strong,
fibrous bands which pass between the contiguous rough surfaces of the tibia and
fibula, and constitute the chief bond of union between the bones. This ligament
is continuous above with the interosseous membrane.
Synovial Membrane.—The synovial membrane lining the articular surface is derived from that of the ankle-joint (Fig. 250).

Actions.—The movement permitted in these articulations is limited to a very slight gliding of the articular surfaces one upon another.

IV. The Tibio-tarsal Articulation or Ankle-joint (Articulatio Talocruralis) (Figs. 249, 250, 251, 252).

The ankle is a ginglymus or hinge-joint. The bones entering into its formation are the lower extremity of the tibia and its malleolus and the external malleolus of the fibula, which forms a mortise (Fig. 248) to receive the upper convex surface of the astragalus and its two lateral facets. The bony surfaces are covered with cartilage and connected together by a capsule (capsula articularis), which in places forms thickened bands constituting the following ligaments:


The Anterior Tibio-tarsal Ligament (ligamentum talotibiale anterius) is a broad, thin, membranous layer, attached, above, to the anterior margin of the lower extremity of the tibia; below, to the margin of the astragalus, in front of its articular surface. It is in relation, in front, with the Extensor tendons of the toes, with the tendons of the Tibialis anticus and Peroneus tertius, and the anterior tibial vessels and nerve; behind, it lies in contact with the synovial membrane.

The Posterior Tibio-tarsal Ligament (ligamentum talotibiale posterius) is very thin, and consists principally of transverse fibres. It is attached, above, to the margin of the articular surface of the tibia, blending with the transverse tibiofibular ligament; below, to the astragalus, behind its superior articular facet. Externally, where a somewhat thickened band of transverse fibres is attached to the hollow on the inner surface of the external malleolus, it is thicker than internally.
The **Internal Lateral** or **Deltoid Ligament** (*ligamentum calcaneotibiale* or *ligamentum deltoideum*) (Figs. 249, 250, and 251) is a strong, flat, triangular band, attached, above, to the apex and anterior and posterior borders of the inner malleolus. The most anterior fibres pass forward to be inserted into the scaphoid bone and the inferior calcaneo-scaphoid ligament; the middle descend almost perpendicularly to be inserted into the sustentaculum tali of the os calcis; and the posterior fibres pass backward and outward to be attached to the inner side of the astragalus. This ligament is covered by the tendons of the Tibialis posticus and Flexor longus digitorum muscles.

The **External Lateral Ligament** (*ligamenta talofibularia et calcaneofibulare*) (Figs. 251 and 252) consists of three distinctly specialized fasciculi of the capsule, taking different directions and separated by distinct intervals; for which reason it is described by some anatomists as three distinct ligaments.¹

The **anterior fasciculus** (*ligamentum talofibulare anterius*), the shortest of the three, passes from the anterior margin of the external malleolus forward and inward to the astragalus, in front of its external articular facet.

The **posterior fasciculus** (*ligamentum talofibulare posterius*), the most deeply seated, passes inward from the depression at the inner and back part of the external malleolus to a prominent tubercle on the posterior surface of the astragalus. Its fibres are almost horizontal in direction.

The **middle fasciculus** (*ligamentum calcaneofibulare*) (Figs. 251 and 252), the longest of the three, is a narrow, rounded cord passing from the apex of the external malleolus downward and slightly backward to a tubercle on the outer surface of the os calcis. It is covered by the tendons of the Peroneus longus and brevis.

**Synovial Membrane.**—The synovial membrane (Fig. 250) invests the inner surface of the ligaments, and sends a duplicature upward between the lower extremities of the tibia and fibula for a short distance.

Relations.—The tendons, vessels, and nerves in connection with the joint are, in front, from within outward, the Tibialis anticus, Extensor proprius hallucis, anterior tibial vessels, anterior tibial nerve, Extensor longus digitorum, and Peroneus tertius; behind, from within outward, the Tibialis posticus, Flexor longus digitorum, posterior tibial vessels, posterior tibial nerve, Flexor longus hallucis; and in the groove behind the external malleolus, the tendons of the Peroneus longus and brevis.

The arteries supplying the joint are derived from the malleolar branches of the anterior tibial and the peroneal.
The nerves are derived from the anterior and posterior tibial.

**Actions.**—The movements of the joint are those of *flexion* and *extension*. Flexion consists in the approximation of the dorsum of the foot to the front of the leg, while in extension the heel is drawn up and the toes pointed downward. The malleoli tightly embrace the astragalus in all positions of the joint, so that any slight degree of lateral movement which may exist is simply due to stretching of the inferior tibio-fibular ligaments and slight bending of the shaft of the fibula. Of the ligaments, the internal, or deltoid, is of very great power—so much so that it usually resists a force which fractures the process of bone to which it is attached. Its middle portion, together with the middle fasciculus of the external lateral ligament, binds the bones of the leg firmly to the foot and resists displacement in every direction. Its anterior and posterior fibres limit extension and flexion of the foot respectively, and the anterior fibres also limit abduction. The posterior portion of the external lateral ligament assists the middle portion in resisting the displacement of the foot backward, and deepens the cavity for the reception of the astragalus. The anterior fasciculus is a security against the displacement of the foot forward, and limits extension of the joint. The movements of *inversion* and *eversion* of the foot, together with the minute changes in form by which it is applied to the ground or takes hold of an object in climbing, etc., are mainly effected in the tarsal joints, the one which enjoys the greatest amount of motion being that between the astragalus and os calcis behind and the scaphoid and cuboid in front. This is often called the *transverse* or *medio-tarsal joint*, and it can, with the subordinate joints of the tarsus, replace the ankle-joint in a great measure when the latter has become ankylosed.

*Extension* of the tarsal bones upon the tibia and fibula is produced by the Gastrocnemius, Soleus, Plantaris, Tibialis posticus, Peroneus longus and brevis, Flexor longus digitorum, and Flexor longus hallucis; *flexion*, by the Tibialis anticus, Peroneus tertius, Extensor longus digitorum, and Extensor proprius hallucis.

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1 The student must bear in mind that the Extensor longus digitorum and Extensor proprius hallucis are extensors of the toes, but flexors of the ankle, and that the Flexor longus digitorum and Flexor longus hallucis are flexors of the toes, but *extensors* of the ankle.—Ed. of 15th English Edition.
(Fig. 251); inversion, in the extended position, is produced by the Tibialis anticus and posticus; and eversion by the Peronei.

**Surface Form.**—The line of the ankle-joint may be indicated by a transverse line drawn across the front of the lower part of the leg, about half an inch above the level of the tip of the internal malleolus.

**Surgical Anatomy.**—Displacement of the trochlear surface of the astragulus from the tibiofibular mortise is not of common occurrence, as the ankle-joint is a very strong and powerful articulation, and great force is required to produce dislocation. Nevertheless, dislocation does occasionally occur, both in an antero-posterior and a lateral direction. In the latter, which is the most common, fracture is a necessary accompaniment of the injury. The dislocation in these cases is somewhat peculiar, and is not a displacement in a horizontally lateral direction, such as usually occurs in lateral dislocations of ginglymoid joints, but the astragulus undergoes a partial rotation round an antero-posterior axis drawn through its own centre, so that the superior surface, instead of being directed upward, is inclined more or less inward or outward according to the variety of the displacement.

The ankle-joint is more frequently sprained than any joint in the body, and this may lead to acute synovitis. In these cases, when the synovial sac is distended with fluid, the bulging appears principally in the front of the joint, beneath the anterior tendons, and on either side, between the tibialis anticus and the internal lateral ligament on the inner side, and between the Peroneus tertius and the external lateral ligament on the outer side. In addition to this, bulging frequently occurs posteriorly, and a fluctuating swelling may be detected on either side of the tendo Achillis.

Chronic synovitis may result from frequent sprains, and when once this joint has been sprained it is more liable to a recurrence of the injury than it was before; chronic synovitis may be tuberculous in its origin, the disease usually commencing in the astragulus and extending to the joint, though it may commence as a synovitis the result probably of some slight strain in a tuberculous subject.

**Excision of the ankle-joint** is not often performed for two reasons. In the first place, disease of the articulation for which this operation is indicated is frequently associated with disease of the tarsal bones, which prevents its performance; and, secondly, the foot after excision is frequently of very little use; far less, in fact, than after a Syme's amputation, which is often, therefore, a preferable operation in these cases. Excision may, however, be attempted in a case of tuberculous arthritis in a young and otherwise healthy subject, where the disease is limited to the bones forming the joint. It may also be required after injury where the vessels and nerves have not been damaged and the patient is young and free from visceral disease. The excision is best performed through two lateral incisions. One commencing two and a half inches above the external malleolus, carried down the posterior border of the fibula, round the end of the bone, and then forward and downward as far as the calcaneo-cuboid joint, midway between the tip of the external malleolus and the tuberosity on the fifth metatarsal bone. Through this incision
the fibula is cleared, the external lateral ligament is divided, and the bone sawn through about half an inch above the level of the ankle-joint and removed. A similar curved incision is now made on the inner side of the foot, commencing two and a half inches above the lower end of the tibia, carried down the posterior border of the bone, round the internal malleolus, and forward and downward to the tuberosity of the scaphoid bone. Through this incision the tibia is cleared in front and behind, the internal lateral, the anterior and posterior ligaments divided, and the end of the tibia protruded through the wound by displacing the foot outward, and sawn off sufficiently high to secure a healthy section of bone. The articular surface of the astragalus is now to be sawn off or the whole bone removed. In cases where the operation is performed for tuberculous arthritis the latter course is probably preferable, as the injury done by the saw is frequently the starting point of fresh caries; and after removal of the whole bone the shortening is not appreciably increased, and the result as regards union appears to be as good as when two sawn surfaces of bone are brought into apposition.

V. Articulations of the Tarsus (Articulationes Intertarseae) (Figs. 249, 251, 252, 254, 255).

1. Articulation of the Os Calcis and Astragalus or the Calcaneo-astragaloid Articulation (Articulatio Talocalcanea) (Fig. 251).

The articulations between the os calcis and astragalus are two in number—anterior and posterior. They are arthrodial joints. The bones are connected together by a capsule (capsula articularis), which is at certain points accentuated into definite ligaments. There are five ligaments in this articulation:

- External Calcaneo-astragaloid.
- Anterior Calcaneo-astragaloid.
- Internal Calcaneo-astragaloid.
- Posterior Calcaneo-astragaloid.
- Interosseous.

The External Calcaneo-astragaloid Ligament (ligamentum talocalcaneum laterale) (Fig. 252) is a short, strong, fasciculus passing from the outer surface of the astragalus, immediately beneath its external malleolar facet, to the outer surface of the os calcis. It is placed in front of the middle fasciculus of the external lateral ligament of the ankle-joint, with the fibres of which it is parallel.

The Internal Calcaneo-astragaloid Ligament (ligamentum talocalcaneum mediale) is a band of fibres connecting the internal tubercle of the back of the astragalus with the back of the sustentaculum tali. Its fibres blend with those of the inferior calcaneo-scaphoid ligament.

The Anterior Calcaneo-astragaloid Ligament (ligamentum talocalcaneum anterius) passes from the front and outer surface of the neck of the astragalus to the superior surface of the os calcis.

The Posterior Calcaneo-astragaloid Ligament (ligamentum talocalcaneum posterius) connects the external tubercle of the astragalus with the upper and inner part of the os calcis; it is a short band, the fibres of which radiate from their narrow attachment to the astragalus.

The Interosseous Ligament (ligamentum talocalcaneum interosseum) (Figs. 250, 251, and 255) forms the chief bond of union between the bones. It consists of numerous vertical and oblique fibres attached by one extremity to the groove between the articulating facets on the under surface of the astragalus; by the other to a corresponding depression on the upper surface of the os calcis. It is very thick and strong, being at least an inch in breadth from side to side, and serves to unite the os calcis and astragalus solidly together.

Synovial Membrane.—The synovial membranes (Fig. 255) are two in number: one for the posterior calcaneo-astragaloid articulation; a second for the anterior calcaneo-astragaloid joint. The latter synovial membrane is continued forward between the contiguous surfaces of the astragalus and scaphoid bones.
ARTICULATIONS OF THE TARSUS

Actions.—The movements permitted between the astragalus and os calcis are limited to a gliding of the one bone on the other in a direction from before backward, and from side to side.

2. Articulation of the Os Calcis with the Cuboid or the Calcaneo-
cuboid Articulation (ArticulatioCalcaneocuboida) (Fig. 251).

In this joint the articular capsule (capsula articularis) is strengthened at certain points by definite ligaments.

The ligaments connecting the os calcis with the cuboid are four in number:

Dorsal or Superior Calcaneo-cuboid. Two Plantar
The Internal Calcaneo-cuboid. Long Calcaneo-cuboid.

The Superior Calcaneo-cuboid Ligament (ligamentumcalcaneocuboidum dorsale) (Fig. 252) is a broad portion of the capsule which passes between the contiguous surfaces of the os calcis and cuboid on the dorsal surface of the joint.

The Internal Calcaneo-cuboid or the Interosseous Ligament (parscalcaneo-
cuboidae ligamenti bifurcati) is a short but thick and strong band of fibres arising from the os calcis, in the deep hollow which intervenes between it and the astragalus, and closely blended, at its origin, with the superior calcaneo-
cuboid ligament. These two ligaments are often regarded as a single bifur-
cated ligament (ligamentumbifurcatum). The internal calcaneo-cuboid ligament is inserted into the inner side of the cuboid bone. This ligament forms one of the chief bonds of union between the first and second rows of the tarsus.

The Long Calcaneo-cuboid or Long Plantar or Superficial Long Plantar Ligament (ligamentumplantarelongum) (Fig. 254), the more superficial of the two plantar ligaments, is the longest of all the ligaments of the tarsus: it is attached to the under surface of the os calcis, from near the tuberosities, as far forward as the anterior tubercle; its fibres pass forward to be attached to the ridge on the under surface of the cuboid bone, the more superficial fibres being continued onward to the bases of the second, third, and fourth metatarsal bones. This ligament crosses the groove on the under surface of the cuboid bone, converting it into a canal for the passage of the tendon of the Peroneus longus.

The Short Calcaneo-cuboid or Short Plantar Ligament (ligamentumcalcaneo-
cuboidaeplantare) (Fig. 254) lies nearer the bones than the preceding, from which it is separated by a little areolar tissue. It is exceedingly broad, about an inch in length, and extends from the tubercle and the depression in front of it, on the forepart of the under surface of the os calcis, to the inferior surface of the cuboid bone behind the peroneal groove.

Synovial Membrane (Fig. 255).—The synovial membrane in this joint is distinct. It lines the inner surface of the ligaments.

Actions.—The movements permitted between the os calcis and cuboid are limited to a slight gliding upon each other.

3. The Ligaments Connecting the Os Calcis and Scaphoid or the Calcaneo-scaphoid Articulation Ligaments.

Though these two bones do not directly articulate, they are connected together by two ligaments:

Superior or External Calcaneo-scaphoid.
Inferior or Internal Calcaneo-scaphoid.

The Superior or External Calcaneo-scaphoid or Calcaneo-navicular (parscalcaneo-navicularisligamenti bifurcati) arises, as already mentioned, with the internal calcaneo-cuboid in the deep hollow between the astragalus and os calcis,
constituting a part of the ligamentum bifurcatum; it passes forward from the upper surface of the anterior extremity of the os calcis to the outer side of the scaphoid bone. These two ligaments resemble the letter Y, being blended together behind, but separated in front.

The Inferior or Internal Calcaneo-scaphoid or Calcaneo-navicular (ligamentum calcaneonaviculare plantare) (Fig. 254) is by far the larger and stronger of the two ligaments between these bones; it is a broad and thick band of fibres, which passes forward and inward from the anterior margin of the sustentaculum tali of the os calcis to the under surface of the scaphoid bone. This ligament not only serves to connect the os calcis and scaphoid, but supports the head of the astragalus, forming part of the articular cavity in which it is received. The upper surface presents a fibro-cartilaginous facet, lined by the synovial membrane continued from the anterior calcaneo-astragaloid articulation, upon which a portion of the head of the astragalus rests. Its under surface is in contact with the tendon of the Tibialis posticus muscle; its inner border is blended with the forepart of the Deltoid ligament, thus completing the socket for the head of the astragalus.

Surgical Anatomy.—The inferior calcaneo-scaphoid ligament, by supporting the head of the astragalus, is principally concerned in maintaining the arch of the foot, and when it yields the head of the astragalus is pressed downward, inward, and forward by the weight of the body, and the foot becomes flattened, expanded, and turned outward, constituting the disease known as flat-foot. This ligament contains a considerable amount of elastic fibre, so as to give elasticity to the arch and spring to the foot; hence it is sometimes called the “spring” ligament. It is supported, on its under surface, by the tendon of the Tibialis posticus, which spreads out at its insertion into a number of fasciculi which are attached to most of the tarsal and metatarsal bones; this prevents undue stretching of the ligament and is a protection against the occurrence of flat-foot.

**Fig. 254.—Ligaments of the plantar surface of the foot.**

4. Articulation of the Astragalus with the Scaphoid Bone or the Astragaloc-saphoid Articulation (Articulatio Talonavicularris) (Fig. 251).

The articulation between the astragalus and scaphoid is an arthrodial joint: the rounded head of the astragalus being received into the conecavity formed by the posterior surface of the scaphoid, the anterior articulating surface of the calcaneum, and the upper surface of the inferior calcaneo-scaphoid ligament, which fills up the triangular interval between these bones. The only ligament of this joint is the superior astragaloscaphoid (Fig. 249). It is a broad band, which passes obliquely forward from the neck of the astragalus to the superior surface of the scaphoid bone. It is thin, and weak in texture, and covered by the Extensor tendons. The inferior calcaneo-scaphoid ligament supplies the place of an inferior astragalos-caphoid ligament.

1 Mr. Hancock describes an extension of this ligament upward on the inner side of the foot, which completes the socket of the joint in that direction (Lancet, 1866, vol. i, p. 618).—Ed. of 15th English Edition.
Synovial Membrane (Fig. 255).—The synovial membrane which lines the joint is continued forward from the anterior calcaneo-astragaloid articulation.

Actions.—This articulation permits of considerable mobility, but its feebleness is such as to allow occasionally of dislocation of the other bones of the tarsus from the astragalus.

The transverse tarsal or medio-tarsal joint (articulatio tarsi transversa [Chopart]) (Figs. 251 and 256) is formed by the articulation of the os calcis with the cuboid, and by the articulation of the astragalus with the scaphoid. The movement which takes place in this joint is more extensive than that in the other tarsal joints, and consists of a sort of rotation by means of which the sole of the foot may be slightly flexed and extended or carried inward (inverted) and outward (everted).

5. The Articulation of the Scaphoid with the Cuneiform Bones (Articulatio Cuneonavicularis) (Fig. 251).

The scaphoid bone is connected to the three cuneiform bones by

Dorsal and Plantar ligaments.

The Dorsal Ligaments (ligamenta navicularicuneiformia dorsalia) (Figs. 249 and 251) are small, longitudinal bands of fibrous tissue arranged as three bundles, one to each of the cuneiform bones. That bundle of fibres which connects the scaphoid with the internal cuneiform is continued round the inner side of the articulation to be continuous with the plantar ligament which connects these two bones.

The Plantar Ligaments (ligamenta navicularicuneiformia plantaria) (Fig. 254) have a similar arrangement to those on the dorsum. They are strengthened by processes given off from the tendon of the Tibialis posticus.

Synovial Membrane (Fig. 255).—The synovial membrane of these joints is part of the great tarsal synovial membrane.

Actions.—The movements permitted between the scaphoid and cuneiform bones are limited to a slight gliding upon each other.

6. The Articulation of the Scaphoid with the Cuboid (Articulatio Cubonavicularis).

The scaphoid bone is connected with the cuboid by

Dorsal, Plantar, and Interosseous ligaments.

The Dorsal Ligament (ligamentum cuboideonaviculare dorsale) (Fig. 252) consists of a band of fibrous tissue which passes obliquely forward and outward from the scaphoid to the cuboid bone.

The Plantar Ligament (ligamentum cuboideonaviculare plantare) consists of a band of fibrous tissue which passes nearly transversely between these two bones.

The Interosseous Ligament (Figs. 251 and 255) consists of strong transverse fibres which pass between the rough non-articular portions of the lateral surfaces of these two bones.

Synovial Membrane (Fig. 255).—The synovial membrane of this joint is part of the great tarsal synovial membrane.

Actions.—The movements permitted between the scaphoid and cuboid bones are limited to a slight gliding upon each other.

7. The Articulations of the Cuneiform Bones with Each Other or the Intercuneiform Articulations (Fig. 251).

These bones are connected together by

Dorsal, Plantar, and Interosseous ligaments.
The Dorsal Ligaments (ligamenta intercuneiformia dorsalia) consist of two bands of fibrous tissue which pass transversely, one connecting the internal with the middle cuneiform, and the other connecting the middle with the external cuneiform.

The Plantar Ligaments (ligamenta intercuneiformia plantaria) have a similar arrangement to those on the dorsum. They are strengthened by the processes given off from the tendon of the Tibialis posticus.

The Interosseous Ligaments (ligamenta intercuneiformia interossea) consist of strong transverse fibres which pass between the rough non-articular portions of the lateral surfaces of the first and second and the second and third cuneiform bones. The outer portion of the third cuneiform is attached to the cuboid by the ligamentum cuneocuboideum interosseum.

Synovial Membrane (Fig. 255).—The synovial membrane of these joints is part of the great tarsal synovial membrane.

Actions.—The movements permitted between the cuneiform bones are limited to a slight gliding upon each other.

8. THE ARTICULATION OF THE EXTERNAL CUNEIFORM BONE WITH THE CUBOID (Fig. 251).

These bones are connected together by

Dorsal, Plantar, and Interosseous ligaments.

The Dorsal Ligament (ligamentum cuneocuboideum dorsale) (Fig. 252) consists of a band of fibrous tissue which passes transversely between these two bones.

The Plantar Ligament (ligamentum cuneocuboideum plantare) has a similar arrangement. It is strengthened by a process given off from the tendon of the Tibialis posticus.

The Interosseous Ligament (ligamentum cuneocuboideum interosseum) (Fig. 251) consists of strong transverse fibres which pass between the rough non-articular portions of the lateral surfaces of the adjacent sides of these two bones.

Synovial Membrane (Fig. 255).—The synovial membrane of this joint is part of the great tarsal synovial membrane.

Actions.—The movements permitted between the external cuneiform and cuboid are limited to a slight gliding upon each other.

Nerve-supply.—All the joints of the tarsus are supplied by the anterior tibial nerve.

Surgical Anatomy.—In spite of the great strength of the ligaments which connect the tarsal bones together, dislocation at some of the tarsal joints does occasionally occur; though, on account of the spongy character of the bones, they are more frequently broken than dislocated, as the result of violence. When dislocation does occur, it is most commonly in connection with the astragalus; for not only may this bone be dislocated from the tibia and fibula at the ankle-joint, but the other bones may be dislocated from it, the trochlear surface of the bone remaining in situ in the tibio-fibular mortise. This constitutes what is known as the subastragaloid dislocation. Or, again, the astragalus may be dislocated from all its connections—from the tibia and fibula above, the os calcis below, and the scaphoid in front—and may even undergo a rotation, either on a vertical or horizontal axis. In the former case the long axis of the bone becoming directed across the joint, so that the head faces the articular surface on one or other malleolus; or, in the latter, the lateral surfaces becoming directed upward and downward, so that the trochlear surface faces to one or the other side. Finally, dislocation may occur at the medio-tarsal joint, the anterior tarsal bones being luxated from the astragalus and calcaneum. The other tarsal bones are also, occasionally, though rarely, dislocated from their connections.

Pes planus, flat-foot, or splay-foot is a condition in which there is abduction, eversion, and loss of both the longitudinal and the transverse arch. The head of the astragalus passes downward and inward; the anterior portion of the foot is turned outward and the inner side of the foot is lengthened and broadened. Deformity is increased when standing. In severe cases
the patient walks on the inner side of the foot. The condition is due to yielding of the tarsal ligaments. Abduction is permitted by yielding of the internal lateral and calcaneo-astragaloid ligaments. Yielding of the calcaneo-scaphoid ligament permits the head of the astragalus to pass downward and forward, and the entire arch falls. Further deformity is induced by the yielding of the ligaments.

VI. Tarso-metatarsal Articulations (Articulationes Tarsometatarseae [Lisfranci]) (Figs. 249, 251, 252, 254, 257).

These are arthrodial joints. The bones entering into their formation are four tarsal bones—viz., the internal, middle, and external cuneiform and the cuboid—which articulate with the metatarsal bones of the five toes. The metatarsal bone of the great toe articulates with the internal cuneiform; that of the second is deeply wedged in between the internal and external cuneiform, resting against the middle cuneiform, and being the most strongly articulated of all the metatarsal bones; the third metatarsal articulates with the extremity of the external cuneiform; the fourth, with the cuboid and external cuneiform; and the fifth, with the cuboid. The articular surfaces are covered with cartilage, lined by synovial membrane, and connected together by capsules and by the following ligaments:

Dorsal. Plantar. Interosseous.

The Dorsal Ligaments (ligamenta tarsometatarsea dorsalia) consist of strong, flat, fibrous bands, which connect the tarsal with the metatarsal bones. The first metatarsal is connected to the internal cuneiform by a single broad, thin, fibrous band; the second has three dorsal ligaments, one from each cuneiform bone; the third has one from the external cuneiform; the fourth has two, one from the external cuneiform and one from the cuboid; and the fifth, one from the cuboid.

The Plantar Ligaments (ligamenta tarsometatarsea plantaria) consist of longitudinal and oblique fibrous bands connecting the tarsal and metatarsal bones, but disposed with less regularity than on the dorsal surface. Those for the first and second metatarsal are the most strongly marked; the second and third metatarsal receive strong fibrous bands which pass obliquely across from the internal cuneiform; the plantar ligaments of the fourth and fifth metatarsal consist of a few scanty fibres derived from the cuboid.

The Interosseous Ligaments (ligamenta cuneometatarsea interossea) are three in number—internal, middle, and external. The internal one is the strongest of the three, and passes from the outer extremity of the internal cuneiform to the adjacent angle of the second metatarsal. The middle one, less strong than the preceding, connects the external cuneiform with the adjacent angle of the second metatarsal. The external interosseous ligament connects the outer angle of the external cuneiform with the adjacent side of the third metatarsal.

Synovial Membrane (Fig. 255).—The synovial membrane between the internal cuneiform bone and the first metatarsal bone is a distinct sac. The synovial membrane between the middle and external cuneiform behind, and the second and third metatarsal bones in front, is part of the great tarsal synovial membrane. Two prolongations are sent forward from it—one between the adjacent sides of the second and third metatarsal bones, and one between the third and fourth metatarsal bones. The synovial membrane between the cuboid and the fourth and fifth metatarsal bones is a distinct sac. From it a prolongation is sent forward between the fourth and fifth metatarsal bones.

Actions.—The movements permitted between the tarsal and metatarsal bones are limited to a slight gliding upon each other.
VII. Articulations of the Metatarsal Bones with Each Other (Articulationes Intermetatarseae) (Figs. 251, 252, 254).

The base of the first metatarsal bone is not connected with the second metatarsal bone by any ligaments; in this respect it resembles the thumb.

The bases of the four outer metatarsal bones are connected together by dorsal, plantar, and interosseous ligaments.

The Dorsal Ligaments (ligamenta basium [oss. metatars.] dorsalia) consist of bands of fibrous tissue which pass transversely between the adjacent metatarsal bones.

The Plantar Ligaments (ligamenta basium [oss. metatars.] plantaria) have a similar arrangement to those on the dorsum.

The Interosseous Ligaments (ligamenta basium [oss. metatars.] interossea) consist of strong transverse fibres which pass between the rough non-articular portions of the lateral surfaces.

Synovial Membrane.—The synovial membrane between the second and third and the third and fourth metatarsal bones is part of the great tarsal synovial membrane. The synovial membrane between the fourth and fifth metatarsal bones is a prolongation of the synovial membrane of the cubo-metatarsal joint (Fig. 255).

Actions.—The movement permitted in the tarsal ends of the metatarsal bones is limited to a slight gliding of the articular surfaces upon one another.

The Synovial Membranes in the Tarsal and Metatarsal Joints.

The synovial membranes (Fig. 255) found in the articulations of the tarsus and metatarsus are six in number; one for the posterior calcaneo-astragaloid articulation; a second for the anterior calcaneo-astragaloid and astragaloscaphoid articulations; a third for the calcaneo-cuboid articulation; and a fourth for the articulations of the scaphoid with the three cuneiform, the three cuneiform with each other, the external cuneiform with the cuboid, and the middle and external cuneiform with the bases of the second and third metatarsal bones, and the lateral surfaces of the second, third, and fourth metatarsal bones with each other; a fifth for the internal cuneiform with the metatarsal bone of the great toe; and a sixth for the articulation of the cuboid with the fourth and fifth metatarsal bones. A small synovial membrane is sometimes found between the contiguous surfaces of the scaphoid and cuboid bones.
Nerve-supply.—The nerves supplying the tarso-metatarsal joints are derived from the anterior tibial.

The digital extremities of all the metatarsal bones are connected together by the transverse metatarsal ligament.

The Transverse Metatarsal Ligament is a narrow fibrous band which passes transversely across the anterior extremities of all the metatarsal bones, connecting them together. It is blended anteriorly with the plantar (glenoid) ligament of each metatarso-phalangeal articulation. To its posterior border is connected the fascia covering the Interossei muscles. Its inferior surface is concave where the Flexor tendons pass over it. Above it the tendons of the Interossei muscles pass to their insertion. It differs from the transverse metacarpal ligament in that it connects the metatarsal bone of the great toe with the rest of the metatarsal bones.

VIII. Metatarso-phalangeal Articulations (Articulationes Metatarso-phalangeae).

The metatarso-phalangeal articulations are of the condyloid kind, formed by the reception of the rounded head of the metatarsal bone into a superficial cavity in the extremity of the first phalanx. Each joint has a capsule and several other ligaments.

These ligaments are—

Plantar.    Two Lateral.

The Plantar Ligaments or the Glenoid Ligaments of Cruveilhier (ligamenta accessoria plantaria) are thick, dense, fibrous structures. Each is placed on the planter surface of the joint in the interval between the lateral ligaments, to which it is connected. The plantar ligaments are loosely united to the metatarsal bones, but very firmly to the bases of the first phalanges. The plantar surface of each is intimately blended with the transverse metatarsal ligament, and, except in the great toe, presents a groove for the passage of the Flexor tendons, the sheath surrounding which is connected to each side of the groove. The plantar ligament of the great toe contains two large sesamoid bones. By their deep surface they form part of the articular surface for the head of the metatarsal bone, and are lined by synovial membrane.

The Lateral Ligaments (ligamenta collateralia) are strong, rounded cords, placed one on each side of the joint, each being attached, by one extremity, to the posterior tubercle on the side of the head of the metatarsal bone; and, by the other, to the contiguous extremity of the phalanx.

The place of a Posterior Ligament is supplied by the extensor tendon over the back of the joint.

Actions.—The movements permitted in the metatarso-phalangeal articulations are flexion, extension, abduction, and adduction.

IX. Articulations of the Phalanges (Articulationes Digitorum Pedis).

The articulations of the phalanges are ginglymoid joints. Besides the capsular the ligaments are—

Plantar.    Two Lateral (ligamenta collateralia).

The arrangement of these ligaments is similar to those in the metatarso-phalangeal articulations; the extensor tendon supplies the place of a posterior ligament.

Actions.—The only movements permitted in the phalangeal joints are flexion and extension; these movements are more extensive between the first and second phalanges than between the second and third. The movement of flexion is very considerable, but extension is limited by the plantar and lateral ligaments.
Surface Form.—The principal joints which it is necessary to distinguish, with regard to the surgery of the foot, are the medio-tarsal and the tarso-metatarsal. The joint between the astragalus and the scaphoid is best found by means of the tubercle of the scaphoid, for the line of the joint is immediately behind this process. If the foot is grasped and forcibly extended, a rounded prominence, the head of the astragalus, will appear on the inner side of the dorsum in front of the ankle-joint, and if a knife is carried downward, just in front of this prominence and behind the line of the scaphoid tubercle, it will enter the astragalo-scaphoid joint. The calcaneo-cuboid joint is situated midway between the external malleolus and the prominent end of the fifth metatarsal bone. The plane of the joint is in the same line as that of the astragalo-scaphoid. The position of the joint between the fifth metatarsal bone and the cuboid is easily found by the projection of the fifth metatarsal bone, which is the guide to it. The direction of the line of the joint is very oblique, so that, if continued onward, it would pass through the head of the first metatarsal bone. The joint between the fourth metatarsal bone and the cuboid and external cuneiform is the direct continuation inward of the previous joint, but its plane is less oblique; it would be represented by a line drawn from the outer side of the articulation to the middle of the first metatarsal bone. The plane of the joint between the third metatarsal bone and the external cuneiform is almost transverse. It would be represented by a line drawn from the outer side of the joint to the base of the first metatarsal bone. The tarso-metatarsal articulation of the great toe corresponds to a groove which can be felt by making firm pressure on the inner side of the foot one inch in front of the tubercle on the scaphoid bone; and the joint between the second metatarsal bone and the middle cuneiform is to be found on the dorsum of the foot, half an inch behind the level of the tarso-metatarsal joint of the great toe. The line of the joints between the metatarsal bones and the first phalanges is about an inch behind the webs of the corresponding toes.

Surgical Anatomy.—Chopart's amputation passes through the middle tarsal joint (astragalo-scaphoid and calcaneo-cuboid articulation). Fig. 256 shows the line of Chopart. Lisfranc amputated at the tarso-metatarsal articulation. Fig. 257 shows the line of Lisfranc. In Hey's amputation the fifth, fourth, third, and second metatarsal bones are disarticulated from the tarsus and the internal cuneiform is sawn through. In the operation of Forbes, of Toledo, the cuneiform bones are disarticulated from the scaphoid, the cuboid is sawn through on a line with the surface exposed by the disarticulation.
THE MUSCLES AND FASCLEÆ.

MYOLOGY is the branch of anatomy which treats of the muscles. The muscles are formed of bundles of reddish fibres, endowed notably with the property of contractility in the direction of the long axes of the muscle cells. Contractions of muscle fibres induce motion. The two principal kinds of muscular tissue found in the body are the more highly differentiated, or voluntary, and the less highly differentiated, or involuntary. The former of these, from the characteristic appearances which its fibres exhibit under the microscope, is known as striated or striped muscle. Stripped muscle is called voluntary because of the fact that it is capable of being put into action and controlled by the will. The fibres of involuntary muscle do not present any cross-striped appearance, and for the most part are not under the control of the will; such muscles are known as unstriated, unstriped or vegetative. The muscular fibres of the heart differ in certain particulars from both these groups, and they are therefore separately described as cardiac muscular fibres.

Thus it will be seen that there are three varieties of muscular fibres: (1) Transversely striated muscular fibres, which are for the most part voluntary and under the control of the will, but some of which are not so (for example, the muscles of the pharynx and upper part of the oesophagus). This variety of muscle is sometimes called skeletal. (2) Transversely striated muscular fibres, which are not under the control of the will—i.e., the cardiac muscles. The cardiac muscle occupies a midposition in the scale between the cells of involuntary and the striated fibres of voluntary muscle. (3) Plain or unstriated muscular fibres, which are involuntary and controlled by a different part of the nervous system from that which controls the activity of the voluntary muscles. Such are the muscular walls of the stomach and intestine, of the uterus and bladder, of the blood-vessels, of certain canals and ducts, etc. The statement that striated muscle is always voluntary, and that non-striated muscle is always involuntary cannot be accepted as invariably and inevitably true. There are animals in which some voluntary muscle is free from distinct striation.

In this section we treat of the skeletal or striated muscles only. The skeletal muscles act upon the bones, and thus produce movement. The primitive contractile elements of a muscle are the fibres. Fibres are gathered into groups known as fasciculi, and fasciculi are aggregated into masses called bundles. In coarse muscles the fasciculi are of considerable size; in fine muscles they are of trivial size. Fasciculi may be long or short, and the length does not depend on the length of the muscle. If a muscle has an insertion only at each end, the fasciculi are sure to be long and may reach from the tendon of origin to the tendon of

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1 The Muscles and Fasciæ are described conjointly, in order that the student may consider the arrangement of the latter in his dissection of the former. It is rare for the student of anatomy in this country to have the opportunity of dissecting the fasciae separately; and it is for this reason, as well as from the close connection that exists between the muscles and their investing sheaths, that they are considered together. Some general observations are first made on the histology and anatomy of the muscles and fasciae, the special description being given in connection with the different regions.

(363)
insertion. If a muscle takes attachments to the side or to septa within the muscle, the fasciculi may be very short even when the muscle is very long.

**Structure of Striated Muscle.**—The striated muscle fibre is a development of a muscle cell. Each cell is long and narrow and is called a fibre, and by shortening of these fibres the muscle, as a whole, is shortened.

A fibre is more or less cylindrical in outline, is usually spindle-shaped, and in some regions the fibres branch. The diameter is very variable, and does not depend in any degree upon the size of the muscle, and in the same muscle are found fibres varying widely in diameter. As a rule, the diameter varies between 0.01 and 0.1 mm.

The fibres are usually short, being seldom over 5 cm. in length. In some muscles, as in the Sartorius, they are much longer, and may be 10 or 12 cm. in length. Sometimes a fibre extends the entire length of a small muscle. A muscle fibre is surrounded by a sheath or wall, the sarcolemma. Muscle fibres are gathered into masses known as primary bundles, which are held to each other by scanty connective tissue called the endomysium. Each primary bundle is surrounded by the perimysium. Primary bundles are aggregated into groups, the secondary bundles, and each secondary bundle is invested by the epimysium which is derived from the muscle sheath.

**Structure of the Muscle Fibre.**—The muscle fibre is an elongated cell containing numerous nuclei and terminating by blending of the sarcolemma with tendon aponeurosis or fibrous septum, or else, after becoming rounded or tapering, joining another cell by fusion of the sarcolemma of both. The sarcolemma completely invests the muscle fibre and attaches the fibre to tendon, aponeurosis, or the sarcolemma of another fibre, as the case may be.

The muscular substance within the sheath of sarcolemma is composed of protoplasm. One part is unchanged protoplasm, and is called sarcoplasm. This contains the muscle nuclei. Another part is highly differentiated; it contains the contractile fibrille and is striated. Transverse striation is due to alteration in the parts of the fibre, so that the altered material has a different refractive index and stains differently from the unaltered portions of the fibre. In man most muscles are of the red type, but some (mixed muscles) contain red and white fibres. A red muscle fibre contains a considerable quantity of sarcoplasm, and the nuclei are toward the centre of the cell; in a white muscle fibre there is less sarcoplasm, the nuclei are toward the periphery, and striation is very distinct.

The Arteries of voluntary muscle are numerous. They pierce the epimysium, pass along the septa from the epimysium, and divide into small branches, which enter between the fasciculi. These small branches pass into capillaries which lie around the fibres. The capillaries form a network between and upon the fibres. Capillary plexuses here and there possess dilatations for the relief of tension during muscular action.

Veins accompany the arteries, and even the smaller ones possess valves (Spalteholz).

The Nerve Endings in voluntary muscle comprise both motor and sensory terminations. A motor nerve pierces the epimysium and breaks up into numerous branches to form an interfascicular plexus in the perimysium. From this plexus nerve fibrils arise and usually one nerve fibril passes to each muscle fibre. The nerve fibril pierces the sarcolemma, the neurilemma and medullary sheath disappearing before the nerve fibril reaches the muscle fibre, and probably being lost by fusing with the sarcolemma. The naked axis-cylinder beneath the sarcolemma of a fibre continues to the surface of the muscle fibre and undergoes arborization to form an end organ. Around the end organ is a quantity of granular

1+A Text-book of Histology. By Dr. Ladislaus Szymbonowicz. Translated and edited by Dr. John Bruce MacCallum.
sarcoplasm, which, with the nerve end organ, constitutes a sole-plate. A sensory
nerve takes origin from a muscle spindle, which consists of a bundle of encapsulated
muscle fibre about sensory nerve twigs. From a muscle spindle arise from two to
eight large myelinic nerve fibres.

The muscles are connected with the bones, cartilages, ligaments, and skin,
either directly or through the intervention of fibrous structures called tendons
or aponeuoses. Where a muscle is attached to bone or cartilage, the fibres ter-
minate in blunt extremities upon the periosteeum or perichondrium, and do not
come into direct relation with the osseous or cartilaginous tissue. Where muscles
are connected with the skin, they either lie as a flattened layer beneath it, or are
connected with its areolar tissue by larger or smaller bundles of fibres, as in the
muscles of the face. The direct continuation of the tendon of a muscle is known
as the belly or venter. The origin of a muscle is its head (caput).

The muscles vary extremely in their form. In the limbs they are of consid-
erable length, especially the more superficial ones, the deep ones being generally
broad; they surround the bones and form an important protection to the various
joints. In the trunk they are broad, flattened, and expanded, forming the parietes
of the cavities which they enclose; hence the reason of the terms long, broad,
short, etc., used in the description of a muscle.

There is a considerable variation in the arrangement of the fibres of certain
muscles with reference to the tendons to which they are attached. In some, the
fibres are parallel and run directly from their origin to their insertion; these are
quadrilateral muscles, such as the Thyro-hyoid. A modification of these is found in
the fusiform muscles (m. fusiformis), in which the fibres are not quite parallel, but
slightly curved, so that the muscle tapers at each end; in their action, however, they
resemble the quadrilateral muscles. Secondly, in other muscles the fibres are con-
vergent; arising by a broad origin, they converge to a narrow or pointed insertion.
This arrangement of fibres is found in the triangular muscles—e. g., the Temporal.
In some muscles, which otherwise would belong to the quadrilateral or triangular
type, the origin and insertion are not in the same plane, but the plane of the line
of origin intersects that of their insertion; such is the case in the Pectineus muscle.
Thirdly, in some muscles the fibres are oblique and converge, like the plumes
of a pen, to one side of a tendon, which runs the entire length of the muscle.
Such a muscle is rhomboidal or penniform (m. unipennatus), as the Peroneal.
A modification of these rhomboidal muscles is found in those cases where oblique
fibres converge to both sides of a central tendon which runs down the middle of
the muscle; these are called bipenniform (m. bipennatus), and an example is afforded
in the Rectus femoris. Finally, we have muscles in which the fibres are arranged
in curved bundles in one or more planes, as in an orbicular muscle (m. orbicularis)
and in that variety of orbicular muscle called a sphincter muscle (m. sphincter).
The arrangement of the muscular fibres is of considerable importance in respect
to their relative strength and range of movement. Those muscles where the
fibres are long and few in number have great range, but diminished strength;
where, on the other hand, the fibres are short and more numerous, there is
great power, but lessened range.

Muscles differ much in size: the Gastrocnemius forms the chief bulk of the
back of the leg; the Sartorius is very long; the Stapedius, a small muscle of the
internal ear, weighs about a grain, and its fibres are not more than two lines in
length.

The names applied to the various muscles have been derived—1, from their
situation, as the Tibialis, Radialis, Ulnaris, Peroncus; 2, from their direction, as
the Rectus abdominis, Obliquus capitis, Transversalis; 3, from their uses, as Flexors,
Extensors, Abductors, etc.; 4, from their shape, as the Deltoid, Trapezius, Rhom-
boideus; 5, from the number of their divisions, as the Biceps, the Triceps; 6,
from their points of attachment, as the Sterno-cleido-mastoid, Sterno-hyoid, Sterno-thyroid.

In the description of a muscle the term origin is meant to imply its more fixed or central attachment, and the term insertion, the movable point to which the force of the muscle is directed; but the origin is absolutely fixed in only a very small number of muscles, such as those of the face, which are attached by one extremity to the bone and by the other to the movable integument; the greater number of muscles can be made to act from either extremity.

In the dissection of the muscles the student should pay especial attention to the exact origin, insertion, and actions of each, and its more important relations with surrounding parts. An accurate knowledge of the points of attachment of the muscles is of great importance in the determination of their action. By a knowledge of the action of the muscles the surgeon is able to explain the causes of displacement in various forms of fracture and the causes which produce distortion in various deformities, and, consequently, to adopt appropriate treatment in each case. The relations, also, of some of the muscles, especially those in immediate apposition with the larger blood-vessels, and the surface-markings they produce, should be especially remembered, as they form useful guides to the surgeon who operates to expose and ligate them.

**Tendons.**—Tendons are white, glistening, fibrous cords, varying in length and thickness, sometimes round, sometimes flattened, of considerable strength, and devoid of elasticity. They consist almost entirely of white fibrous tissue, the fibrils of which have an undulating course parallel with each other and are firmly united together. They are very sparingly supplied with blood-vessels, the smaller tendons presenting in their interior not a trace of them. Nerves also are not present in the smaller tendons, but the larger ones, as the tendon Achilles, receive nerves which accompany nutrient vessels. The tendons consist principally of a substance which yields gelatin.

**Aponeuroses.**—Aponeuroses are flattened or ribbon-shaped tendons, of a pearly-white color, iridescent, glistening, and similar in structure to the tendons. They are destitute of nerves, and the thicker ones are only sparingly supplied with blood-vessels.

The tendons and aponeuroses are connected, on the one hand, with the muscles, and, on the other hand, with movable structures, as the bones, cartilages, ligaments, fibrous membranes (for instance, the sclerotic). Where the muscular fibres are in a direct line with those of the tendon or aponeurosis, the two are directly continuous, the muscular fibre being distinguishable from that of the tendon only by its striation. But where the muscular fibres join the tendon or aponeurosis at an oblique angle the former terminate, according to Kölliker, in rounded extremities, which are received into corresponding depressions on the surface of the latter, the connective tissue between the fibres being continuous with that of the tendon. The latter mode of attachment occurs in all the penniform and bipenniform muscles, and in those muscles the tendons of which commence in a membranous form, as the Gastrocnemius and Soleus.

**Fasciae.**—The fasciae (fascia, a bandage) are fibro-areolar or aponeurotic laminae of variable thickness and strength, found in all regions of the body, investing the softer and more delicate organs. The fasciae have been subdivided, from the situation in which they are found, into two groups, superficial and deep.

**Superficial Fascia (panniculus adiposus).**—The superficial fascia is found immediately beneath the integument over almost the entire surface of the body. It connects the skin with the deep or aponeurotic fascia, and consists of fibro-areolar tissue, containing in its meshes pellicles of fat in varying quantity. In the eyelids and scrotum, where adipose tissue is rarely deposited, this tissue is very liable to
serous inflammation. The superficial fascia varies in thickness in different parts of the body; in the groin it is so thick as to be capable of being subdivided in several laminae. Beneath the fatty layer of the superficial fascia, which is immediately subcutaneous, there is generally another layer of the same structure, comparatively devoid of adipose tissue, in which the trunks of the subcutaneous vessels and nerves are found, as the superficial epigastric vessels in the abdominal region, the radial and ulnar veins in the forearm, the saphenous veins in the leg and thigh, and the superficial lymphatic glands; certain cutaneous muscles also are situated in the superficial fascia, as the Platysma myoides in the neck, and the Orbicularis palpebrarum around the eyelids. This fascia is most distinct at the lower part of the abdomen, the scrotum, perineum, and extremities; is very thin in those regions where muscular fibres are inserted into the integument, as on the side of the neck, the face, and around the margin of the anus. It is very dense in the scalp, in the palms of the hands and soles of the feet, forming a fibro-fatty layer which binds the integument firmly to the subjacent structure. The superficial fascia connects the skin to the subjacent parts, facilitates the movement of the skin, serves as a soft medium for the passage of vessels and nerves to the integument, and retains the warmth of the body, since the fat contained in its areolae is a bad conductor of heat.

Deep Fascia.—The deep or aponeurotic fascia is a dense, inelastic, unyielding fibrous membrane, forming sheaths for the muscles and affording them broad surfaces for attachment. It consists of shining tendinous fibres, placed parallel with one another, and connected together by other fibres disposed in a rectilinear manner. It is usually exposed on the removal of the superficial fascia, forming a strong investment, which not only binds down collectively the muscles in each region, but gives a separate sheath to each, as well as to the vessels and nerves. The fasciae are thick in unprotected situations, as on the outer side of a limb, and thinner on the inner side. The deep fasciae assist the muscles in their action by the degree of tension and pressure they make upon their surface; and in certain situations this is increased and regulated by muscular action; as, for instance, by the Tensor fasciae latae and Gluteus maximus in the thigh, by the Biceps in the upper and lower extremities, and Palmaris longus in the hand. In the limbs the fasciae not only invest the entire limb, but give off septa which separate the various muscles, and are attached beneath to the periosteum: these prolongations of fasciae are usually spoken of as intermuscular septa.

The Muscles and Fasciae may be arranged, according to the general division of the body, into those of the cranium, face, and neck; those of the trunk; those of the upper extremity; and those of the lower extremity.

MUSCLES AND FASCIÆ OF THE CRANIUM AND FACE.

The muscles of the cranium and face consist of ten groups, arranged according to the region in which they are situated:

1. Cranial Region.
2. Auricular Region.
3. Palpebral Region.
4. Orbital Region.
5. Nasal Region.
6. Maxillary Region.
7. Mandibular Region.
8. Intermaxillary Region.
9. Temporo-mandibular Region.
10. Pterygo-mandibular Region.
The muscles contained in each of these groups are the following:

1. Cranial Region.
   - Occipito-frontalis.

2. Auricular Region.
   - Attrahens auriculam.
   - Attollens auriculam.
   - Retrahens auriculam.

3. Palpebral Region.
   - Orbicularis palpebrarum.
   - Corrugator supercilii.
   - Tensor tarsi.

4. Orbital Region.
   - Levator palpebræ.
   - Rectus superior.
   - Rectus inferior.
   - Rectus internus.
   - Rectus externus.
   - Obliquus superior.
   - Obliquus inferior.

5. Nasal Region.
   - Pyramidalis nasi.
   - Levator labii superioris alæque nasi.
   - Dilator naris posterior.
   - Dilator naris anterior.
   - Compressor nasi.
   - Compressor narium minor.
   - Depressor alæ nasi.

6. Maxillary Region.
   - Levator labii superioris.
   - Levator anguli oris.
   - Zygomaticus major.
   - Zygomaticus minor.

7. Mandibular Region.
   - Levator labii inferioris.
   - Depressor labii inferioris.
   - Depressor anguli oris.

8. Intermaxillary Region.
   - Buccinator.
   - Risorius.
   - Orbicularis oris.

9. Temporo-mandibular Region.
   - Masseter.
   - Temporal.

10. Pterygo-mandibular Region.
    - Pterygoideus externus.
    - Pterygoideus internus.

1. The Cranial Region.
   - Occipito-frontalis.

Dissection (Fig. 258).—The head being shaved, and a block placed beneath the back of the neck, make a vertical incision through the skin from before backward, commencing at the root of the nose in front, and terminating behind at the occipital protubercance; make a second incision in a horizontal direction along the forehead and round the side of the head, from the anterior to the posterior extremity of the preceding. Raise the skin in front, from the subjacent muscle, from below upward; this must be done with extreme care, removing the integument from the outer surface of the vessels and the nerves which lie immediately beneath the skin.

The Skin of the Scalp.—This is thicker than in any other part of the body. It is intimately adherent to the superficial fascia, which attaches it firmly to the underlying aponeurosis and muscle. Movements of the muscle move the skin. The hair-follicles are very closely set together, and extend throughout the whole thickness of the skin. It also contains a number of sebaceous glands.

Superficial Fascia.—The superficial fascia in the cranial region is a firm, dense, fibro-fatty layer, intimately adherent to the integument, and to the occipito-frontalis and its tendinous aponeurosis; it is continuous, behind, with the superficial fascia at the back part of the neck; and, laterally, is continued over the temporal fascia. It contains between its layers the superficial vessels and nerves and much granular fat.
Surgical Anatomy.—The subcutaneous tissue is composed of bands of fibrous tissue enclosing spaces filled with fat. The fibrous character of this tissue greatly limits discoloration and swelling when inflammation occurs. The edges of a wound which does not involve the aponeurosis or muscle do not retract, hence the wound does not gap. The blood-vessels run practically in the skin, and as they lie in very dense tissue and are adherent to it, wounds bleed profusely, the arteries being unable to freely contract and retract. It is very difficult or impossible to pick up with forceps a vessel in the skin of the scalp, and bleeding must be arrested by suture ligatures or by the stitches which close the wound. Sebaceous glands in the skin of the scalp may develop into sebaceous cysts (wens).

The Occipito-frontalis (m. epicranius) (Fig. 260).—The Occipito-frontalis is a broad musculo-fibrous layer, which covers the whole of one side of the vertex of the skull, from the occiput to the eyebrow. It consists of two muscular slips, separated by an intervening tendinous aponeurosis. The occipital portion, the occipitalis muscle (m. occipitalis), is thin, quadrilateral in form, and about an inch and a half in length; it arises from the outer two-thirds of the superior curved line of the occipital bone, and from the mastoid portion of the temporal bone. Its fibres of origin are tendinous, but they soon become muscular, and ascend in a parallel direction to terminate in a tendinous aponeurosis. The frontal portion, the frontalis muscle (m. frontalis), is thin, of a quadrilateral form, and intimately adherent to the superficial fascia. It is broader, its fibres are longer, and their structure paler than the occipital portion. Its internal fibres are continuous with those of the Pyramidalis nasi. Some anatomists con-
sider the Pyramidalis muscle as simply the lower fibres of the frontalis, and give these bundles of muscle fibre the name of *musculus procerus*. Its middle fibres become blended with the Corrugator supercilii and Orbicularis palpebrarum; and the outer fibres are also blended with the latter muscle over the external angular process. According to Theile, the innermost fibres are attached to the nasal bones, the outer to the external angular process of the frontal bone. From these attachments the fibres are directed upward, and join the aponeurosis below the coronal suture. The inner margins of the frontal portions of the two muscles are joined together for some distance above the root of the nose; but between the occipital portions there is a considerable, though variable, interval, which is occupied by the aponeurosis.

The middle portion of the Occipito-frontalis muscle or the *aponeurosis* (*epicranial aponeurosis, Galea aponeurotica*) covers the upper part of the vertex of the skull, being continuous across the middle line with the aponeurosis of the

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*Fig. 260.—Muscles of the head, face, and neck.*
opposite muscle. Behind, it is attached, in the interval between the occipital origins, to the occipital protuberance and highest curved lines of the occipital bone; in front, it forms a short and narrow prolongation between the frontal portions; and on each side it has connected with it the Attollens and Attrahens auriculam muscles. This aponeurosis is closely connected to the integument by the firm, dense, fibro-fatty layer which forms the superficial fascia; it is connected with the pericranium by loose cellular tissue, which allows of a considerable degree of movement of the integument. It is continuous with the temporal fascia below the temporal ridge, and it is in reality the representative of the deep fascia.

Nerves.—The frontal portion of the Occipito-frontalis is supplied by the facial nerve; its occipital portion by the posterior auricular branch of the facial.

Actions.—The frontal portion of the muscle raises the eyebrows and the skin over the root of the nose, and at the same time draws the scalp forward, throwing the integument of the forehead into transverse wrinkles. The posterior portion draws the scalp backward. By bringing alternately into action the frontal and occipital portions the entire scalp may be moved forward and backward. In the ordinary action of the muscles, the eyebrows are elevated, and at the same time the aponeurosis is fixed by the posterior portion, thus giving to the face the expression of surprise: if the action is more exaggerated, the eyebrows are still further raised, and the skin of the forehead thrown into transverse wrinkles, as in the expression of fright or horror.

Surgical Anatomy.—The skull is covered by the scalp (Fig. 259). This consists of five layers: (1) the pericranium; (2) a layer of connective tissue beneath the Occipito-frontalis aponeurosis (subaponeurotic tissue); (3) the Occipito-frontalis muscle and aponeurosis; (4) subcutaneous fat; (5) skin. If a wound involves the muscle or aponeurosis, it gaps widely, the greatest amount of gaping being observed in transverse wounds. The space between the aponeurosis and the pericranium is called by Treves the dangerous area of the scalp. It contains a layer of connective tissue and suppuration in this tissue spreads widely. An abscess in the dangerous area should be opened above the superior curved line of the occipital bone, above the eyebrow or above the zygoma. In a wound or contusion above the aponeurosis but little blood can be, effused in the tissue because the fibrous structure prevents it, and abscesses do not tend to spread widely. Between the aponeurosis and the pericranium a great amount of blood can be effused. An effusion of blood beneath the pericranium is called a cephalohematoma. Such a condition may occur from pressure during birth. An extravasation beneath the pericranium is limited to the surface of one bone. The pericranium is tightly attached to the sutures, but adheres lightly to the surface of the bone, and abscess beneath the pericranium is restricted to the surface of one bone.

2. The Auricular Region (Fig. 260).


These three small muscles are placed immediately beneath the skin around the external ear. In man, in whom the external ear is almost immovable, they are rudimentary. They are the analogues of large and important muscles in some of the mammalia.

Dissection.—This requires considerable care, and should be performed in the following manner: To expose the Attollens auriculam, draw the pinna, or broad part of the ear, downward, when a tense band will be felt beneath the skin, passing from the side of the head to the upper part of the concha; by dividing the skin over this band in a direction from below upward, and then reflecting it on each side, the muscle is exposed. To bring into view the Attrahens auriculam, draw the helix backward by means of a hook, when the muscle will be made tense, and may be exposed in a similar manner to the preceding. To expose the Retrahens auriculam, draw the pinna forward, when the muscle, being made tense, may be felt beneath the skin at its insertion into the back part of the concha, and may be exposed in the same manner as the other muscles.
The Attrahens Auriculam or Aurem (m. auricularis anterior), the smallest of the three, is thin, fan-shaped, and its fibres pale and indistinct; they arise from the lateral edge of the aponeurosis of the Occipito-frontalis, and converge to be inserted into a projection on the front of the helix.

Relations.—Superficially, with the skin; deeply, with the areolar tissue derived from the aponeurosis of the Occipito-frontalis, beneath which are the temporal artery and vein and the temporal fascia.

The Attollens Auriculam or Aurem (m. auricularis superior), the largest of the three, is thin and fan-shaped; its fibres arise from the aponeurosis of the Occipito-frontalis and converge to be inserted by a thin, flattened tendon into the upper part of the cranial surface of the pinna.

Relations.—Superficially, with the integument; deeply, with the areolar tissue derived from the aponeurosis of the Occipito-frontalis, beneath which is the temporal fascia.

The Retrahens Auriculam or Aurem (m. auricularis posterior) consists of two or three fleshy fasciculi, which arise from the mastoid portion of the temporal bone by short aponeurotic fibres. They are inserted into the lower part of the cranial surface of the concha.

Relations.—Superficially, with the integument; deeply, with the mastoid portion of the temporal bone and the posterior auricular artery and nerve.

Nerves.—The Attrahens and Attollens auriculam are supplied by the temporal branch of the facial; the Retrahens auriculam is supplied by the posterior auricular branch of the same nerve.

Actions.—In man, these muscles possess very little action: the Attrahens auriculam draws the ear forward and upward; the Attollens auriculam slightly raises it; and the Retrahens auriculam draws it backward.

3. The Palpebral Region (Fig. 260).

| Orbicularis palpebrarum. | Levator palpebræ. |
| Corrugator supercilii. | Tensor tarsi. |

Dissection (Fig. 258).—In order to expose the muscles of the face, continue the longitudinal incision made in the dissection of the Occipito-frontalis down the median line of the face to the tip of the nose, and from this point onward to the upper lip; and carry another incision along the margin of the lip to the angle of the mouth, and transversely across the face to the angle of the jaw. Then make an incision in front of the external ear, from the angle of the jaw upward, to join the transverse incision made in exposing the Occipito-frontalis. These incisions include a square-shaped flap, which should be removed in the direction marked in the figure, with care, as the muscles at some points are intimately adherent to the integument.

The Orbicularis Palpebrarum (m. orbicularis oculi) is a sphincter muscle, which surrounds the circumference of the orbit and eyelids. It arises from the internal angular process of the frontal bone, from the nasal process of the superior maxillary bone in front of the lachrymal groove for the nasal duct, and from the anterior surface and borders of a short tendon, the tendo oculi, or internal tarsal ligament, placed at the inner angle of the orbit. From this origin the fibres are directed outward, forming a broad, thin, and flat layer, which covers the eyelids, surrounds the circumference of the orbit, and spreads out over the temple and downward on the cheek. The internal or palpebral portion (pars palpebralis) of the Orbicularis is thin and pale; it arises from the bifurcation of the tendo palpebrarum, and forms a series of concentric curves, which are on the outer side of the eyelids inserted into the external tarsal ligament. The external or orbital portion (pars orbitalis) is thicker and of a reddish color; its fibres are well developed, and form complete ellipses. The upper fibres of this portion blend with the Occipito-frontalis and Corrugator supercili.
Relations.—By its superficial surface, with the integument. By its deep surface, above, with the Occipito-frontalis and Corrugator supercilii, with which it is intimately blended, and with the supraorbital vessels and nerve; below, it covers the lachrymal sac, and the origin of the Levator labii superioris alaeque nasi, the Levator labii superioris, and the Zygomaticus minor muscles. Internally, it is occasionally blended with the Pyramidalis nasi. Externally, it lies on the temporal fasonia. On the eyelids it is separated from the conjunctiva by the Levator palpebræ, the tarsal ligaments, the tarsal plates, and the Meibomian glands.

The tendo oculi or internal tarsal ligament (ligamentum palpebrale mediale) is a short tendon, about two lines in length and one in breadth, attached to the nasal process of the superior maxillary bone in front of the lachrymal groove. Crossing the lachrymal sac, it divides into two parts, each division being attached to the inner extremity of the corresponding tarsal plate. As the tendon crosses the lachrymal sac, a strong aponeurotic lamina is given off from the posterior surface, which expands over the sac, and is attached to the ridge on the lachrymal bone. This is the reflected aponeurosis of the tendo oculi.

The external tarsal ligament (raphe palpebrales lateralis) is a much weaker structure than the tendo oculi. It is attached to the margin of the frontal process of the malar bone, and passes inward to the outer commissure of the eyelids; it connects together the outer extremities of the two tarsal cartilages.

Use of Tendo Oculi.—Besides giving attachment to part of the Orbicularis palpebrarum and to the tarsal plates, it serves to suck the tears into the lachrymal sac, by its attachment to the sac. Thus, each time the eyelids are closed, the tendo oculi becomes tightened, through the action of the Orbicularis, and draws the wall of the lachrymal sac outward and forward, so that a vacuum is made in the sac, and the tears are sucked along the lachrymal canals into it.

The Corrugator Supercilii (Figs. 259 and 260) is a small narrow, pyramidal muscle, placed at the inner extremity of the eyebrow, beneath the Occipito-frontalis and Orbicularis palpebrarum muscles. It arises from the inner extremity of the superciliary ridge, from whence its fibres pass upward and outward, and are inserted into the deep surface of the skin, opposite the middle of the orbital arch.

Relations.—By its anterior surface with the Occipito-frontalis and Orbicularis palpebrarum muscles; by its posterior surface, with the frontal bone and supra trochlear nerve.

The Levator Palpebræ will be described with the muscles of the orbital region.

The Tensor Tarsi or Horner's Muscle (pars lacrimalis of the orbicularis palpebrarum) (Fig. 261) is a small thin muscle about three lines in breadth and six in length, situated at the inner side of the orbit, behind the tendo oculi. It is usually considered to be composed of fibres derived from the Orbicularis palpebrarum. It arises from the crest and adjacent part of the orbital surface of the lachrymal bone, and, passing across the lachrymal sac, divides into two slips, which cover the lachrymal canals and are inserted into the tarsal plates internal to the puncta lachrymalia. Its fibres appear to be continuous with those of the palpebral portion of the Orbicularis palpebrarum; it is occasionally very indistinct.

Nerves.—The Orbicularis palpebrarum, Corrugator supercilii, and Tensor tarsi are supplied by the facial nerve. Recent investigations tend to show that the Orbicularis palpebrarum, Corrugator supercilii, and frontal part of the Occipito-frontalis are in reality supplied by fibres of the motor oculi nerve, which descend through the pons to join the facial nerve.

Actions.—The Orbicularis palpebrarum is the sphincter muscle of the eyelids. The palpebral portion acts involuntarily, closing the lids gently, as in sleep or in blinking; the orbicular portion is subject to the will. When the entire muscle is brought into action, the skin of the forehead, temple, and cheek is drawn inward
toward the inner angle of the orbit, and the eyelids are firmly closed as a photo-
phobia. When the skin of the forehead, temple, and cheek is thus drawn inward
by the action of the muscle it is thrown into folds, especially radiating from the
outer angle of the eyelids, which give rise in old age to the so-called "crow's feet." The Levator palpebræ is the direct antagonist of this muscle; it raises the upper
eyelid and exposes the globe. The Corrugator supercilii draws the eyebrow
downward and inward, producing the vertical wrinkles of the forehead. It is the
"frowning" muscle, and may be regarded as the principal agent in the expression
of suffering. The Tensor tarsi draws the eyelids inward and compresses the eye-
lids and the extremities of the lachrymal canals against the surface of the globe
of the eye; thus placing the canals in the most favorable situation for receiving
the tears. It serves, also, to compress the lachrymal sac.

4. The Orbital Region (Fig. 262).

Levator palpebræ superioris. Rectus internus.

Rectus superior. Rectus externus.

Rectus inferior. Obliquus oculi superior.

Obliquus oculi inferior.

Dissection.—To open the cavity of the orbit, remove the skull-cap and brain; then saw
through the frontal bone at the inner extremity of the supraorbital ridge, and externally at its
junction with the malar. Break in pieces the thin roof of the orbit by a few slight blows of
the hammer, and take it away; drive forward the superciliary portion of the frontal bone
by a smart stroke, but do not remove it, as that would destroy the pulley of the Obliquus
superior. When the fragments are cleared away, the periosteum of the orbit will be exposed;
this being removed, together with the fat which fills the cavity of the orbit, the several muscles
of this region can be examined. The dissection will be facilitated by distending the globe
of the eye. In order to effect this, puncture the optic nerve near the eyeball with a curved
needle, and push the needle onward into the globe; insert the point of a blowpipe through
this aperture, and force a little air into the cavity of the eyeball; then apply a ligature round
the nerve so as to prevent the air escaping. The globe being now drawn forward, the muscles
will be put upon the stretch.
The Levator Palpebrae Superioris is thin, flat, and triangular in shape. It arises from the under surface of the lesser wing of the sphenoid, above and in front of the optic foramen, from which it is separated by the origin of the Superior rectus (Fig. 263). At its origin it is narrow and tendinous, but soon becomes broad and fleshy, and finally terminates in a wide aponeurosis, which is inserted into the upper margin of the superior tarsal plate. From this aponeurosis a thin expansion is continued onward, passing between the fibres of the Orbicularis to be inserted into the skin of the lid, and some deeper fibres blend with an expansion from the sheath of the Superior rectus muscle, and are with it prolonged into the conjunctiva.

Relations.—By its upper surface, with the frontal nerve and supraorbital artery, the periostea of the orbit and lachrymal gland; and, in the lid, with the inner surface of the tarsal ligament; by its under surface, with the Superior rectus, and, in the lid, with the conjunctiva. A small branch of the motor-oculi nerve enters its under surface.

The Superior Rectus (m. rectus superior), the thinnest and narrowest of the four Recti, arises from the upper margin of the optic foramen (Fig. 263) beneath the Levator palpebrae, and from the fibrous sheath of the optic nerve; and is inserted by a tendinous expansion into the sclerotic coat, about three or four lines from the margin of the cornea.

Relations.—By its upper surface, with the Levator palpebrae; by its under surface, with the optic nerve, the ophthalmic artery, the nasal nerve, and the branch of the motor-oculi nerve which supplies it; and, in front, with the tendon of the Superior oblique and the globe of the eye.

The Inferior Rectus (m. rectus inferior) and the Internal Rectus (m. rectus medialis) arise by a common tendon, the ligament of Zinn\(^1\) (annulus tendineus communis), which is attached round the circumference of the optic foramen, except at its upper and outer part (Fig. 263).

The External Rectus (m. rectus lateralis) has two heads: the upper one arises from the outer margin of the optic foramen immediately beneath the Superior rectus; the lower head, partly from the ligament of Zinn and partly from a small

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\(^1\) The ligament of Zinn ought, perhaps more appropriately, to be termed the aponeurosis or tendon of Zinn. Mr. C. B. Lockwood has described a somewhat similar structure on the under surface of the Superior rectus muscle, which is attached to the jesser wing of the sphenoid, forming the upper and outer margin of the optic foramen. This superior tendon gives origin to the Rectus superior, the superior head of the External rectus, and the upper part of the Internal rectus.—Journal of Anatomy and Physiology, vol. xx. part i. p. 1.
pointed process of bone on the lower margin of the sphenoidal fissure (Fig. 263). Each muscle passes forward in the position implied by its name, to be inserted by a tendinous expansion, the tunica albuginea, into the sclerotic coat, about three or four lines from the margin of the cornea. Between the two heads of the External rectus is a narrow interval through which passes the motor-oculi, the nasal branch of the ophthalmic division of the trigeminal, and the abducent nerve, and the ophthalmic vein. Although nearly all of these muscles present a common origin and are inserted in a similar manner into the sclerotic coat, there are certain differences to be observed in them as regards their length and breadth. The Internal rectus is the broadest, the External is the longest, and the Superior is the thinnest and narrowest.

The Superior Oblique (m. obliquus superior) is a fusiform muscle placed at the upper and inner side of the orbit, internal to the Levator palpebrae. It arises about a line above the inner margin of the optic foramen (Fig. 263), and, passing forward to the inner angle of the orbit, terminates in a rounded tendon, which plays in a ring or pulley, the trochlea (trochlea m. obliqui superioris), formed by a cartilaginous tissue attached to a depression beneath the internal angular process of the frontal bone, the contiguous surfaces of the tendon and ring being lined by a delicate synovial membrane and enclosed in a thin fibrous investment. The tendon is reflected backward, outward, and downward beneath the Superior rectus to the outer part of the globe of the eye, and is inserted into the sclerotic coat, behind the equator of the eyeball, the insertion of the muscle lying between the Superior and External recti.

Relations.—By its upper surface, with the peristomeum covering the roof of the orbit and the trochlear nerve: the tendon, where it lies on the globe of the eye, is covered by the Superior rectus; by its under surface, with the nasal nerve, ethmoidal arteries, and the upper border of the internal rectus.

The Inferior Oblique (m. obliquus inferior) is a thin, narrow muscle placed near the anterior margin of the orbit. It arises from a depression on the orbital plate of the superior maxillary bone, external to the lachrymal groove (Fig. 262). Passing outward, backward, and upward between the Inferior rectus and the floor of the orbit, and then between the eyeball and the External rectus, it is inserted into the outer part of the sclerotic coat between the Superior and External recti, near to, but somewhat behind, the tendon of insertion of the Superior oblique.

Relations.—By its ocular surface, with the globe of the eye and with the Inferior rectus; by its orbital surface, with the periostome covering the floor of the orbit, and with the External rectus. Its borders look forward and backward; the posterior one receives a branch of the motor oculi nerve.

The orbital muscle or Müller's muscle (musculus orbitalis), which spans the spheno-maxillary fissure and infraorbital groove, is composed of non-striated fibres, and is a rudimentary structure continuous with the periostome of the orbit.¹

Nerves.—The Levator palpebrae, Inferior oblique, and all the Recti excepting the External, are supplied by the motor oculi nerve; the Superior oblique, by the trochlear; the External rectus, by the abducent.

Actions.—The Levator palpebrae raises the upper eyelid, and is the direct antagonist of the Orbicularis palpebrarum. The four Recti muscles are attached in such a manner to the globe of the eye that, acting singly, they will turn it either

upward, downward, inward, or outward, as expressed by their names. The movement produced by the Superior or Inferior rectus is not quite a simple one, for, inasmuch as they pass obliquely outward and forward to the eyeball, the elevation or depression of the cornea must be accompanied by a certain deviation inward, with a slight amount of rotation, which, however, is corrected by the Oblique muscles, the Inferior oblique correcting the deviation inward of the Superior rectus, and the Superior oblique that of the Inferior rectus. The contraction of the External and Internal recti, on the other hand, produces a purely horizontal movement. If any two contiguous recti of one eye act together, they carry the globe of the eye in the diagonal of these directions—viz., upward and inward, upward and outward, downward and inward, or downward and outward. The movement of circumduction, as in looking round a room, is performed by the alternate action of the four Recti. The Oblique muscles rotate the eyeball on its antero-posterior axis, this kind of movement being required for the correct viewing of an object when the head is moved laterally, as from shoulder to shoulder, in order that the picture may fall in all respects on the same part of the retina of each eye. It should be noted that sometimes the corresponding Recti and sometimes the opposite ones of the two eyes act together; for instance, the two superior and inferior Recti carry both eyeballs upward and downward, respectively. In looking toward the right the right External and left Internal recti act together, the reverse being the case in looking toward the left. In turning both eyes toward the middle line, as in directing our vision toward an object less than twenty feet distant, the two internal recti act together.

**Fascia of the Orbit.**—The connective tissue of the orbit is in various places condensed into thin membranous layers, which may be conveniently described as

(1) the orbital fascia; (2) the sheaths of the muscles; and (3) the covering of the eyeball.

(1) **The Orbital Fascia.**—This forms the periosteum of the orbit. It is loosely connected to the bones, from which it can be readily separated. **Behind,** it is connected with the dura by processes which pass through the optic foramen and sphenoidal fissure, and with the sheath of the optic nerve. **In front** it is connected with the periosteum at the margin of the orbit, and sends off a process which assists in forming the palpebral fascia. From its internal surface two processes are given off—one to enclose the lachrymal gland, the other to hold the pulley of the Superior oblique muscle in position.

(2) **The Sheaths of the Muscles.**—The sheaths of the muscles give off expansions to the margins of the orbit which limit the action of the muscles.

(3) **The Covering of the Eyeball**—**Ténon's capsule**—surrounds the posterior two-thirds of the eyeball; it will be described in the sequel.

**Surgical Anatomy.**—The position and exact point of insertion of the tendons of the Internal and External recti muscles into the globe should be carefully examined from the front of the eyeball, as the surgeon is often required to divide the one or the other muscle for the cure of strabismus (squint). In convergent strabismus, which is the more common form of the disease, the eye is turned inward, requiring the division of the Internal rectus. In the divergent form, which is more rare, the eye is turned outward, the External rectus being especially implicated. The deformity produced in either case is to be remedied by division of one or the other muscle. The operation is thus performed: The lids are to be well separated; the eyeball being rotated outward or inward, the conjunctiva should be raised by a pair of forceps and divided immediately beneath the lower border of the tendon of the muscle to be divided, a little behind its insertion into the sclerotic; the submucous areolar tissue is then divided, and into the small aperture thus made a blunt hook is passed upward between the muscle and the globe, and the tendon of the muscle and conjunctiva covering it divided by a pair of blunt-pointed scissors. Or the tendon may be divided by a subconjunctival incision, one blade of the scissors being passed

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1. On the Oblique Muscles of the Eye in Man and Vertebrate Animals, by John Struthers, M.D., in Anatomical and Physiological Observations. For a fuller account of the various co-ordinate actions of the muscles of a single eye and of both eyes than our space allows see Dr. M. Foster's Text-book of Physiology.—Ed. of 15th English edition.
upward between the tendon and the conjunctiva, and the other between the tendon and the sclerotic. The student, when dissecting these muscles, should remove on one side of the subject the conjunctiva from the front of the eye, in order to see more accurately the position of the tendons, while on the opposite side the operation may be performed. Inflammation of the synovial membrane lining the trochlea of the Superior oblique may lead to the formation of a cyst of considerable size.

In performing enucleation of the eyeball the conjunctiva is clipped with scissors near the cornea and the capsule of Ténon is divided with it. One rectus muscle after another is caught up on a blunt hook and divided. The scissors are now pushed well in along the outer orbital wall, and the optic nerve is divided. Finally the oblique muscles, the ciliary vessels and nerves, and fragments of tissue helping to retain the globe are cut and the eyeball is enucleated.

An orbital abscess is evacuated by making an incision close to the border of the orbit, above or below the eyeball.

### 5. The Nasal Region (Fig. 260).

<table>
<thead>
<tr>
<th>Pyramidalis nasi.</th>
<th>Dilator naris anterior.</th>
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<tr>
<td>Levator labii superioris alæque nasi.</td>
<td>Compressor nasi.</td>
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<tr>
<td>Dilator naris posterior.</td>
<td>Compressor narium minor.</td>
</tr>
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Depressor alæ nasi.

The Pyramidalis Nasi is a small pyramidal slip placed over the nasal bone. Its origin is by tendinous fibres from the fascia covering the lower part of the nasal bone and upper part of the cartilage, where it blends with the Compressor nasi, and it is inserted into the skin over the lower part of the forehead between the two eyebrows, its fibres decussating with those of the Occipito-frontalis (see page 371).

**Relations.**—By its upper surface, with the skin; by its under surface, with the frontal and nasal bones.

The Levator Labii Superioris Alæque Nasi is a thin triangular muscle placed by the side of the nose, and extending between the inner margin of the orbit and upper lip. It arises by a pointed extremity from the upper part of the nasal process of the superior maxillary bone, and, passing obliquely downward and outward, divides into two slips, one of which is inserted into the cartilage of the ala of the nose and the under surface of the skin over the ala; the other is prolonged into the upper lip, becoming attached to the under surface of the skin and blended with the Orbicularis oris and Levator labii superioris proprius.

**Relations.**—In front, with the integument, and with a small part of the Orbicularis palpebrarum above.

The Dilator Naris Posterior is a small muscle which is placed partly beneath the elevator of the nose and lip. It arises from the margin of the nasal notch of the superior maxilla and from the sesamoid cartilages, and is inserted into the skin near the margin of the nostril.

The Dilator Naris Anterior is a thin delicate fasciculus passing from the cartilage of the ala of the nose to the integument near its margin. This muscle is situated in front of the preceding.

The Compressor Nasi is a small, thin, triangular muscle arising by its apex from the superior maxillary bone, above and a little external to the incisive fossa; its fibres proceed upward and inward, expanding into a thin aponeurosis which is attached to the fibro-cartilage of the nose and is continuous on the bridge of the nose with that of the muscle of the opposite side and with the aponeurosis of the Pyramidalis nasi. His uses the term musculus nasalis to include the Compressor nasi (transverse portion of the nasal muscle), and the Dilator naris posterior and the Dilatator naris anterior (alar portion of the nasal muscle).

The Compressor Narium Minor is a small muscle attached by one end to the alar cartilage, and by the other to the integument at the end of the nose.

The Depressor Alæ Nasi (depressor septi) is a short radiated muscle arising from the incisive fossa of the superior maxilla; its fibres ascend to be inserted into
the septum and back part of the ala of the nose. This muscle lies between the mucous membrane and muscular structure of the lip.

Nerves.—All of the muscles of this group are supplied by the facial nerve.

Actions.—The Pyramidalis nasi draws down the inner angle of the eyebrows and produces transverse wrinkles over the bridge of the nose. The Levator labii superioris alaeque nasi draws upward the upper lip and ala of the nose; its most important action is upon the nose, which it dilates to a considerable extent. The action of this muscle produces a marked influence over the countenance, and it is the principal agent in the expression of contempt and disdain. The two Dilatatores nasi enlarge the aperture of the nose. Their action in ordinary breathing is to resist the tendency of the nostrils to close from atmospheric pressure, but in difficult breathing they may be noticed to be in violent action, as well as in some emotions, as anger. The Depressor alae nasi is a direct antagonist of the other muscles of the nose, drawing the ala of the nose downward, and thereby constricting the aperture of the nares. The Compressor nasi depresses the cartilaginous part of the nose and compresses the alae together.

6. The Superior Maxillary Region (Fig. 260).

| Levator labii superioris. | Zygomaticus major. |
| Levator anguli oris. | Zygomaticus minor. |

By the term musculus quadratus labii superioris, His includes three muscles. The caput angularare is called in this book the Levator labii superioris alaeque nasi. The caput infraorbitale is called the Levator labii superioris. The caput zygomaticum is called the Zygomaticus minor.

The Levator Labii Superioris (proprius) is a thin muscle of a quadrilateral form. It arises from the lower margin of the orbit immediately above the infraorbital foramen, some of its fibres being attached to the superior maxilla, others to the malar bone; its fibres converge to be inserted into the muscular substance of the upper lip.

Relations.—By its superficial surface above, with the lower segment of the Orbicularis palpebrarum; below, it is subcutaneous. By its deep surface it conceals the origin of the Compressor nasi and Levator anguli oris muscles, and the infraorbital vessels and nerve, as they escape from the infraorbital foramen.

The Levator Anguli Oris (m. caninus) arises from the canine fossa immediately below the infraorbital foramen; its fibres incline downward and a little outward, to be inserted into the deep surface of the skin and into the subcutaneous tissue near the angle of the mouth and intermingle with the fibres of the Zygomaticus major, the Depressor anguli oris, and the Orbicularis.

Relations.—By its superficial surface, with the Levator labii superioris and the infraorbital vessels and nerves; by its deep surface, with the superior maxilla, the Buccinator, and the mucous membrane.

The Zygomaticus Major (m. zygomaticus) is a slender fasciculus which arises from the malar bone, in front of the zygomatic suture, and, descending obliquely downward and inward, is inserted into the deep surface of the skin and subcutaneous tissue at the outer portion of the upper lip and into the angle of the mouth, where it blends with the fibres of the Levator anguli oris, the Orbicularis oris, and the Depressor anguli oris.

Relations.—By its superficial surface, with the subcutaneous adipose tissue; by its deep surface, with the Masseter and Buccinator muscles and the facial artery and vein.

The Zygomaticus Minor, which is often absent, arises from the malar bone immediately behind the maxillary suture, and, passing downward and inward, is inserted into the deep surface of the skin and the adjacent muscles at the upper margin of the exposed vermillion surface of the lip midway between the middle
line of the lip and the angle of the mouth. It is continuous with the Orbicularis oris at the outer margin of the Levator labii superioris. It lies in front of the preceding.

Relations.—By its superficial surface, with the integument and the Orbicularis palpebrarum above; by its deep surface, with the Masseter, Buccinator, and Levator anguli oris, and the facial artery and vein.

Nerves.—This group of muscles is supplied by the facial nerve.

Actions.—The Levator labii superioris is the proper elevator of the upper lip, carrying it at the same time a little forward. It assists in forming the naso-labial ridge, which passes from the side of the nose to the upper lip and gives to the face an expression of sadness. The Levator anguli oris raises the angle of the mouth and draws it inward, and assists the Levator labii superioris in producing the naso-labial ridge. The Zygomaticus major draws the angle of the mouth backward and upward, as in laughing; whilst the Zygomaticus minor, being inserted into the outer part of the upper lip and not into the angle of the mouth, draws it backward, upward, and outward, and thus gives to the face an expression of sadness.

7. The Mandibular Region (Fig. 260).


Dissection.—The muscles in this region may be dissected by making a vertical incision through the integument from the margin of the lower lip to the chin; a second incision should then be carried along the margin of the lower jaw as far as the angle, and the integument carefully removed in the direction shown in Fig. 258.

The Levator Labii Inferioris or Levator Menti (m. mentalis) is to be dissected by evert ing the lower lip and raising the mucous membrane. It is a small conical fasciculus placed on the side of the frenum of the lower lip. It arises from the incisive fossa, external to the symphysis of the lower jaw; its fibres descend to be inserted into the integument of the chin.

Relation.—On its inner surface, with the mucous membrane; in the median line, it is blended with the muscle of the opposite side; and on its outer side, with the Depressor labii inferioris.

The Depressor Labii Inferioris or Quadratus Menti (m. quadratus labii inferioris) (Fig. 264) is a small quadrilateral muscle. It arises from the external oblique line of the lower jaw, between the symphysis and mental foramen, and passes obliquely upward and inward, to be inserted into the integument of the lower lip, its fibres blending with the Orbicularis oris and with those of its fellow of the opposite side. It is continuous with the fibres of the Platysma at its origin. This muscle contains much yellow fat intermingled with its fibres.

Relations.—By its superficial surface, with part of the Depressor anguli oris and with the integument, to which it is closely connected; by its deep surface, with the mental vessels and nerves, the mucous membrane of the lower lip, the labial glands, and the Levator menti, with which it is intimately united.

The Depressor Anguli Oris or Triangularis Menti (m. triangularis) (Fig. 260) is triangular in shape, arising, by its broad base, from the external oblique line of the lower jaw, from whence its fibres pass upward, to be inserted, by a narrow fasciculus, into the angle of the mouth. It is continuous with the Platysma at its origin and with the Orbicularis oris and Risorius at its insertion, and some of its fibres are directly continuous with those of the Levator anguli oris. Muscular fibres connecting the two muscles below the chin are occasionally met with; they constitute the Musculus transversus menti of His and Waldeyer.
Relations.—By its superficial surface, with the integument; by its deep surface, with the Depressor labii inferioris and Buccinator.

Nerves.—This group of muscles is supplied by the facial nerve.

Actions.—The Levator labii inferioris raises the lower lip and protrudes it forward, and at the same time wrinkles the integument of the chin, expressing doubt or disdain. The Depressor labii inferioris draws the lower lip directly downward and a little outward, as in the expression of irony. The Depressor anguli oris depresses the angle of the mouth, being the antagonist to the Levator anguli oris and Zygomaticus major; acting with these muscles, it will draw the angle of the mouth directly backward.

8. The Intermaxillary Region.


Dissection.—The dissection of these muscles may be considerably facilitated by filling the cavity of the mouth with tow, so as to distend the cheeks and lips; the mouth should then be closed by a few stitches and the integument carefully removed from the surface.

The Orbicularis oris (Figs. 260 and 264) is not a sphincter muscle, like the Orbicularis palpebrarum, but consists of numerous strata of muscular fibres, having different directions, which surround the orifice of the mouth. These fibres are partially derived from the other facial muscles which are inserted into the lips, and are partly fibres proper to the lips themselves. Of the former, a considerable number are derived from the Buccinator and form the deeper stratum of the Orbicularis. Some of them—namely, those near the middle of the muscle—decussate at the angle of the mouth, those arising from the upper jaw passing to the lower lip, and those from the lower jaw to the upper lip. Other fibres of the muscle, situated at its upper and lower part, pass across the lips from side to side without decussation. Superficial to this stratum is a second, formed by the Levator and Depressor anguli oris, which cross each other at the angle of the mouth, those from the Depressor passing to the upper lip, and those from the Levator to the lower lip, along which they run to be inserted into the skin near the median line. In addition to these there are fibres from the other muscles inserted into the lips—the Levator labii superioris, the Levator labii superioris alaeque nasi, the Zygomatici, and the Depressor labii inferioris; these intermingle with the transverse fibres above described, and have principally an oblique direction. The proper fibres of the lips are oblique, and pass from the under surface of the skin to the mucous membrane through the thickness of the lip. And in addition to these are fibres by which the muscle is connected directly with the maxillary bones and the septum of the nose. These consist, in the upper lip, of four bands, two of which (m. incisivus superior) arise from the alveolar border of the superior maxilla, opposite the lateral incisor tooth, and, arching outward on each side, are continuous at the angles of the mouth with the other muscles inserted into this part. The two remaining muscular slips, called the Nasolabialis, connect the upper lip to the back of the septum of the nose: as they descend from the septum an interval is left between them. It is this interval which forms the depression seen on the surface of the skin beneath the septum of the nose, which is called the philtrum. The additional fibres for the lower segment (m. incisivus inferior) arise from the inferior maxilla, externally to the Levator labii inferioris, and arch outward to the angles of the mouth, to join the Buccinator and the other muscles attached to this part.

Relations.—By its superficial surface, with the integument, to which it is closely connected; by its deep surface, with the buccal mucous membrane, the labial glands, and coronary vessels; by its outer circumference it is blended with the
numerous muscles which converge to the mouth from the various parts of the face. Its inner circumference is free, and covered by the mucous membrane.

The **Buccinator** (Fig. 264) is a broad, thin muscle, quadrilateral in form, which occupies the interval between the jaws at the side of the face. It **arises** from the outer surface of the alveolar processes of the upper and lower jaws, corresponding to the three molar teeth, and, behind, from the anterior border of the pterygo-maxillary ligament. The fibres converge toward the angle of the mouth, where the central fibres intersect each other, those from below being continuous with the upper segment of the Orbicularis oris, and those from above with the inferior segment; the highest and lowest fibres continue forward uninterrupted into the corresponding segment of the lip, without decussation.
Relations.—By its superficial surface, behind, with a large mass of fat, the sucking or suckorial pad (corpus adiposum buccae), which separates it from the ramus of the lower jaw, the Masseter, and a small portion of the Temporal muscle. The sucking pad is much more developed relatively in children than in adults. It assists sucking by aiding the cheek to resist atmospheric pressure. The buccinator muscle is in relation, anteriorly, with the Zygomatici, Risorius, Levator anguli oris, Depressor anguli oris, and Stenson’s duct, which pierces it opposite the second molar tooth of the upper jaw; the facial artery and vein cross it from below upward; it is also crossed by the branches of the facial and buccal nerves; by its internal surface, with the buccal glands and mucous membrane of the mouth.

The Pterygo-maxillary or Pterygo-mandibular Ligament (raphe pterygomandibularis) separates the Buccinator muscle from the Superior constrictor of the pharynx. It is a tendinous thickening of the bucco-pharyngeal fascia, attached by one extremity to the apex of the internal pterygoid plate, and by the other to the posterior extremity of the internal oblique line of the lower jaw. Its inner surface corresponds to the cavity of the mouth, and is lined by mucous membrane. Its outer surface is separated from the ramus of the jaw by a quantity of adipose tissue. Its posterior border gives attachment to the Superior constrictor of the pharynx; its anterior border, to the fibres of the Buccinator.

The Bucco-pharyngeal fascia (fascia buccopharyngea) is a thin fascia covering the external surface of the Buccinator muscle. It is gradually lost in front of the angle of the mouth. Posteriorly it is continued over the external surface of the throat muscles. Its thickened cord-like portion is the stylo-mandibular ligament.

The Risorius or Santorini’s Muscle (m. risorius) (Fig. 260) consists of a narrow bundle of fibres which arises in the fascia over the Masseter muscle, and, passing horizontally forward, is inserted with the Depressor anguli oris into the subcutaneous and muscular tissue at the angle of the mouth. It is placed superficial to the Platysma, and is broadest at its outer extremity. This muscle varies much in its size and form.

Nerves.—The muscles in this group are all supplied by the facial nerve. The buccal branch of the inferior maxillary nerve pierces the Buccinator muscle, and by some anatomists is regarded as partly supplying this muscle. Probably it merely pierces it on its way to the mucous membrane of the cheek.

Actions.—The Orbicularis oris in its ordinary action produces the direct closure of the lips; by its deep fibres, assisted by the oblique ones, it closely applies the lips to the alveolar arch. The superficial part, consisting principally of the decussating fibres, brings the lips together and also protrudes them forward. The Buccinators contract and compress the cheeks, so that, during the process of mastication, the food is kept under the immediate pressure of the teeth. When the cheeks have been previously distended with air, the Buccinator muscles expel it from between the lips, as in blowing a trumpet. Hence the name (buccina, a trumpet). The Risorius retracts the angles of the mouth, and produces ‘the unpleasant expression which is sometimes seen in tetanus, and is known as risus sardonicus, the sardonic laugh.

9. The Temporo-mandibular Region.

Masseter.

Temporal.

The Masseteric Fascia (fascia parotideomasseterica) covers the outer and inner surfaces of the parotid gland as a thick membrane, called the parotid fascia. It passes forward, and becomes thinner to cover the Masseter muscle, to which it is firmly connected. It is derived from the deep cervical fascia. Above, this fascia is attached to the lower border of the zygoma. It is lost in front below the Risorius and Platysma.

The Masseter Muscle is exposed by the removal of this fascia (Fig. 260); it is a short, thick muscle, somewhat quadrilateral in form, consisting of two portions,
superficial and deep. The superficial portion, the larger, arises by a thick, tendinous aponeurosis from the malar process of the superior maxilla, and from the anterior two-thirds of the lower border of the zygomatic arch; its fibres pass downward and backward, to be inserted into the angle and lower half of the outer surface of the ramus of the jaw. The deep portion is much smaller and more muscular in texture; it arises from the posterior third of the lower border and the whole of the inner surface of the zygomatic arch; its fibres pass downward and forward, to be inserted into the upper half of the ramus and outer surface of the coronoid process of the jaw. The deep portion of the muscle is partly concealed, in front by the superficial portion; behind, it is covered by the parotid gland. The fibres of the two portions are united at their insertion.

Relations.—By its superficial surface, with the Zygomatici, the parotid gland and Socia parotidis, and Stenson's duct; the branches of the facial nerve and the transverse facial vessels, which cross it; the masseteric fascia; the Risorius, Platysma myoides, and the integument; by its deep surface, with the Temporal muscle at its insertion, the ramus of the jaw, the Buccinator and the long buccal nerve, from which it is separated by a mass of fat (suctorial or sucking pad). The masseteric nerve and artery enter in on its under surface. Its posterior margin is overlapped by the parotid gland. Its anterior margin projects over the Buccinator muscle, and the facial vein lies on it below.

Temporal Fascia (fascia temporalis).—The temporal fascia is seen, at this stage of a dissection, covering in the Temporal muscle. It is a strong, fibrous investment, covered, on its outer surface, by the Attrahens and Attollens auriculam muscles, the aponeurosis of the Occipito-frontalis, and by part of the Orbicularis palpebrarum. The temporal vessels and the auriculo-temporal nerve cross it from below upward. Above, it is a single layer, attached to the entire extent of the upper temporal ridge; but below, where it is attached to the zygoma, it consists of two layers, one of which is inserted into the outer, and the other into the inner, border of the zygomatic arch. A small quantity of fat, the orbital branch of the temporal artery, and a filament from the orbital, or temporo-malar, branch of the superior maxillary nerve are contained between these two layers. It affords attachment by its inner surface to the superficial fibres of the Temporal muscle.

Dissection.—In order to expose the Temporal muscle, remove the temporal fascia, which may be effected by separating it at its attachment along the upper border of the zygoma, and dissecting it upward from the surface of the muscle. The zygomatic arch should then be divided in front at its junction with the malar bone, and behind near the external auditory meatus, and drawn downward with the Masseter, which should be detached from its insertion into the ramus and angle of the jaw. The whole extent of the Temporal muscle is then exposed.

The Temporal Muscle (m. temporalis) (Figs. 264 and 265) is a broad, radiating muscle situated at the side of the head and occupying the entire extent of the temporal fossa. It arises from the whole of the temporal fossa except that portion of it that is formed by the malar bone. Its attachment extends from the external angular process of the frontal in front to the mastoid portion of the temporal behind, and from the curved line on the frontal and parietal bones above to the pterygoid ridge on the great wing of the sphenoid below. It is also attached to the inner surface of the temporal fascia. Its fibres converge as they descend, and terminate in an aponeurosis, the fibres of which, radiated at its commencement, converge into a thick and flat tendon, which is inserted into the inner surface, apex, and anterior border of the coronoid process of the jaw, nearly as far forward as the last molar tooth.

Relations.—By its superficial surface, with the integument, the Attrahens and Attollens auriculam muscles, the temporal vessels and nerves, the aponeurosis of the Occipito-frontalis, the temporal fascia, the zygoma, and Masseter; by its deep surface, with the temporal fossa, the External pterygoid and part of the Buccinator muscles, the internal maxillary artery and its deep temporal branches,
and the deep temporal nerves. Behind the tendon are the masseteric vessels and nerve, and in front of it the buccal vessels and nerve. Its anterior border is separated from the malar bone by a mass of fat.

Nerves.—Both muscles are supplied by the inferior maxillary nerve.

**10. The Pterygo-mandibular Region (Figs. 266, 267).**

External pterygoid.  

**Dissection.**—The Temporal muscle having been examined, saw through the base of the coronoid process, and draw it upward, together with the Temporal muscle, which should be detached from the surface of the temporal fossa. Divide the ramus of the jaw just below the condyle, and also, by a transverse incision extending across the middle, just above the dental foramen; remove the fragment, and the Pterygoid muscles will be exposed.
The **External Pterygoid Muscle** (*m. pterygoideus externus*) is a short, thick muscle, somewhat conical in form, which extends almost horizontally between the zygomatic fossa and the condyle of the jaw. It *arises* by two heads, separated by a slight interval: the **upper head** *arises* from the inferior surface of the greater wing of the sphenoid and from the pterygoid ridge, which separates the zygomatic from the temporal fossa; the **lower head** from the outer surface of the external pterygoid plate. Its fibres pass horizontally backward and outward, to be *inserted* into a depression in front of the neck of the condyle of the lower jaw and into the corresponding part of the interarticular fibro-cartilage.

![Diagram of Pterygoid Muscles](image)

**Fig. 267.**—Pterygoid muscles, viewed from behind, the back portion of the skull having been removed. (Testut.)

**Relations.**—By its *external surface*, with the ramus of the lower jaw, the internal maxillary artery, which crosses it, the tendon of the Temporal muscle, and the Masseter; by its *internal surface* it rests against the upper part of the Internal pterygoid muscle, the internal lateral ligament, the middle meningeal artery, and inferior maxillary nerve; by its *upper border* it is in relation with the temporal and masseteric branches of the inferior maxillary nerve; by its *lower border* it is in relation with the inferior dental and gustatory nerves. Through the interval between the two portions of the muscle, the buccal nerve emerges and the internal maxillary artery passes, when the trunk of this vessel lies on the muscle.

The **Internal Pterygoid Muscle** (*m. pterygoideus internus*) is a thick, quadrilateral muscle, and resembles the Masseter in form. It *arises* from the pterygoid fossa, being attached to the inner surface of the external pterygoid plate and to the grooved surface of the tuberosity of the palate bone, and by a second slip from

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1 This is the usual relation, but in many cases the artery will be found below the muscle.—Ed. of 15th English edition.
the outer surface of the tuberosities of the palate and superior maxillary bones; its fibres pass downward, outward, and backward, to be inserted, by a strong, tendinous lamina, into the lower and back part of the inner side of the ramus and angle of the lower jaw, as high as the dental foramen.

**Relations.**—By its external surface, with the ramus of the lower jaw, from which it is separated, at its upper part, by the External pterygoid muscle, the internal lateral ligament, the internal maxillary artery, the dental vessels and nerves, and the lingual nerve, and a process of the parotid gland. By its internal surface, with the Tensor palati, being separated from the Superior constrictor of the pharynx by a cellular interval.

**Nerves.**—These muscles are supplied by the inferior maxillary nerve.

**Actions.**—The Temporal and Masseter and Internal pterygoid raise the lower jaw against the upper with great force. The superficial portion of the Masseter assists the External pterygoid in drawing the lower jaw forward upon the upper, the jaw being drawn back again by the deep fibres of the Masseter and posterior fibres of the Temporal. The External pterygoid muscles are the direct agents in the trituration of the food, drawing the lower jaw directly forward, so as to make the lower teeth project beyond the upper. If the muscle of one side acts, the corresponding side of the jaw is drawn forward, and, the other condyle remaining fixed, the symphysis deviates to the opposite side. The alternation of these movements on the two sides produces trituration.

**Surface Form.**—The outline of the muscles of the head and face cannot be traced on the surface of the body, except in the case of two of the masticatory muscles. Those of the head are thin, so that the outline of the bone is perceptible beneath them. Those in the face are small, covered by soft skin, and often by a considerable layer of fat, so that their outline is concealed, but they serve to round off and smooth prominent borders and to fill up what would be otherwise unsightly angular depressions. Thus, the Orbicularis palpebrarum rounds off the prominent margin of the orbit, and the Pyramidalis nasi fills in the sharp depression beneath the glabella, and thus softens and tones down the abrupt depression which is seen on the unclothed bone. In like manner, the labial muscles, converging to the lips and assisted by the superimposed fat, fill in the sunken hollow of the lower part of the face. Although the muscles of the face are usually described as arising from the bones and inserted into the nose, lips, and corners of the mouth, they have fibres inserted into the skin of the face along their whole extent, so that almost every point of the skin of the face has its muscular fibre to move it; hence it is that when in action the facial muscles produce alterations in the skin-surface, giving rise to the formation of various folds or wrinkles, or otherwise altering the relative position of the parts, so as to produce the varied expressions with which the face is endowed; hence these muscles are termed the muscles of expression. The only two muscles in this region which greatly influence surface form are the Masseter and the Temporal. The Masseter is a quadrilateral muscle, which imparts fulness to the hinder part of the cheek. When the muscle is firmly contracted, as when the teeth are clenched, its outline is plainly visible; the anterior border forms a prominent vertical ridge, behind which is a considerable fulness, especially marked at the lower part of the muscle; this fulness is entirely lost when the mouth is opened and the muscle no longer in a state of contraction. The Temporal muscle is fan-shaped, and fills the Temporal fossa, substituting for it a somewhat convex form, the anterior part of which, on account of the absence of hair over the temple, is more marked than the posterior, and stands out in strong relief when the muscle is in a state of contraction.

**MUSCLES AND FASCLE OF THE NECK.**

The muscles of the neck may be arranged into groups corresponding with the region in which they are situated.

These groups are nine in number:

1. Superficial Cervical Region. 5. Muscles of the Pharynx.
3. Elevators of the Os Hyoideum and Larynx. 7. Muscles of the Anterior Vertebral Region.
The muscles contained in each of these groups are the following:

1. **Superficial Region.**
   - Platysma myoideus.
   - Sterno-cleido-mastoid.

   **Infra-hyoid Region.**

2. **Depressors of Os hyoideum and Larynx.**
   - Sterno-hyoid.
   - Sterno-thyroid.
   - Thyro-hyoid.
   - Omo-hyoid.

3. **Elevators of Os hyoideum and Larynx.**
   - Digastric.
   - Stylo-hyoid.
   - Mylo-hyoid.
   - Genio-hyoid.

   **Lingual Region.**

4. **Muscles of the Tongue.**
   - Genio-hyo-glossus.
   - Hyo-glossus.
   - Chondro-glossus.
   - Stylo-glossus.
   - Palato-glossus.

5. **Muscles of the Pharynx.**
   - Inferior constrictor.
   - Middle constrictor.
   - Superior constrictor.
   - Stylo-pharyngeus.
   - Palato-pharyngeus.

6. **Muscles of the Soft Palate.**
   - Levator palatii.
   - Tensor palatii.
   - Ayzgos uvulae.
   - Palato-glossus.
   - Palato-pharyngeus.
   - Salpingo-pharyngeus.

7. **Muscles of the Anterior Vertebral Region.**
   - Rectus capitis anticus major.
   - Rectus capitis anticus minor.
   - Rectus capitis lateralis.
   - Longus colli.

8. **Muscles of the Lateral Vertebral Region.**
   - Scalenus anticus.
   - Scalenus medius.
   - Scalenus posticus.

9. **Muscles of the Larynx.**
   - Included in description of the Larynx.

1. **The Superficial Cervical Region.**

   **Platysma myoideus.**

   **Stheno-cleido-mastoid.**

   **Dissection.**—A block having been placed at the back of the neck, and the face turned to the side opposite that to be dissected, so as to place the parts upon the stretch, make two transverse incisions; one from the chin, along the margin of the lower jaw, to the mastoid process, and the other along the upper border of the clavicle. Connect these by an oblique incision made in the course of the Sterno-mastoid muscle, from the mastoid process to the sternum; the two flaps of integument having been removed in the direction shown in Fig. 258, the superficial fascia will be exposed.

**Superficial Cervical Fascia.**—The superficial cervical fascia is a thin, apon-eurotic lamina which is hardly demonstrable as a separate membrane. Beneath it is found the Platysma myoideus muscle.

The **Platysma Myoideus** (m. platysma) (Fig. 260) is a broad, thin plane of muscular fibres placed immediately beneath the superficial fascia on each side of the neck. It arises by thin, fibrous bands from the fascia covering the upper part of the Pectoral and Deltoid muscles; its fibres pass over the clavicle and proceed obliquely upward and inward along the side of the neck. The anterior fibres interlace, below and behind the symphysis menti, with the fibres of the muscle of the opposite side; the posterior fibres pass over the lower jaw, some of them being attached to the bone below the external oblique line, others passing on to be inserted into the skin and subcutaneous tissue of the lower part of the face, many of these fibres blending with the muscles about the angle and lower part of the mouth. Some-
times fibres can be traced to the Zygomatic muscles or to the margin of the Orbicularis oris. Beneath the Platysma the external jugular vein may be seen descending in a line from the angle of the jaw to the middle of the clavicle.

Relations.—By its external surface, with the integument, to which it is united more closely below than above; by its internal surface, with the Pectoralis major and Deltoid, and with the clavicle. In the neck, with the external and anterior jugular veins, the deep cervical fascia, the superficial branches of the cervical plexus, the Sterno-mastoid, Sterno-hyoid, Omo-hyoid, and Digastric muscles; behind the Sterno-mastoid muscle it covers in the posterior triangle of the neck. On the face it is in relation with the parotid gland, the facial artery and vein, and the Masseter and Buccinator muscles.

Nerves.—The lower division of the facial nerve chiefly innervates this muscle, and superficial branches from the cervical plexus also reach it.

Action.—The Platysma myoides produces a slight wrinkling of the surface of the skin of the neck, in an oblique direction, when the entire muscle is brought into action. Its anterior portion, the thickest part of the muscle, depresses the lower jaw; it also serves to draw down the lower lip and angle of the mouth on each side, being one of the chief agents in the expression of melancholy. In the pressure upon the blood-vessels of the neck induced by strong inspiratory effort, this muscle draws away the skin and fascia, and by so doing, greatly diminishes the pressure on the veins.

Deep Cervical Fascia (fascia colli) (Fig. 268).—The deep cervical fascia lies under cover of the Platysma myoides muscle and constitutes a complete investment for the neck. It also forms a sheath for the carotid vessels, and, in addition, is prolonged deeply in the shape of certain processes or lamellae, which come into close relation with the structures situated in front of the vertebral column.

The investing portion of the fascia is attached, behind, to the ligamentum nuchae and to the spine of the seventh cervical vertebra. Along this line it splits to enclose the Trapezius muscle, at the anterior border of which the two enclosing lamellae unite and form a strong membrane, which extends forward so as to roof in the posterior triangle of the neck. Along the hinder edge of the Sterno-mastoid the membrane divides to enclose this muscle, at the anterior edge of which it once more forms a single lamella, which roofs in the anterior triangle of the neck, and, reaching forward to the middle line, is continuous with the corresponding part from the opposite side of the neck. In the middle line of the neck it is attached to the symphysis menti and to the body of the hyoid bone.

Above, the fascia is attached to the superior curved line of the occiput, to the mastoid process of the temporal, and to the whole length of the body of the jaw. Opposite the angle of the jaw the fascia is very strong, and binds the anterior edge of the Sterno-mastoid firmly to that bone. Between the jaw and the mastoid process it enshrouds the parotid gland—the layer which covers the gland extending upward under the name of the parotid fascia to be fixed to the zygomatic arch. The parotid fascia is prolonged forward to cover the masseter muscle, the masseteric fascia. From the layer which passes under the parotid a strong band, the stylo-mandibular ligament, reaches from the styloïd process to the angle of the jaw. The parotid and masseteric fasciae constitute the fascia parotideo-masseterica.

Below, the cervical fascia is attached to the acromion process, the clavicle, and to the manubrium sterni. Some little distance above the last-named point, however, it splits into two layers, superficial and deep. The former is attached to the anterior border of the manubrium, the latter to its posterior border and to the interclavicular ligament. Between these two layers is a slit-like interval, the suprasternal space or space of Burns (spatium suprasternale). It contains a small quantity of areolar tissue, and sometimes a lymphatic gland; the lower portions
of the anterior jugular veins and their transverse connecting branch; and also the sternal heads of the Sterno-mastoid muscles.

The fascia which lines the deep aspect of the Sterno-mastoid gives off certain important processes, viz.: (1) A process to envelop the tendon of the Omo-hyoid, and bind it down to the sternum and first costal cartilage. (2) A strong sheath, the carotid sheath, for the large vessels of the neck, enclosed within which are the carotid artery, internal jugular vein, the vagus, and descendens hypoglossi nerves. (3) The prevertebral fascia (fascia praevertebralis), which extends inward behind the carotid vessels, where it assists in forming their sheath, and passes in front of the prevertebral muscles. It thus forms the posterior limit of a fibrous compartment which contains the larynx and trachea, the thyroid gland, and the pharynx and oesophagus. The prevertebral fascia is fixed above to the base of the skull, while below it is continued into the thorax in front of the Longus colli muscles. Parallel to the carotid vessels and along their inner aspect it gives off a thin lamina, the bucco-pharyngeal fascia (fascia buccopharyngea), which closely invests the constrictor muscles of the pharynx, and is continued forward from the Superior constrictor on to the Buccinator. It is attached to the prever-
tebral layer by loose connective tissue only, and thus an easily distended space, the retro-pharyngeal space (spatium retropharyngea), is found between them. This space is limited above by the base of the skull, while below it extends behind the osophagus into the thorax, where it is continued into the posterior mediastinum. The prevertebral fascia is prolonged downward and outward behind the carotid vessels and in front of the Scaleni muscles, and forms a sheath for the brachial plexus of nerves and for the subclavian vessels in the posterior triangle of the neck, and, continuing under the clavicle as the axillary sheath, is attached to the deep surface of the costo-coracoid membrane. Immediately above the clavicle an areolar space exists between the investing layer and the sheath of the subclavian vessels, and in it are found the lower part of the external jugular vein, the descending clavicular nerves, the suprascapular and transversalis colli vessels, and the posterior belly of the Omo-hyoid muscle. This space extends downward behind the clavicle, and is limited below by the fusion of the costo-coracoid membrane with the anterior wall of the axillary sheath. (4) The pre-tracheal fascia, which extends inward in front of the carotid vessels, and assists in forming the carotid sheath. It is further continued behind the Depressor muscles of the hyoid bone, and, after enveloping the thyroid body, is prolonged in front of the trachea to meet the corresponding layer of the opposite side. Above, it is fixed to the hyoid bone, while below it is carried downward in front of the trachea and large vessels at the root of the neck, and ultimately blends with the fibrous pericardium.

Surgical Anatomy.—The cervical fascia is of considerable importance from a surgical point of view. As will be seen from the foregoing description, it may be divided into three layers: (1) A superficial layer; (2) a layer passing in front of the trachea, and forming with the superficial layer a sheath for the depressors of the hyoid bone; (3) a prevertebral layer passing in front of the bodies of the cervical vertebrae, and forming with the second layer a space in which are contained the trachea, osophagus, etc. The superficial layer forms a complete investment for the neck. It is attached behind to the ligamentum nuchae and the spine of the seventh cervical vertebra; above it is attached to the external occipital protuberance, to the superior curved line of the occiput, to the mastoid process, to the zygoma and the lower jaw; below it is attached to the manubrium sterni, the clavicle, the acromion process, and the spine of the scapula; in front it blends with the fascia of the opposite side. This layer opposes the extension of abscesses or new-growths toward the surface, and pus forming beneath it has a tendency to extend laterally. If pus is in the posterior triangle, it might extend backward under the Trapezius, forward under the Sterno-mastoid, or downward under the clavicle for some distance, until stopped by the junction of the cervical fascia to the Costocoracoid membrane. If the pus is contained in the anterior triangle, it might find its way into the anterior mediastinum, being situated in front of the layer of fascia which passes down into the thorax to become continuous with the pericardium; but owing to the lesser density and thickness of the fascia in this situation it more frequently finds its way through it and points above the sternum. The second layer of fascia is connected above with the hyoid bone. It passes down beneath the depressors and in front of the thyroid body and trachea to become continuous with the fibrous layer of the pericardium. Laterally it invests the great vessels of the neck and is connected with the superficial layer beneath the Sterno-mastoid. Pus forming beneath this layer would in all probability find its way into the posterior mediastinum. The third layer (the prevertebral fascia) is connected above to the base of the skull. Pus forming beneath this layer, in cases, for instance, of caries of the bodies of the cervical vertebrae, might extend toward the posterior and lateral part of the neck and point in this situation, or might perforate this layer of fascia and the pharyngeal fascia and point into the pharynx (retro-pharyngeal abscess).

In cases of cut throat the cervical fascia is of considerable importance. When the wound involves only the superficial layer the injury is usually trivial, the only special danger being injury to the external jugular vein, and the only special complication being diffuse cellulitis. But where the second of the two layers has been opened up, important structures may have been injured, which may lead to serious results.

It may be worth while mentioning that in Burns's space is contained the sternal head of origin of the Sterno-mastoid muscles, so that this space is opened in division of this tendon. The anterior jugular vein is also contained in the same space.

The Sterno-mastoid or Sterno-cleido-mastoid (m. sterno-cleido-mastoidus) (Fig. 269) is a large, thick muscle, which passes obliquely across the side of the
neck, being enclosed between two layers of the deep cervical fascia. It is thick and narrow at its central part, but is broader and thinner at each extremity. It arises, by two heads, from the sternum and clavicle. The sternal portion is a rounded fasciculus, tendinous in front, fleshy behind, which arises from the upper and anterior part of the first piece of the sternum, and is directed upward, outward, and backward. The clavicular portion arises from the inner third of the superior border and anterior surface of the clavicle, being composed of fleshy and aponeurotic fibres; it is directed almost vertically upward. These two portions are separated from one another, at their origin, by a triangular cellular interval, but become gradually blended, below the middle of the neck, into a thick, rounded muscle, which is inserted, by a strong tendon, into the outer surface of the mastoid process of the temporal bone, from its apex to its superior border, and by a thin aponeurosis into the outer half of the superior curved line of the occipital bone. The Sterno-mastoid varies much in its extent of attachment to the clavicle: in one case the clavicular may be as narrow as the sternal portion; in another, the former may be as much as three inches in breadth. When the clavicular origin is broad, it is occasionally subdivided into numerous slips separated by narrow intervals. More rarely, the corresponding margins of the Sterno-mastoid and Trapezius have been found in contact. In the application of a ligature to the third part of the subclavian artery it will be necessary, where the Sterno-mastoid and Trapezius come close together, to divide a portion of one or of both. This muscle divides the quadrilateral space at the side of the neck into two triangles, an anterior and a posterior. The boundaries of the anterior triangle are, in front, the median line of the neck; above, the lower border of the body of the jaw, and an imaginary line drawn from the angle of the jaw to the mastoid process; behind, the anterior border of the Sterno-mastoid muscle. The apex of the triangle is at the upper border of the sternum. The boundaries of the posterior

Fig. 269.—Muscles of the neck and boundaries of the triangles.
triangle are, in front, the posterior border of the Sterno-mastoid; below, the middle third of the clavicle; behind, the anterior margin of the Trapezius. The apex corresponds with the meeting of the Sterno-mastoid and Trapezius on the occipital bone.

**Relations.**—By its superficial surface, with the integument and Platysma, from which it is separated by the external jugular vein, the superficial branches of the cervical plexus, and the anterior layer of the deep cervical fascia. By its deep surface it is in relation with the Sterno-clavicular articulation; a process of the deep cervical fascia; the Sterno-hyoid, Sterno-thyroid, Omo-hyoid, posterior belly of the Digastric, Levator anguli scapulae, Splenius and Scaleni muscles; common carotid artery, internal and anterior jugular veins, commencement of the internal and external carotid arteries, the occipital, subclavian, transversalis colli, and suprascapular arteries and veins; the phrenic, vagus, hypoglossal, descendens and communicans hypoglossi nerves; the accessory nerve, which pierces its upper third; the cervical plexus, parts of the thyroid and parotid glands, and deep lymphatic glands.

**Nerves.**—The Sterno-cleido-mastoid is supplied by the accessory nerve and deep branches of the cervical plexus.

**Actions.**—When only one Sterno-mastoid muscle acts, it draws the head toward the shoulder of the same side, assisted by the Splenius and the Obliquus capitis inferior of the opposite side. At the same time it rotates the head so as to carry the face toward the opposite side. When the two muscles act together they flex the head upon the neck. If the head is fixed, the two muscles assist in elevating the thorax in forced inspiration.

**Surface Form.**—The anterior edge of the muscle forms a very prominent ridge beneath the skin, which is important to notice, as it forms a guide to the surgeon in making the necessary incisions for ligature of the common carotid artery and for cesophagectomy.

**Surgical Anatomy.**—The relations of the sternal and clavicular parts of the Sterno-mastoid should be carefully examined, as the surgeon is sometimes required to divide one or both portions of the muscle in wry-neck (torticollis). One variety of this distortion is produced by spasmodic contraction or rigidity of the Sterno-mastoid; the head being carried down toward the shoulder of the same side, and the face turned to the opposite side and fixed in that position. When there is permanent shortening, subcutaneous division of the muscle is resorted to by some surgeons. This is performed by introducing a tenotomy knife beneath it, close to its origin, and dividing it from behind forward whilst the muscle is put well upon the stretch. There is seldom any difficulty in dividing the sternal portion by making a puncture on the inner side of the tendon, and then pushing a blunt tenotome behind it, and cutting forward. In dividing the clavicular portion care must be taken to avoid wounding the external jugular vein, which runs parallel with the posterior border of the muscle in this situation, or the anterior jugular vein, which crosses beneath it. If the external jugular vein lies near the muscle, it is safer to make the first puncture at the outer side of the tendon, and introduce a blunt tenotome from without inward. Many surgeons prefer dividing the muscle by open incision, because by this method all of the contracted fibres, muscular and facial, can be certainly and safely divided. An incision is made over the origin of the muscle, the origin is exposed, a director is passed underneath it, and it is then divided. With care and attention to asepsis this plan of treatment is devoid of risk, and in this way the accidental division of vessels can be avoided. Some of the fibres of the Sterno-mastoid muscle are occasionally torn during birth, especially in breech presentations; this is accompanied by hemorrhage and formation of a swelling within the substance of the muscle. This by some is believed to be one of the causes of wry-neck, the scar tissue which is formed contracting and shortening the muscle.

2. The Infra-hyoid Region (Figs. 269, 270).

**Depressors of the Os HYOIDEUM and LARYNX.**

- Sterno-hyoid.
- Sterno-thyroid.
- Thyro-hyoid.
- Omo-hyoid.

**Dissection.**—The muscles in this region may be exposed by removing the deep fascia from the front of the neck. In order to see the entire extent of the Omo-hyoid it is necessary to divide the sterno-mastoid at its centre, and turn its ends aside, and to detach the Trapezius from the clavicle and scapula. This, however, should not be done until the Trapezius has been dissected.

1 The anatomy of these triangles will be more exactly described with that of the vessels of the neck.—En. of 15th English edition.
The **Sterno-hyoid** (*m. sternohyoides*) is a thin, narrow, ribbon-like muscle, which *arises* from the inner extremity of the clavicle, the posterior sternoclavicular ligament, and the upper and posterior part of the first piece of the sternum; passing upward and inward, it is *inserted*, by short, tendinous fibres, into the lower border of the body of the hyoid bone. This muscle is separated, below, from its fellow by a considerable interval; but the two muscles come into contact with one another in the middle of their course, and from this upward lie side by side. It sometimes presents, immediately above its origin, a transverse tendinous intersection, like those in the Rectus abdominis. As a rule, two bursae, the **sterno-hyoid bursae** (*bursae sternohyoidi*), lie between the crico-thyroid membrane, on one hand, and the Sterno-hyoid muscle and the cervical fascia, on the other. Sometimes there is one large median bursa instead of two lateral bursae. Not unusually there is no bursa at all.

**Relations.**—By its *superficial surface*, below, with the sternum, the sternal end of the clavicle, and the Sterno-mastoid; and above, with the Platysma and deep cervical fascia; by its *deep surface*, with the Sterno-thyroid, Crico-thyroid, and

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**THE MUSCLES AND FASCIAE**

394

Fig. 270.—Muscles of the neck. Anterior view.

Thyro-hyoid muscles, the thyroid gland, the superior thyroid vessels, the thyroid cartilage, the crico-thyroid and thyro-hyoid membranes.

The **Sterno-thyroid** (*m. sternothyroideus*) is situated beneath the preceding muscle, but is shorter and wider than it. It *arises* from the posterior surface of the first piece of the sternum, below the origin of the Sterno-hyoid, and from the edge of the cartilage of the first rib, occasionally of the second rib also, and is *inserted* into the oblique line on the side of the ala of the thyroid cartilage. This muscle is in close contact with its fellow at the lower part of the neck, and is occasionally traversed by a transverse or oblique tendinous intersection, like those in the Rectus abdominis.
THE INFRA-HYOID REGION

Relations.—By its anterior surface, with the Sterno-hyoid, Omo-hyoid, and Sterno-mastoid; by its posterior surface, from below upward, with the trachea, vena innominata, common carotid (and on the right side the arteria innominata), the thyroid gland and its vessels, and the lower part of the larynx and pharynx. The inferior thyroid vein lies along its inner border, a relation which it is important to remember in the operation of tracheotomy. On the left side the deep surface of the muscle is in relation to the oesophagus.

The Thyro-hyoid (m. thyreohyoideus) is a small, quadrilateral muscle appearing like a continuation of the Sterno-thyroid. It arises from the oblique line on the side of the thyroid cartilage, and passes vertically upward to be inserted into the lower border of the body and greater cornu of the hyoid bone. The thyro-hyoid bursa (bursae thyreohyoidi) lie inferior to the greater cornua of the hyoid bone and upon the thyro-hyoid membrane. There is one bursa on each side beneath the corresponding Thyro-hyoid muscle.

Relations.—By its external surface, with the Sterno-hyoid and Omo-hyoid muscles; by its internal surface, with the thyroid cartilage, the thyro-hyoid membrane, and the superior laryngeal vessels and nerve.

The Omo-hyoid (m. omohyoides) passes across the side of the neck, from the scapula to the hyoid bone. It consists of two fleshy bellies, united by a central tendon. It arises from the upper border of the scapula, and occasionally from the transverse ligament which crosses the suprascapular notch, its extent of attachment to the scapula varying from a few lines to an inch. From this origin the posterior belly (venter inferior) forms a flat, narrow fasciculus, which inclines forward and slightly upward across the lower part of the neck, behind the Sterno-mastoid muscle, where it becomes tendinous; it then changes its direction, forming an obtuse angle, and terminates in the anterior belly (venter superior), which passes almost vertically upward, close to the outer border of the Sterno-hyoid, to be inserted into the lower border of the body of the hyoid bone, just external to the insertion of the Sterno-hyoid. The central tendon of this muscle, which varies much in length and form, is held in position by a process of the deep cervical fascia, which includes it in a sheath. This process is prolonged down, to be attached to the clavicle and first rib. It is by this means that the angular form of the muscle is maintained.

This muscle subdivides each of the two large triangles at the side of the neck into two smaller triangles; the two posterior ones being the posterior superior or occipital triangle, and the posterior inferior or subclavian triangle; the two anterior, the anterior superior or superior carotid triangle, and the anterior inferior or inferior carotid triangle.

Relations.—By its superficial surface, with the Trapezius, the Sterno-mastoid, deep cervical fascia, Platysma, and integument; by its deep surface, with the Scaleni muscles, phrenic nerve, lower cervical nerves, which go to form the brachial plexus, the suprascapular vessels and nerve, sheath of the common carotid artery and internal jugular vein, the Sterno-thyroid and Thyro-hyoid muscles.

Nerves.—The Thyro-hyoid is supplied by the hypoglossal; the other muscles of this group by branches from the loop of communication between the descendens and communicans hypoglossi.

Actions.—These muscles depress the larynx and hyoid bone, after they have been drawn up with the pharynx in the act of deglutition. The Omo-hyoid muscles not only depress the hyoid bone, but carry it backward and to one side. It is concerned especially in prolonged inspiratory efforts; for by tensing the lower part of the cervical fascia it lessens the inward suction of the soft parts, which would otherwise compress the great vessels and the apices of the lungs. This action is synergistic with that of the Platysma. The Thyro-hyoid may act as an elevator of the thyroid cartilage when the hyoid bone ascends, drawing
upward the thyroid cartilage, behind the hyoid bone. The Sterno-thyroid acts as a depressor of the thyroid cartilage.

3. The Supra-hyoid Region (Figs. 269, 270).

ELEVATORS OF THE OS HYOIDUM—DEPRESSORS OF THE LOWER JAW.

Digastric. Mylo-hyoid.


Dissection.—To dissect these muscles a block should be placed beneath the back of the neck, and the head drawn backward and retained in that position. On the removal of the deep fascia the muscles are at once exposed.

The Digastric (m. digastricus) consists of two fleshy bellies united by an intermediate, rounded tendon. It is a small muscle, situated below the side of the body of the lower jaw, and extending, in a curved form, from the side of the head to the symphysis of the jaw. The posterior belly (venter posterior), longer than the anterior, arises from the digastric groove on the inner side of the mastoid process of the temporal bone, and passes downward, forward, and inward. The anterior belly (venter anterior) arises from a depression on the inner side of the lower border of the jaw, close to the symphysis, and passes downward and backward. The two bellies terminate in the central tendon which perforates the Stylo-hyoid, and is held in connection with the side of the body and the greater cornu of the hyoid bone by a fibrous loop, lined by a synovial membrane. A broad aponeurotic layer is given off from the tendon of the Digastric on each side, which is attached to the body and great cornu of the hyoid bone: this is termed the supra-hyoid aponeurosis. It forms a strong layer of fascia between the anterior portion of the two muscles, and a firm investment for the other muscles of the supra-hyoid region which lie deeper.

The Digastric muscle divides the anterior superior triangle of the neck into two smaller triangles; the upper, or submaxillary triangle, being bounded, above, by the lower border of the body of the jaw, and a line drawn from its angle to the mastoid process; below, by the posterior belly of the Digastric and the Stylo-hyoid muscles; in front, by the middle line of the neck and the anterior belly of the Digastric, the lower or superior carotid triangle being bounded above by the posterior belly of the Digastric, behind by the Sterno-mastoid, below by the anterior belly of the Omo-hyoid.

Relations.—By its superficial surface, with the mastoid process, the Platysma, Sterno-mastoid, part of the Splenius, Trachelo-mastoid, and Stylo-hyoid muscles, and the parotid gland. By its deep surface, the anterior belly lies on the Mylo-hyoid; the posterior belly on the Stylo-glossus, Stylo-pharyngeus, and Hyo-glossus muscles, the external carotid artery and its occipital, lingual, facial, and ascending pharyngeal branches, the internal carotid artery, internal jugular vein, and hypoglossal nerve.

The Stylo-hyoid (m. stylohyoideus) is a small, slender muscle, lying in front of, and above, the posterior belly of the Digastric. It arises from the back and outer surface of the styloid process of the temporal bone, near the base; and, passing downward and forward, is inserted into the body of the hyoid bone, just at its junction with the greater cornu, and immediately above the Omohyoid. This muscle is perforated, near its insertion, by the tendon of the Digastric.

Relations.—By its superficial surface above with the parotid gland and deep cervical fascia; below it is superficial, being situated immediately beneath the deep cervical fascia. By its deep surface, with the posterior belly of the Digastric, the external carotid artery, with its lingual and facial branches, the Hyo-glossus muscle, and the hypoglossal nerve.
The Stylo-hyoid Ligament (ligamentum stylohyoideus).—In connection with the Stylo-hyoid muscle may be described a ligamentous band, the stylo-hyoid ligament. It is a fibrous cord, often containing a little cartilage in its centre, which continues the styloid process down to the hyoid bone, being attached to the tip of the former and the small cornu of the latter. It is often more or less ossified, and in many animals forms a distinct bone, the epiphyal.

The anterior belly of the Digastric should be removed, in order to expose the next muscle.

The Mylo-hyoid (m. mylohyoideus) (Fig. 271) is a flat, triangular muscle, situated immediately beneath the anterior belly of the Digastric, and forming, with its fellow of the opposite side, a muscular floor for the cavity of the mouth. It arises from the whole length of the mylo-hyoid ridge of the lower jaw, extending from the symphysis in front to the last molar tooth behind. The posterior fibres pass inward and slightly downward, to be inserted into the body of the hyoid bone. The middle and anterior fibres are inserted into a median fibrous raphe, extending from the symphysis of the lower jaw to the hyoid bone, where they join at an angle with the fibres of the opposite muscle. The median raphe is sometimes wanting; the muscular fibres of the two sides are then directly continuous with one another.

Relations.—By its cutaneous or under surface, with the Platysma, the anterior belly of the Digastric, the supra-hyoid aponeurosis, the submaxillary gland, submental vessels, and mylo-hyoid vessels and nerve; by its deep or superior surface, with the Genio-hyoid, part of the Hyo-glossus and Stylo-glossus muscles, the hypoglossal and lingual nerves, the submaxillary ganglion, the sublingual gland, the deep portion of the submaxillary gland, and Wharton’s duct; the sublingual and ranine vessels, and the buccal mucous membrane.

Dissection.—The Mylo-hyoid should now be removed, in order to expose the muscles which lie beneath; this is effected by reflectting it from its attachments to the hyoid bone and jaw, and separating it by a vertical incision from its fellow of the opposite side.

The Genio-hyoid (m. geniohyoideus) (Fig. 272) is a narrow, slender muscle, situated immediately beneath the inner border of the preceding. It arises from the inferior genial tubercle on the inner side of the symphysis of the jaw, and

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1 This refers to the depth of the muscles from the skin in the order of dissection. In the erect position of the body the Genio-hyoid is above the Mylo-hyoid.
passes downward and backward, to be inserted into the anterior surface of the body of the hyoid bone. This muscle lies in close contact with its fellow of the opposite side, and increases slightly in breadth as it descends.

**Relations.**—It is covered by the Mylo-hyoid and lies along the lower border of the Genio-hyo-glossus.

**Nerves.**—The anterior belly of the Digastric is supplied by the mylo-hyoid branch of the inferior dental; its posterior belly, by the facial; the Stylo-hyoid is supplied by the facial; the Mylo-hyoid, by the mylo-hyoid branch of the inferior dental; the Genio-hyoid, by the hypoglossal.

**Actions.**—This group of muscles performs two very important actions. They raise the hyoid bone, and with it the base of the tongue, during the act of deglutition; or, when the hyoid bone is fixed by its depressors and those of the larynx, they depress the lower jaw. During the first act of deglutition, when the mass is being driven from the mouth into the pharynx, the hyoid bone, and with it the tongue, is carried upward and forward by the anterior belly of the Digastric, the Mylo-hyoid, and Genio-hyoid muscles. In the second act, when the mass is pass-

![Fig. 272.—Muscles of the tongue. Left side.](image)

4. The Lingual Region (Figs. 272, 273).

- Genio-hyo-glossus.
- Hyo-glossus.
- Stylo-glossus.
- Palato-glossus.
- Chondro-glossus.
Dissection.—After completing the dissection of the preceding muscles, saw through the lower jaw just external to the symphysis. Then draw the tongue forward, and attach it, by a stitch, to the nose; when its muscles, which are thus put on a stretch, may be examined.

The Genio-hyo-glossus (m. genioglossus) has received its name from its triple attachment to the jaw, hyoid bone, and tongue, but it is better to name it the Genio-glossus, since its attachment to the hyoid bone is very slight or altogether absent. It is a flat, triangular muscle, placed vertically on either side of the middle line, its apex corresponding with its point of attachment to the lower jaw, its base with its insertion into the tongue and hyoid bone. It arises by a short tendon from the superior genial tubercle on the inner side of the symphysis of the jaw, immediately above the Genio-hyoid; from this point the muscle spreads out in a fan-like form, a few of the inferior fibres passing downward, to be attached by a thin aponeurosis into the upper part of the body of the hyoid bone, a few fibres passing between the Hyo-glossus and Chondro-glossus to blend with the Constrictor muscles of the pharynx; the middle fibres passing backward, and the superior ones upward and forward, to enter the whole length of the under surface of the tongue, from the base to the apex. The two muscles lie on either side of the median plane; behind they are quite distinct from each other, and are separated at their insertion into the under surface of the tongue by a tendinous raphé, which extends through the middle of the organ; in front, the two muscles are more or less blended: distinct fasciculi are to be seen passing off from one muscle, crossing the middle line, and intersecting with bundles of fibres derived from the muscle on the other side.

Relations.—By its internal surface it is in contact with its fellow of the opposite side; by its external surface, with the Inferior lingualis, the Hyo-glossus, the lingual artery and hypoglossal nerve, the lingual nerve, and sublingual gland; by its upper border, with the mucous membrane of the floor of the mouth (fraenum linguae); by its lower border with the Genio-hyoid.

The Hyo-glossus (m. hyoglossus) is a thin, flat, quadrilateral muscle which arises from the side of the body and whole length of the greater cornu of the hyoid bone, and passes almost vertically upward to enter the side of the tongue, between the Stylo-glossus and Lingualis. Those fibres of this muscle which arise from the body are directed upward and backward, overlapping those arising from the greater cornu, which are directed upward and forward.

Relations.—By its external surface, with the Digastric, the Stylo-hyoid, Stylo-glossus, and Mylo-hyoid muscles, the submaxillary ganglion, the lingual and hypoglossal nerves, Wharton's duct, the ranine vein, the sublingual gland, and the deep portion of the submaxillary gland. By its deep surface, with the Stylo-hyoid ligament, the Genio-hyo-glossus, Lingualis, and Middle constrictor, the lingual vessels and the glosso-pharyngeal nerve.

The Chondro-glossus (m. chondroglossus) is a distinct muscular slip, though it is sometimes described as a part of the Hyo-glossus, from which, however, it is separated by the fibres of the Genio-hyo-glossus, which pass to the side of the pharynx. It is about three-quarters to an inch in length, and arises from the inner side and base of the lesser cornu and contiguous portion of the body of the hyoid bone, and passes directly upward to blend with the intrinsic muscular fibres of the tongue, between the Hyo-glossus and Genio-hyo-glossus. A small slip of muscular fibre is occasionally found, arising from the cartilago triticea in the thyro-hyoid ligament, and passing upward and forward to enter the tongue with the hindermost fibres of the Hyo-glossus.

The Stylo-glossus (m. styloglossus), the shortest and smallest of the three styloid muscles, arises from the anterior and outer side of the styloid process, near its apex, and from the stylo-mandibular ligament, to which its fibres, in most cases, are attached by a thin aponeurosis. Passing downward and forward between the internal and external carotid arteries, and becoming nearly horizontal in its direction, it divides upon the side of the tongue into two portions: one longitudinal, which
enters the side of the tongue near its dorsal surface, blending with the fibres of the Lingualis in front of the Hyo-glossus; the other oblique, which overlaps the Hyo-glossus muscle and decussates with its fibres.

**Relations.**—By its *external surface*, from above downward, with the parotid gland, the Internal pterygoid muscle, the lingual nerve, and the mucous membrane of the mouth; by its *internal surface*, with the tonsil, the Superior constrictor, and the Hyo-glossus muscle.

The **Palato-glossus** or **Constrictor Isthmi Fauces** (*m. glossopalatinus*), although it is one of the muscles of the tongue, serving to draw its base upward during the act of deglutition, is more nearly associated with the soft palate, both in its situation and function; it will consequently be described with that group of muscles.

**Nerves.**—The Palato-glossus is probably innervated by the accessory nerve, through the pharyngeal plexus; the remaining muscles of this group, by the hypoglossal nerve.

**Muscular Substance of the Tongue** (Figs. 273 and 274).—The muscular fibres of the tongue run in various directions. These fibres are divided into two sets—**Extrinsic** and **Intrinsic**. The **extrinsic muscles** of the tongue are those which have their origin external, and only their terminal fibres contained in the substance of the organ. They are: the Stylo-glossus, the Hyo-glossus, the Palato-glossus, the Genio-hyo-glossus, and part of the Superior constrictor of the pharynx (Pharyngeo-glossus). The **intrinsic muscles** are those which are contained entirely within the tongue, and form the greater part of its muscular structure.

The tongue consists of symmetrical halves separated from each other in the middle line by a **fibrous septum** (*septum linguae*). Each half is composed of muscular fibres arranged in various directions, containing much interposed fat, and supplied by vessels and nerves.

To demonstrate the various fibres of the tongue, the organ should be subjected to prolonged boiling, in order to soften the connective tissue; the dissection may then be commenced from the dorsum (Figs. 273 and 274). Immediately beneath the
mucous membrane is a submucous, fibrous layer, into which the muscular fibres which terminate on the surface of the tongue are inserted. Upon removing this, with the mucous membrane, the first stratum of muscular fibres is exposed. This belongs to the group of intrinsic muscles, and has been named the Superior lingualis (m. longitudinalis superior). It consists of a thin layer of oblique and longitudinal fibres which arise from the submucous fibrous layer, close to the Epiglottis, and from the fibrous septum, and pass forward and outward to the edges of the tongue. Between its fibres pass some vertical fibres derived from the Genio-hyo-glossus and from the vertical intrinsic muscle, which will be described later on. Beneath this layer is the second stratum of muscular fibres, derived principally from the extrinsic muscles. In front it is formed by the fibres derived from the Stylo-glossus, running along the side of the tongue, and sending one set of fibres over the dorsum which run obliquely forward and inward to the middle line, and another set of fibres seen at a later period of the dissection, on to the under surface of the sides of the anterior part of the tongue, which run forward and inward, between the fibres of the Hyo-glossus, to the middle line. Behind this layer of fibres, derived from the Stylo-glossus, are fibres derived from the Hyo-glossus, assisted by some few fibres of the Palato-glossus. The Hyo-glossus, entering the side of the under surface of the tongue, between the Stylo-glossus and Inferior lingualis, passes round its margin and spreads out into a layer on the dorsum, which occupies the middle third of the organ, and runs almost transversely inward to the septum. It is reinforced by some fibres from the Palato-glossus; other fibres of this muscle pass more deeply and intermingle with the next layer. The posterior part of the second layer of the muscular fibres of the tongue is derived from those fibres of the Hyo-glossus which arise from the lesser cornu of the hyoid bone, and are here described as a separate muscle—the Chondro-glossus. The fibres of this muscle are arranged in a fan-shaped manner, and spread out over the posterior third of the tongue. Beneath this layer is the great mass of the intrinsic muscles of the tongue, intersected at right angles by the terminal fibres of one of the extrinsic muscles—the Genio-hyo-glossus. This portion of the tongue is paler in color and softer in texture than that already described, and is sometimes designated the medullary portion in contradistinction to the firmer superficial part, which is termed the cortical portion. It consists largely of transverse fibres, the Transverse lingualis (m. transversus linguæ), and of vertical fibres, the Vertical lingualis (m. verticalis linguæ). The Transverse lingualis forms the largest portion of the third layer of muscular fibres of the tongue. The fibres arise from the median septum, and pass outward to be inserted into the submucous fibrous layer at the sides of the tongue. Intermingled with these transverse intrinsic fibres are transverse extrinsic fibres derived from the Palato-glossus and the Superior constrictor of the pharynx. These transverse extrinsic fibres, however, run in the opposite direction, passing inward toward the septum. Intersecting the transverse fibres are a large number of vertical fibres derived partly from the Genio-hyo-glossus and partly from intrinsic fibres, the Vertical lingualis. The fibres derived from the Genio-hyo-glossus enter the under surface of the tongue on each side of the median septum from base to apex. They ascend in a radiating manner to the dorsum, being inserted into the submucous fibrous layer covering the tongue on each side of the middle line. The Vertical lingualis is found only at the borders of the forepart of the tongue, external to the fibres of the Genio-hyo-glossus. Its fibres extend from the upper to the under surface of the organ, decussating with the fibres of the other muscles, and especially with the Transverse lingualis. The fourth layer of muscular fibres of the tongue consists partly of extrinsic fibres derived from the Stylo-glossus, and partly of intrinsic fibres, the Inferior lingualis (m. longitudinalis inferior). At the sides of the under surface of the organ are some fibres derived from the Stylo-glossus, which, as it runs forward at the side of
the tongue, giving off fibres which, passing forward and inward between the fibres of the Hyo-glossus, form an inferior oblique stratum which joins in front with the anterior fibres of the Inferior lingualis. The Inferior lingualis is a longitudinal band, situated on the under surface of the tongue, and extending from the base to the apex of the organ. Behind, some of its fibres are connected with the body of the hyoid bone. It lies between the Hyo-glossus and the Genio-hyo-glossus, and in front of the Hyo-glossus it enters into relation with the Stylo-glossus, with the fibres of which it blends. It is in relation by its under surface with the ranine artery.

Surgical Anatomy.—The fibrous septum which exists between the two halves of the tongue is very complete, so that the anastomosis between the two lingual arteries is not very free, a fact often illustrated by injecting one-half of the tongue with colored size, while the other half is left uninjected or is injected with size of a different color. This is a point of considerable importance in connection with removal of one-half of the tongue for cancer, an operation which is now frequently resorted to when the disease is strictly confined to one side of the anterior portion of the tongue. If the mucus membrane is divided longitudinally exactly in the middle line, the tongue can be split into halves along the median raphe without any appreciable hemorrhage, and the diseased half can then be removed.

Actions.—The movements of the tongue, although numerous and complicated, may be understood by carefully considering the direction of the fibres of its muscles. The Genio-hyo-glossus muscles, by means of their posterior fibres, draw the base of the tongue forward, so as to protrude the apex from the mouth. The anterior fibres draw the tongue back into the mouth. The whole length of these two muscles, acting along the middle line of the tongue, draw it downward, so as to make it concave from side to side, forming a channel along which fluids may pass toward the pharynx, as in sucking. The Hyo-glossus muscles depress the tongue and draw down its sides, so as to render it convex from side to side. The Stylo-glossus muscles draw the tongue upward and backward. The Palato-glossus muscles draw the base of the tongue upward. With regard to the intrinsic muscles, both the Superior and Inferior linguals tend to shorten the tongue, but the former, in addition, turn the tip and sides upward so as to render the dorsum concave, while the latter pull the tip downward and cause the dorsum to become convex. The Transverse lingualis narrows and elongates the tongue, and the Vertical lingualis flattens and broadens it. The complex arrangement of the muscular fibres of the tongue, and the various directions in which they run, give to this organ the power of assuming the various forms necessary for the enunciation of the different consonantal sounds; and Dr. Macalister states that "there is reason to believe that the musculature of the tongue varies in different races owing to the hereditary practice and habitual use of certain motions required for enunciating the several vernacular languages."

5. The Pharyngeal Region (Figs. 275, 276, 277).

Inferior constrictor. Superior constrictor.
Middle constrictor. Stylo-pharyngeus.
Palato-pharyngeus. } (See next section.)
Salpingo-pharyngeus. |

Dissection (Fig. 275).—In order to examine the muscles of the pharynx, cut through the trachea and esophagus just above the sternum, and draw them upward by dividing the loose areolar tissue connecting the pharynx with the front of the vertebral column. The parts being drawn well forward, apply the edge of the saw immediately behind the styloid processes, and saw the base of the skull through from below upward. The pharynx and mouth should then be stuffed with tow, in order to distend its cavity and render the muscles tense and easier of dissection.

The Inferior Constrictor (m. constrictor pharyngis inferior), the most superficial and thickest of the three constrictors, arises from the sides of the cricoid and
thyroid cartilages. To the cricoid cartilage it is attached in the interval between the Crico-thyroid muscle in front and the articular facet for the thyroid cartilage behind. To the thyroid cartilage it is attached to the oblique line on the side of the great ala, the cartilaginous surface behind it, nearly as far as its posterior border, and to the inferior cornu. From these attachments the fibres spread backward and inward, to be inserted into the fibrous raphe in the posterior median line of the pharynx. The inferior fibres are horizontal, and continuous with the fibres of the oesophagus: the rest ascend, increasing in obliquity, and overlap the Middle constrictor.

**Relations.**—It is covered by a thin membrane which surrounds the entire pharynx, **bucco-pharyngeal fascia** (fascia buccopharyngea). **Behind,** it is in relation with the vertebral column and the prevertebral fascia and muscles; **laterally,** with the thyroid gland, the common carotid artery, and the Sterno-thyroid muscle; by its **internal surface,** with the Middle constrictor, the Stylo-pharyngeus, Palato-pharyngeus, the fibrous coat and mucous membrane of the pharynx. The internal laryngeal nerve and the laryngeal branch of the Superior Thyroid artery pass near the upper border, and the inferior, or recurrent laryngeal nerve, and the laryngeal branch of the Inferior Thyroid artery, beneath the lower border of this muscle, previous to their entering the larynx.

The **Middle Constrictor** (m. constrictor pharyngis medius) is a flattened, fan-shaped muscle, smaller than the preceding. It arises from the whole length of the upper border of the greater cornu of the hyoid bone, from the lesser cornu, and from the stylo-hyoid ligament. The fibres diverge from their origin, the lower ones descending beneath the Inferior constrictor, the middle fibres passing transversely, and the upper fibres ascending and overlapping the Superior constrictor. The muscle is inserted into the posterior median fibrous raphe, blending in the middle line with the one of the opposite side.

**Relations.**—Between this muscle and the Superior constrictor are the glosso-pharyngeal nerve, the Stylo-pharyngeus muscle and the stylo-hyoid ligament; and between it and the Inferior constrictor is the superior laryngeal nerve. **Behind,** it lies on the vertebral column, the Longus colli, and the Rectus capitis anticus major. **On each side** it is in relation with the carotid vessels, the pharyngeal plexus, and some lymphatic glands. Near its origin it is covered by the Hyo-glossus, the lingual vessels being placed between the two muscles. It lies upon the Superior constrictor, the Stylo-pharyngeus, the Palato-pharyngeus, the fibrous coat, and the mucous membrane of the larynx.

The **Superior Constrictor** (m. constrictor pharyngis superior) is a quadrilateral muscle, thinner and paler than the other constrictors, and situated at the upper part of the pharynx. It arises from the lower third of the posterior margin of the
internal pterygoid plate and its hamular process from the contiguous portion of the palate bone and the reflected tendon of the Tensor palati muscle, from the pterygo-maxillary ligament, from the alveolar process above the posterior extremity of the mylo-hyoid ridge, and by a few fibres from the side of the tongue. From these points the fibres curve backward, to be inserted into the median raphé, being also prolonged by means of a fibrous aponeurosis to the pharyngeal spine on the basilar process of the occipital bone. The superior fibres arch beneath the Levator palati and the Eustachian tube, the interval between the upper border of the muscle and the basilar process being deficient in muscular fibres and closed by a portion of the pharyngeal aponeurosis (fascia pharyngobasilaris). This interval is known as the sinus of Morgagni.

**Fig. 276.**—The muscles of the pharynx. On the right side most of the inferior constrictor has been removed, on the left side the Digastric and Stylo-hyoid have been removed. (Spalteholz.)

**Relations.**—By its outer surface, with the prevertebral fascia and muscles, the vertebral column, the internal carotid and ascending pharyngeal arteries, the internal jugular vein and pharyngeal venous plexus, the glosso-pharyngeal, vagus, accessory, hypoglossal, lingual, and sympathetic nerves, the Middle constrictor
and Internal pterygoid muscles, the Styloid process, the Stylo-hyoid ligament, and the Stylo-pharyngeus. By its internal surface, with the Palato-pharyngeus, the tonsil, the fibrous coat and mucous membrane of the pharynx.

The **Stylo-pharyngeus** (*m. stylopharyngeus*) is a long, slender muscle, round above, broad and thin below. It arises from the inner side of the base of the styloid process of the temporal bone, passes downward, along the side of the pharynx between the Superior and Middle constrictors, and spreads out beneath the mucous membrane, where some of its fibres are lost in the Constrictor muscles; and others, joining with the Palato-pharyngeus, are inserted into the posterior border of the thyroid cartilage. The glosso-pharyngeal nerve runs on the outer side of this muscle, and crosses over it in passing forward to the tongue.

**Relations.**—Externally, with the Stylo-glossus muscle, the parotid gland, the external carotid artery, and the Middle constrictor; internally, with the internal carotid, the internal jugular vein, the Superior constrictor, Palato-pharyngeus, and mucous membrane.

**Nerves.**—The Constrictors are supplied by branches from the pharyngeal plexus. The Inferior constrictor also receives an additional branch from the external laryngeal nerve and one from the recurrent laryngeal. The Stylopharyngeus is supplied by the glosso-pharyngeal nerve.

**Actions.**—When deglutition is about to be performed, the pharynx is drawn upward and dilated in different directions, to receive the morsel propelled into it from the mouth. The Stylo-pharyngei, which are much farther removed from one another at their origin than at their insertion, draw the sides of the pharynx upward and outward, and so increase its transverse diameter, its breadth in the antero-posterior direction being increased by the larynx and tongue being carried forward in their ascent. As soon as the morsel is received in the pharynx, the Elevator muscles relax, the bag descends, and the Constrictors contract upon the morsel, and convey it gradually downward into the oesophagus. Besides its action in deglutition, the pharynx also exerts an important influence in the modulation of the voice, especially in the production of the higher tones.

6. **The Palatal Region** (Fig. 277).

- **Levator palatii.**
- **Tensor palatii.**
- **Azygos uvulae.**

**Palato-glossus.**

**Palato-pharyngeus.**

**Salpingo-pharyngeus.**

**Dissection** (Fig. 277).—Lay open the pharynx from behind by a vertical incision extending from its upper to its lower part, and partially divide the occipital attachment by a transverse incision on each side of the vertical one; the posterior surface of the soft palate is then exposed. Having fixed the uvula so as to make it tense, the mucous membrane and glands should be carefully removed from the posterior surface of the soft palate, and the muscles of this part are at once exposed.

The **Levator Palati** (*m. levator veli palatini*) is a long, thick, rounded muscle, placed on the outer side of the posterior nares. It arises from the under surface of the apex of the petrous portion of the temporal bone, and from the inner surface of the cartilaginous portion of the Eustachian tube; after passing into the pharynx, above the upper concave margin of the Superior constrictor, it passes obliquely downward and inward, its fibres spreading out in the soft palate as far as the middle line, where they blend with those of the opposite side.

**Relations.**—Externally, with the Tensor palatii and Superior constrictor and Eustachian tube; internally, with the mucous membrane of the pharynx; posteriorly, with the posterior fasciculus of the Palato-pharyngeus, the Azygos uvulae, and the mucous lining of the soft palate.
The Circumflexus or Tensor Palati (m. tensor veli palatini) is a broad, thin, ribbon-like muscle, placed on the outer side of the Levator palati, and consisting of a vertical and a horizontal portion. The vertical portion arises by a flat lamella from the scaphoid fossa at the base of the internal pterygoid plate; from the spine of the sphenoid and the outer side of the cartilaginous portion of the Eustachian tube: descending vertically between the internal pterygoid plate and the inner surface of the Internal pterygoid muscle, it terminates in a tendon, which winds round the hamular process, being retained in this situation by some of the fibres of origin of the Internal pterygoid muscle. Between the hamular process and the tendon is a small bursa (bursa m. tensoris veli palati). The tendon or horizontal portion then passes horizontally inward, and is inserted into a broad aponeurosis, the palatine aponeurosis, and into the transverse ridge on the horizontal portion of the palate bone.

Relations.—Externally, with the Internal pterygoid; internally, with the Levator palati, from which it is separated by the Eustachian tube and Superior constrictor and with the internal pterygoid plate. In the soft palate its tendon and the palatine aponeurosis are anterior to those of the Levator palati, being covered by the Palato-glossus and the mucous membrane.

Palatine Aponeurosis.—Attached to the posterior border of the hard palate is a thin, firm, fibrous lamella which supports the muscles and gives strength to the soft palate. It is thicker above than below, where it becomes very thin and difficult to define. Laterally, it is continuous with the pharyngeal aponeurosis.
The Azygos Uvulae (m. uvulae) is not a single muscle, as would be inferred from its name, but a pair of narrow cylindrical fleshy fasciculi placed on either side of the median line of the soft palate. Each muscle arises from the posterior nasal spine of the palate bone and from the contiguous tendinous aponeurosis of the soft palate, and descends to be inserted into the uvula.

Relations.—Anteriorly, with the tendinous expansion of the Levatores palati; behind, with the posterior fasciculus of the Palato-pharyngeus and the mucous membrane.

The next two muscles are exposed by removing the mucous membrane from the pillars of the fauces throughout nearly their whole extent.

The Palato-glossus or the Constrictor Isthmi Faucium (m. glossopalatinus) is a small fleshy fasciculus, narrower in the middle than at either extremity, forming, with the mucous membrane covering its surface, the anterior pillar of the soft palate. It arises from the anterior surface of the soft palate on each side of the uvula, and, passing downward, forward, and outward in front of the tonsil, is inserted into the side of the tongue, some of its fibres spreading over the dorsal, and others passing deeply into the substance of the organ to intermingle with the Transverse lingualis. In the soft palate the fibres of this muscle are continuous with those of the muscle of the opposite side.

The Palato-pharyngeus (m. pharyngopalatinus) is a long, fleshy fasciculus, narrower in the middle than at either extremity, forming, with the mucous membrane covering its surface, the posterior pillar of the soft palate. It is separated from the Palato-glossus by an angular interval, in which the tonsil is lodged. It arises from the soft palate by an expanded fasciculus, which is divided into two parts by the Levator palati and Azygos uvulae. The posterior fasciculus lies in contact with the mucous membrane, and also joins with the corresponding muscle in the middle line; the anterior fasciculus, the thicker, lies in the soft palate between the Levator and Tensor, and joins in the middle line the corresponding part of the opposite muscle. Passing outward and downward behind the tonsil, the Palato-pharyngeus joins the Stylo-pharyngeus, and is inserted with that muscle into the posterior border of the thyroid cartilage, some of its fibres being lost on the side of the pharynx, and others passing across the middle line posteriorly to decussate with the muscle of the opposite side.

Relations.—In the soft palate its posterior surface is covered by mucous membrane, from which it is separated by a layer of palatine glands. By its anterior surface it is in relation with the Tensor palati. Where it forms the posterior pillar of the fauces it is covered by mucous membrane, excepting on its outer surface. In the pharynx it lies between the mucous membrane and the Constrictor muscles.

The Salpingo-pharyngeus arises from the inferior part of the Eustachian tube near its orifice; it passes downward and blends with the posterior fasciculus of the Palato-pharyngeus.

In a dissection of the soft palate from its posterior or nasal surface to its anterior or oral surface, the muscles would be exposed in the following order—viz., the posterior fasciculus of the Palato-pharyngeus, covered over by the mucous membrane reflected from the floor of the nasal fossa; the Azygos uvulae; the Levator palati; the anterior fasciculus of the Palato-pharyngeus; the aponeurosis of the Tensor palati, and the Palato-glossus, covered over by a reflection from the oral mucous membrane.

Nerves.—The Tensor palati is supplied by a branch from the otic ganglion; the remaining muscles of this group are in all probability supplied by the internal branch of the accessory, whose fibres are distributed along with certain branches of the vagus through the pharyngeal plexus. It is possible, however, that the

Levator palati may be supplied by the facial through the Petrosal branch of the Vidian.

Actions.—During the first stage of deglutition the morsel of food is driven back into the fauces by the pressure of the tongue against the hard palate, the base of the tongue being, at the same time, retracted, and the larynx raised with the pharynx, and carried forward under it. During the second stage the entrance to the larynx is closed, not, as was formerly supposed, by the folding backward of the epiglottis over it, but, as Anderson Stuart has shown, by the drawing forward of the arytenoid cartilages toward the cushion of the epiglottis—a movement produced by the contraction of the External thyro-arytenoid, the Arytenoid, and Aryteno-epiglottidean muscles.

The morsel of food after leaving the tongue passes on to the posterior or laryngeal surface of the epiglottis, and glides along this for a certain distance; then the Palato-glossi muscles, the constrictors of the fauces, contract behind the food; the soft palate is slightly raised by the Levator palati, and made tense by the Tensor palati; and the Palato-pharyngei, by their contraction, pull the pharynx upward over the morsel of food, and at the same time come nearly together, the uvula filling up the slight interval between them. By these means the food is prevented passing into the upper part of the larynx or the posterior nares; at the same time the latter muscles form an inclined plane, directed obliquely downward and backward, along the under surface of which the morsel descends into the lower part of the pharynx. The Salpingo-pharyngeus raises the upper and lateral part of the pharynx—i.e., that part which is above the point where the Stylo-pharyngeus is attached to the pharynx.

Surgical Anatomy.—The muscles of the soft palate should be carefully dissected, the relations they bear to the surrounding parts especially examined, and their action attentively studied upon the dead subject, as the surgeon is required to divide one or more of these muscles in the operation of staphylorraphy. Sir W. Fergusson was the first to show that in the congenital deficiency called cleft palate the edges of the fissure are forcibly separated by the action of the Levatores palati and Palato-pharyngei muscles, producing very considerable impediment to the healing process after the performance of the operation for uniting their margins by adhesion; he consequently recommended the division of these muscles as one of the most important steps in the operation. This he effected by an incision made with a curved knife introduced behind the soft palate. The incision is to be half-way between the hamular process and Eustachian tube and perpendicular to a line drawn between them. This incision perfectly accomplishes the division of the Levator palati. The Palato-pharyngeus may be divided by cutting across the posterior pillar of the soft palate, just below the tonsil, with a pair of blunt-pointed curved scissors; and the anterior pillar may be divided also. To divide the Levator palati the plan recommended by Mr. Pollock is to be greatly preferred. The soft palate being put upon the stretch, a double-edged knife is passed through it just on the inner side of the hamular process and above the line of the Levator palati. The handle being now alternately raised and depressed, a sweeping cut is made along the posterior surface of the soft palate, and the knife withdrawn, leaving only a small opening in the mucous membrane on the anterior surface. If this operation is performed on the dead body and the parts afterward dissected, the Levator palati will be found completely divided. In the present day, however, this division of the muscles, as part of the operation of staphylorraphy, is not so much insisted upon. All tension is prevented by making longitudinal incisions on either side, parallel to the cleft and just internal to the hamular process, in such a position as to avoid the posterior palatine artery.

7. The Anterior Vertebral Region (Fig. 278).

Rectus capitis anticus major. Rectus capitis lateralis.
Rectus capitis anticus minor. Longus colli.

The Rectus Capitis Anticus Major or the Longus Capitis, broad and thick above, narrow below, appears like a continuation upward of the Scapular region.
lenus anticus. It arises by four tendinous slips from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebrae, and ascends, converging toward its fellow of the opposite side, to be inserted into the basilar process of the occipital bone.

**Relations.**—By its anterior surface, with the pharynx, the sympathetic nerve, and the sheath enclosing the internal and common carotid artery, internal jugular vein, and vagus nerve; by its posterior surface, with the Longus colli, the Rectus capitis anticus minor, and the upper cervical vertebrae.

![Diagram of the prevertebral muscles](image)

**Fig. 278.**—The prevertebral muscles.

The **Rectus Capitis Anticus Minor** is a short, flat muscle, situated immediately behind the upper part of the preceding. It arises from the anterior surface of the lateral mass of the atlas and from the root of its transverse process, and, passing obliquely upward and inward, is inserted into the basilar process immediately behind the preceding muscle.

**Relations.**—By its anterior surface, with the Rectus capitis anticus major; by its posterior surface, with the front of the occipito-atlantal articulation.

The **Rectus Capitis Lateralis** is a short, flat muscle, which arises from the upper surface of the transverse process of the atlas, and is inserted into the under surface of the jugular process of the occipital bone.

**Relations.**—By its anterior surface, with the internal jugular vein; by its posterior surface, with the vertebral artery. On its outer side lies the occipital artery; on its inner side, the suboccipital nerve.

The **Longus Colli** is a long, flat muscle, situated on the anterior surface of the spine, between the atlas and the third thoracic vertebra. It is broad in the middle,
narrow and pointed at each extremity, and consists of three portions: a superior oblique, an inferior oblique, and a vertical portion. The **superior oblique portion** arises from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebrae, and, ascending obliquely inward, is inserted by a narrow tendon into the tubercle on the anterior arch of the atlas. The **inferior oblique portion**, the smallest part of the muscle, arises from the front of the bodies of the first two or three thoracic vertebrae, and, ascending obliquely outward, is inserted into the anterior tubercles of the transverse processes of the fifth and sixth cervical vertebrae. The **vertical portion** lies directly on the front of the spine; it arises, below, from the front of the bodies of the upper three thoracic and lower three cervical vertebrae, and is inserted above into the front of the bodies of the second, third, and fourth cervical vertebrae.

**Relations.**—By its anterior surface, with the prevertebral fascia, the pharynx, the oesophagus, sympathetic nerve, the sheath of the great vessels of the neck, the inferior thyroid artery, and recurrent laryngeal nerve; by its posterior surface, with the cervical and thoracic portions of the spine. Its inner border is separated from the opposite muscle by a considerable interval below, but they approach each other above.

### 8. The Lateral Vertebral Region (Figs. 278, 279).

**Scaleus anticus.**  **Scaleus medius.**  **Scaleus posticus.**

The **Scaleus Anticus** (*m. scalenus anterior*) is a conical-shaped muscle, situated deeply at the side of the neck, behind the Sterno-mastoid. It arises from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebrae, and, descending almost vertically, is inserted by a narrow, flat tendon into the **Scalene tubercle** on the inner border and upper surface of the first rib. The lower part of this muscle separates the subclavian artery and vein, the latter being in front, and the former, with the brachial plexus, behind.

**Relations.**—In front, with the clavicle, the Subclavius, Sterno-mastoid, and Omo-hyoid muscles, the Transversalis colli, the suprascapular and ascending cervical arteries, the subclavian vein, and the phrenic nerve; by its posterior surface, with the Scaleus medius, pleura, subclavian artery, and brachial plexus of nerves. It is separated from the Longus colli, on the inner side, by the vertebral artery. On the anterior tubercles of the transverse processes of the cervical vertebrae, between the attachments of the Scaleus anticus and Longus colli, lies the ascending cervical branch of the inferior thyroid artery.

The **Scaleus Medius**, the largest and longest of the three Scaleni, arises from the posterior tubercles of the transverse processes of the lower six cervical vertebrae.
and, descending along the side of the vertebral column, is inserted by a broad attachment into the upper surface of the first rib, behind the groove for the subclavian artery, as far back as the tubercle. It is separated from the Scaleneus anticus by the subclavian artery below and the cervical nerves above. The posterior thoracic, or nerve of Bell, is formed in the substance of the Scaleneus medius and emerges from it. The nerve to the Rhomboids also pierces it.

**Relations.**—By its anterior surface, with the Sterno-mastoid; it is crossed by the clavicle, the Omo-hyoid muscle, subclavian artery, and cervical nerves. To its outer side is the Levator anguli scapule and the Scaleneus posticus muscle.

The Scalenum Posticus (m. scalenus posterior), the smallest of the three Scaleni, arises, by two or three separate tendons, from the posterior tubercles of the transverse processes of the lower two or three cervical vertebrae, and, diminishing as it descends, is inserted by a thin tendon into the outer surface of the second rib, behind the attachment of the Serratus magnus. This is the most deeply placed of the three Scaleni, and is occasionally blended with the Scaleneus medius.

**Nerves.**—The Rectus capitis anticus major and minor and the Rectus lateralis are supplied by the first cervical nerve, and from the loop formed between it and the second; the Longus colli and Scaleni, by branches from the anterior divisions of the lower cervical nerves (fifth, sixth, seventh, and eighth) before they form the brachial plexus. The Scaleneus medius also receives a filament from the deep external branches of the cervical plexus.

**Actions.**—The Rectus anticus major and minor are the direct antagonists of the muscles at the back of the neck, serving to restore the head to its natural position after it has been drawn backward. These muscles also serve to flex the head, and, from their obliquity, rotate it, so as to turn the face to one or the other side. The Longus colli flexes and slightly rotates the cervical portion of the spine. The Scaleni muscles, when they take their fixed point from above, elevate the first and second ribs, and are, therefore, inspiratory muscles. When they take their fixed point from below, they bend the spinal column to one or the other side. If the muscles of both sides act, lateral movement is prevented, but the spine is slightly flexed. The Rectus lateralis, acting on one side, bends the head laterally.

**Surface Form.**—The muscles in the neck, with the exception of the Platysma myoides, are invested by the deep cervical fascia, which softens down their form, and is of considerable importance in connection with deep cervical abscesses and tumors, modifying the direction of the growth of tumors and of the enlargement of abscesses, and causing them to extend laterally instead of toward the surface. The Platysma myoides does not influence surface form except when in action, when it produces wrinkling of the skin of the neck, which is thrown into oblique ridges parallel with the fasciculi of the muscle. Sometimes this contraction takes place suddenly and repeatedly as a sort of spasmodic twitching, the result of a nervous habit. The Sterno-pleido-mastoid is the most important muscle of the neck as regards its surface form. If the muscle is put into action by drawing the chin downward and to the opposite shoulder, its surface form will be plainly outlined. The sternal origin will stand out as a sharply-defined ridge, while the clavicular origin will present a flatter and not so prominent an outline. The fleshy middle portion will appear as an oblique roll or elevation, with a thick rounded anterior border gradually becoming less marked above. On the opposite side—i. e., on the side to which the head is turned—the outline is lost, its place being occupied by an oblique groove in the integument. When the muscle is at rest its anterior border is still visible, forming an oblique rounded ridge, terminating below in the sharp outline of the sternal head. The posterior border of the muscle does not show above the clavicular head. The anterior border is defined by drawing a line from the tip of the mastoid process to the sternoclavicular joint. It is an important surface-marking in the operation of ligature of the common carotid artery and in some other operations. Between the sternal and clavicular heads is a slight depression, most marked when the muscle is in action. This is bounded below by the prominent sternal extremity of the clavicle. Between the sternal origins of the two muscles is a V-shaped space, the suprasternal notch, more pronounced below, and becoming toned down above, where the Sterno-hyoid and Sterno-thyroid muscles, lying upon the trachea, become more prominent. Above the hyoid bone, in the middle line, the anterior belly of the Diagonal to a certain extent influences surface form. It corresponds to a line drawn from the symphysis of the lower jaw to
the side of the body of the hyoid bone, and renders this part of the hyo-mental region convex. In the posterior triangle of the neck, the posterior belly of the Omo-hyoid, when in action, forms a conspicuous object, especially in thin necks, presenting a cord-like form running across this region, almost parallel with, and a little above, the clavicle.

MUSCLES AND FASCIAE OF THE TRUNK.

The muscles of the Trunk may be arranged in four groups, corresponding with the region in which they are situated.

I. The Back. II. The Thorax. III. The Abdomen. IV. The Perineum.

I. MUSCLES OF THE BACK.

The muscles of the Back are very numerous, and may be subdivided into five layers:

**FIRST LAYER.**

Trapezius. Latissimus dorsi.

**SECOND LAYER.**


**THIRD LAYER.**


**FOURTH LAYER.**

Sacral and Lumbar Regions. Erector spine.

Dorsal Region.

Ilio-costalis. Musculus accessorius ad ilio-costalem.

**The First Layer** (Fig. 281).

Trapezius. Latissimus dorsi.

**Dissection** (Fig. 280).—Place the body in a prone position, with the arms extended over the sides of the table, and the chest and abdomen supported by several blocks, so as to render the muscles tense. Then make an incision along the middle line of the back from the occipital protuberance to the coccyx. Make a transverse incision from the upper end of this to the mastoid process, and a third incision from its lower end, along the crest of the ilium to about its middle. This large intervening space should, for convenience of dissection, be subdivided by a fourth incision, extending obliquely from the spinous process of the last thoracic vertebra, upward and outward, to the acromion process. This incision corresponds with the lower border of the Trapezius muscle. The flaps of integument are then to be removed in the direction shown in the figure.
Superficial Fascia.—The superficial fascia is exposed upon removing the skin from the back. It forms a layer of considerable thickness and strength, in which a quantity of granular pinkish fat is contained. It is continuous with the superficial fascia in other parts of the body.

Deep Fascia.—The deep fascia is a dense fibrous layer attached to the occipital bone, the spines of the vertebrae, the crest of the ilium, and the spine of the scapula. It covers over the superficial muscles, forming sheaths for them, and in the neck forms the posterior part of the deep cervical fascia; in the thorax it is continuous with the deep fascia of the axilla and chest, and in the abdomen with that covering the abdominal muscles. In the back of the thoracic region the deep fascia is called the vertebral aponeurosis or the aponeurosis of the latissimus dorsi muscle. It covers the erector spinae muscles, and is the posterior layer of the lumbar fascia.

The Trapezius is a broad, flat, triangular muscle, placed immediately beneath the skin and fascia, and covering the upper and back part of the neck and shoulders. It arises from the external occipital protuberance and the inner third of the superior curved line of the occipital bone; from the ligamentum nuchae, the spinous process of the seventh cervical, and the spinous processes of all the thoracic vertebrae; and from the corresponding portion of the supraspinous ligament. From this origin the superior fibres proceed downward and outward, the inferior ones upward and outward, and the middle fibres horizontally, and are inserted, the superior ones into the outer third of the posterior border of the clavicle; the middle fibres into the inner margin of the acromion process, and into the superior lip of the posterior border or crest of the spine of the scapula; the inferior fibres converge near the scapula, and terminate in a triangular aponeurosis, which glides over a smooth surface at the inner extremity of the spine, to be inserted into a tubercle at the outer part of this smooth surface. The Trapezius is fleshy in the greater part of its extent, but tendinous at its origin and insertion. At its occipital origin it is connected to the bone by a thin fibrous lamina, firmly adherent to the skin, and wanting the lustrous, shining appearance of aponeuroses. At its origin from the spines of the vertebrae it is connected to the bones by means of a broad semi-elliptical aponeurosis, which occupies the space between the sixth cervical and the third thoracic vertebrae, and forms, with the aponeurosis of the opposite muscle, a tendinous ellipse. The rest of the muscle arises by numerous short tendinous fibres. If the Trapezius is dissected on both sides, the two muscles resemble a trapezium or diamond-shaped quadrangle; two angles corresponding to the shoulders; a third to the occipital protuberance; and the fourth to the spinous process of the last thoracic vertebra. The clavicular insertion of this muscle varies as to the extent of its attachment; it sometimes advances as far as the middle of the clavicle, and may even become blended with the posterior edge of the Sterno-mastoid or overlap it. This should be borne in mind in the operation for tying the third part of the subclavian artery.
FIG. 281.—Muscles of the back. On the left side is exposed the first layer; on the right side, the second layer and part of the third.
Relations.—By its superficial surface, with the integument; by its deep surface, in the neck, with the Complexus, Splenius, Levator anguli scapulae, and Rhomboideus minor; in the back, with the Rhomboideus major, Supraspinatus, Infraspinatus, and Vertebral aponeurosis (which separates it from the prolongations of the Erector spinae), and the Latissimus dorsi. The accessory nerve and the superficial cervical artery and branches from the third and fourth cervical nerves pass beneath the anterior border of this muscle. The anterior margin of its cervical portion forms the posterior boundary of the posterior triangle of the neck, the other boundaries being the Sterno-mastoid in front and the clavicle below.

The Ligamentum nuchae (Fig. 281) is a fibrous membrane, which, in the neck, represents the supraspinous and interspinous ligaments of the lower vertebrae. It extends from the external occipital protuberance to the spinous process of the seventh cervical vertebra. From its anterior border a fibrous lamina (fascia nuchae) is given off, which is attached to the external occipital crest, the posterior tubercle of the atlas, and the spinous process of each of the cervical vertebrae, so as to form a septum between the muscles on each side of the neck. In man it is merely the rudiment of an important elastic ligament, which, in some of the lower animals, serves to sustain the weight of the head.

The Latissimus Dorsi is a broad flat muscle, which covers the lumbar and the lower half of the thoracic regions, and is gradually contracted into a narrow fasciculus at its insertion into the humerus. It arises by tendinous fibres from the spinous processes of the six inferior thoracic vertebrae and from the posterior layer of the lumbar fascia (see page 418), by which it is attached to the spines of the lumbar and sacral vertebrae and to the supraspinous ligament. It also arises from the external lip of the crest of the ilium, behind the origin of the External oblique, and by fleshy digitations from the three or four lower ribs, which are interposed between similar processes of the External oblique muscle (Fig. 288, page 436). From this extensive origin the fibres pass in different directions, the upper ones horizontally, the middle obliquely upward, and the lower vertically upward, so as to converge and form a thick fasciculus, which crosses the inferior angle of the scapula, and occasionally receives a few fibres of origin from it. The muscle then curves around the lower border of the Teres major, and is twisted upon itself so that the superior fibres become at first posterior and then inferior, and the vertical fibres at first anterior and then superior. It then terminates in a short quadrilateral tendon, about three inches in length, which, passing in front of the tendon of the Teres major, is inserted into the bottom of the bicipital groove of the humerus, its insertion extending higher on the humerus than that of the tendon of the Pectoralis major. The lower border of the tendon of this muscle is united with that of the Teres major, the surfaces of the two being separated by a bursa; another bursa is sometimes interposed between the muscle and the inferior angle of the scapula. This muscle at its insertion gives off an expansion to the deep fascia of the arm.

A muscular slip, the axillary arch, varying from 3 to 4 inches in length, and from ½ to ¾ of an inch in breadth, occasionally arises from the upper edge of the Latissimus dorsi about the middle of the posterior fold of the axilla, and crosses the axilla in front of the axillary vessels and nerves, to join the under surface of the tendon of the Pectoralis major, the Coraco-brachialis, or the fascia over the Biceps. The position of this abnormal slip is a point of interest in its relation to the axillary artery, as it crosses the vessel just above the spot usually selected for the application of a ligature, and may mislead the surgeon during the operation. It may be easily recognized by the transverse direction of its fibres. Dr. Struther found it, in 8 out of 105 subjects, occurring seven times on both sides. In most subjects there is a fibrous axillary arch, in only a few is the arch muscular.

There is usually a fibrous slip which passes from the lower border of the tendon of the Latissimus dorsi, near its insertion, to the long head of the Triceps. This is occasionally muscular, and is the representative of the Dorso-epitrochlearis muscle of apes.
Relations.—Its superficial surface is subcutaneous, excepting at its upper part, where it is covered by the Trapezius, and at its insertion, where its tendon is crossed by the axillary vessels and the brachial plexus of nerves. By its deep surface it is in relation with the lumbar fascia, the Serratus posterior inferior, the lower External intercostal muscles and ribs, inferior angle of the scapula, Rhomboideus major, Infraspinatus, and Teres major. Its outer margin is separated below from the External oblique by a small triangular interval, the triangle of Petit (trigonum lumbale [Petiti]); and another triangular interval exists between its upper border and the margin of the Trapezius, in which the Rhomboideus major muscle is exposed.

Nerves.—The Trapezius is supplied by the accessory, and by branches from the anterior divisions of the third and fourth cervical nerves: the Latissimus dorsi, by the middle or long subscapular nerve.

The Second Layer (Fig. 281).

Levator anguli scapulae. Rhomboideus minor.
Rhomboideus major.

Dissection.—The Trapezius must be removed, in order to expose the next layer; to effect this, detach the muscle from its attachment to the clavicle and spine of the scapula, and turn it back toward the spine.

The Levator Anguli Scapulae (m. levator scapulae) is situated at the back part and side of the neck. It arises by tendinous slips from the transverse process of the atlas, and from the posterior tubercles of the transverse processes of the second, third, and fourth cervical vertebrae; these, becoming fleshy, are united so as to form a flat muscle, which, passing downward and backward, is inserted into the posterior border of the scapula, between the superior angle and the triangular smooth surface at the root of the spine.

Relations.—By its superficial surface, with the integument, Trapezius, and Sterno-mastoid; by its deep surface, with the Splenius colli, Transversalis cervicis, Cervicalis ascendens, and Serratus posterior superior muscles, and with the posterior scapular artery and the nerve to the Rhomboids.

The Rhomboideus Minor arises from the ligamentum nuchae and spinous processes of the seventh cervical and first thoracic vertebrae. Passing downward and outward, it is inserted into the margin of the triangular smooth surface at the root of the spine of the scapula. This small muscle is usually separated from the Rhomboideus major by a slight cellular interval.

Relations.—By its superficial (posterior) surface, with the Trapezius; by its deep (anterior) surface, with the same structures as the Rhomboideus major.

The Rhomboideus Major is situated immediately below the preceding, the adjacent margins of the two being occasionally united. It arises by tendinous fibres from the spinous processes of the four or five upper thoracic vertebrae and the supraspinous ligament, and is inserted into a narrow tendinous arch attached above to the lower part of the triangular surface at the root of the spine; below, to the inferior angle, the arch being connected to the border of the scapula by a thin membrane. When the arch extends, as it occasionally does, but a short distance, the muscular fibres are inserted into the scapula itself.

Relations.—By its superficial (posterior) surface, with the Trapezius and Latissimus dorsi; by its deep (anterior) surface, with the Serratus posterior superior, posterior scapular artery, the vertebral aponeurosis which separates it from the prolongations from the Erector spine, the Intercostal muscles, and ribs.

Nerves.—The Rhomboid muscles are supplied by branches from the anterior division of the fifth cervical nerve; the Levator anguli scapulae, by the anterior
divisions of the third and fourth cervical nerves, and frequently by a branch from
the nerve to the Rhomboids.

Actions.—The movements effected by the preceding muscles are numerous, as
may be conceived from their extensive attachment. The whole of the Trapezius
when in action retracts the scapula and braces back the shoulder; if the head is
fixed, the upper part of the Trapezius will elevate the point of the shoulder, as in
supporting weights; when the lower fibres are brought into action, they assist in
depressing the bone. The middle and lower fibres of the muscle rotate the
scapula, causing elevation of the acromion process. If the shoulders are fixed, both
Trapezii, acting together, will draw the head directly backward; or if only one
acts the head is drawn to the corresponding side. The Latissimus dorsi, when it
acts upon the humerus, depresses it, draws it backward, adducts, and at the same
time rotates it inward. It is the muscle which is principally employed in giving a
downward blow, as in felling a tree or in sabre practice. If the arm is fixed, the
muscle may act in various ways upon the trunk; thus, it may raise the lower ribs and
assist in forcible inspiration; or, if both arms are fixed, the two muscles may
assist the Abdominal and great Pectoral muscles in suspending and drawing the
whole trunk forward, as in climbing or walking on crutches. The Levator anguli
scapulae raises the superior angle of the scapula, and by so doing depresses the
point of the shoulder. It assists the Trapezius in bearing weights and in shrugging
the shoulders. If the shoulder be fixed, the Levator anguli scapulae inclines the
neck to the corresponding side and rotates it in the same direction. The Rhom-
boid muscles carry the inferior angle backward and upward, thus producing a
slight rotation of the scapula upon the side of the chest, the Rhomboideus major
acting especially on the lower angle of the scapula through the tendinous arch by
which it is inserted. The Rhomboid muscles, acting together with the middle and
inferior fibres of the Trapezius, will draw the scapula directly backward toward
the spine.

The Third Layer.

Serratus posticus superior.          Serratus posticus inferior.

Splenius  \{ Splenius capitis.
           \{ Splenius colli.

Dissection.—To bring into view the third layer of muscles, remove the whole of the second,
together with the Latissimus dorsi, by cutting through the Levator anguli scapulae and Rhom-
boid muscles near their origin, and reflecting them downward, and by dividing the Latissimus
dorsi in the middle by a vertical incision carried from its upper to its lower part, and reflecting
the two halves of the muscle.

The Serratus Posticus Superior (m. serratus posterior superior) is a thin, flat,
quadrilateral muscle situated at the upper and back part of the thorax. It arises
by a thin and broad aponeurosis from the ligamentum nuchae, and from the
spinous processes of the last cervical and two or three upper thoracic vertebrae and
from the supraspinous ligament. Inclining downward and outward, it becomes
muscular, and is inserted, by four fleshy digitations, into the upper borders of the
second, third, fourth, and fifth ribs, a little beyond their angles.

Relations.—By its superficial surface, with the Trapezius, Rhomboidei, and
Levator anguli scapulae; by its deep surface, with the Splenius and the vertebral
aponeurosis, which separates it from the prolongations of the Erector spinae, and
with the Intercostal muscles and ribs.

The Serratus Posticus Inferior (m. serratus posterior inferior) (Fig. 281) is
situated at the junction of the thoracic and lumbar regions; it is of an irregularly
quadrilateral form, broader than the preceding, and separated from it by a consider-
able interval. It arises by a thin aponeurosis from the spinous processes of the
last two thoracic and two or three upper lumbar vertebrae, and from the supra-
spinous ligaments. Passing obliquely upward and outward, it becomes fleshy, and divides into four flat digitations, which are inserted into the lower borders of the four lower ribs, a little beyond their angles. The thin aponeurosis of origin is intimately blended with the lumbar fascia.

**Relations.**—By its superficial surface, with the Latissimus dorsi. By its deep surface, with the Erector spinae, ribs, and Intercostal muscles. Its upper margin is continuous with the vertebral aponeurosis.

The vertebral aponeurosis is a thin, fibrous lamina, extending along the whole length of the back part of the thoracic region, serving to bind down the long Extensor muscles of the back which support the spine and head, and separate them from those muscles which connect the spine to the upper extremity. It consists of longitudinal and transverse fibres blended together, forming a thin lamella, which is attached in the median line to the spinous processes of the thoracic vertebra; externally, to the angles of the ribs; and below, to the upper border of the Serratus posticus inferior and a portion of the lumbar fascia, which gives origin to the Latissimus dorsi; above, it passes beneath the Serratus posticus superior and the Splenius, and blends with the deep fascia of the neck.

The lumbar fascia or aponeurosis (Figs. 281 and 294), which may be regarded as the posterior aponeurosis of the Transversalis abdominis muscle, consists of three laminae, which are attached as follows: the posterior layer, to the spines of the lumbar and sacral vertebrae and their supraspinous ligaments; the middle layer, to the tips of the transverse processes of the lumbar vertebrae and their intertransverse ligaments; the anterior layer, to the roots of the lumbar transverse processes. The posterior layer is continued above as the vertebral aponeurosis, while inferiorly it is fixed to the outer lip of the iliac crest. With this layer are blended the aponeurotic origin of the Serratus posticus inferior and part of that of the Latissimus dorsi. The middle layer is attached above to the last rib, and below to the iliac crest; the anterior layer is fixed below to the iliolumbar ligament and iliac crest; while above it is thickened to form the external arcuate ligament of the Diaphragm, and stretches from the tip of the last rib to the transverse process of the first or second lumbar vertebra. These three layers, together with the vertebral column, enclose two spaces, the posterior of which is occupied by the Erector spinae muscle, and the anterior by the Quadratus lumborum.

Now detach the Serratus posticus superior from its origin, and turn it outward, when the Splenius muscle will be brought into view.

The Splenius (Fig. 281) is situated at the back of the neck and upper part of the thoracic region. At its origin it is a single muscle, which soon after its origin becomes broad, and divides into two portions, which have separate insertions. It arises, by tendinous fibres, from the lower half of the ligamentum nuchae, from the spinous processes of the last cervical and of the six upper thoracic vertebrae, and from the supraspinous ligament. From this origin the fleshy fibres proceed obliquely upward and outward, forming a broad flat muscle, which divides as it ascends into two portions, the Splenius capitis and Splenius colli.

The Splenius capitis (m. splenius capitis) is inserted into the mastoid process of the temporal bone, and into the rough surface on the occipital bone just beneath the superior curved line.

The Splenius colli (m. splenius cervicis) is inserted, by tendinous fascieuli, into the posterior tubercles of the transverse processes of the two or three upper cervical vertebrae.

The Splenius is separated from its fellow of the opposite side by a triangular interval, in which is seen the Complexus.

**Relations.**—By its superficial surface, with the Trapezius, from which it is separated below by the Rhomboidei and the Serratus posticus superior. It is covered
at its insertion by the Sterno-mastoid, and at the lower and back part of the neck
by the Levator anguli scapulae; by its deep surface, with the Spinalis dorsi, Longissimus dorsi, Semispinalis colli, Complexus, Trachelo-mastoid, and Transversalis cervicis.

**Nerves.**—The Splenius is supplied from the external branches of the posterior divisions of the cervical nerves; the Serratus posticus superior is supplied by the external branches of the posterior divisions of the upper thoracic nerves; the Serratus posticus inferior by the external branches of the posterior divisions of the lower thoracic nerves.

**Actions.**—The Serrati are respiratory muscles. The Serratus posticus superior elevates the ribs; it is therefore an inspiratory muscle; while the Serratus inferior draws the lower ribs downward and backward, and thus elongates the thorax. It also fixes the lower ribs, thus aiding the downward action of the diaphragm and resisting the tendency which it has to draw the lower ribs upward and forward. It must therefore be regarded as a muscle of inspiration. This muscle is also probably a tensor of the vertebral aponeurosis. The Splenii muscles of the two sides, acting together, draw the head directly backward, assisting the Trapezius and Complexus; acting separately, they draw the head to one or the other side, and slightly rotate it, turning the face to the same side. They also assist in supporting the head in the erect position.

**The Fourth Layer** (Fig. 282).

**I. Erector spinae.**

- **a. Outer Column.**
  - Ilio-costalis.
  - Musculus accessorius.
  - Cervicalis ascendens.

- **b. Middle Column.**
  - Longissimus dorsi.
  - Transversalis cervicis.
  - Trachelo-mastoid.

- **c. Inner Column.**
  - Spinalis dorsi.
  - Spinalis colli.

**II. Complexus.**

**Dissection.**—To expose the muscles of the fourth layer, remove entirely the Serrati and the vertebral and lumbar fasciae. Then detach the Splenius by separating its attachment to the spinous processes and reflecting it outward.

The **Erector Spinae** (m. sacrospinalis) and its prolongations in the thoracic and cervical regions fill up the vertebral groove on each side of the spine. It is covered in the lumbar region by the lumbar fascia; in the thoracic region, by the Serrati muscles and the vertebral aponeurosis; and in the cervical region, by a layer of cervical fascia continued beneath the Trapezius and the Splenius. This large muscular and tendinous mass varies in size and structure at different parts of the spine. In the sacral region the Erector spinae is narrow and pointed, and its origin chiefly tendinous in structure. In the lumbar region the muscle becomes enlarged, and forms a large, fleshy mass. In the thoracic region it subdivides into two parts, which gradually diminish in size as they ascend to be inserted into the vertebrae and ribs.

The Erector spinae arises from the anterior surface of a very broad and thick tendon, which is attached, internally, to the spines of the sacrum, to the spinous processes of the lumbar and the eleventh and twelfth thoracic vertebrae, and the supraspinous ligament; externally, to the back part of the inner lip of the crest of the ilium, and to the series of eminences on the posterior part of the sacrum, which represents the transverse processes, where it blends with the great sacro-sciatic and posterior sacro-iliac ligaments. Some of its fibres are continuous with the fibres
THE MUSCLES AND FASCÈLE

Occipital bone.

MULTIFIDUS SPINA.

First dorsal vertebra.

1st rib.

2nd.

3rd.

First lumbar vertebra.

First sacral vertebra.

Fig. 282.—Muscles of the back. Deep layers.
of origin of the Gluteus maximus. The muscular fibres form a single large fleshy mass, bounded in front by the transverse processes of the lumbar vertebrae and by the middle lamella of the lumbar fascia. Opposite the last rib it divides into two parts, the **Ilio-costalis** and the **Longissimus dorsi**; the Spinalis dorsi is given off from the latter in the upper thoracic region.

The **Ilio-costalis** or **Sacro-lumbalis** (*m. iliocostalis lumborum*), the external portion of the Erector spinae, is inserted, generally, by six or seven flattened tendons into the inferior borders of the angles of the six or seven lower ribs. The number of the tendons of this muscle is, however, very variable, and therefore the number of ribs into which it is inserted vary. Frequently it is found to possess nine or ten tendons, and sometimes as many tendons as there are ribs, and is then inserted into the angles of all the ribs. If this muscle is reflected outward, it will be seen to be reinforced by a series of muscular slips which arise from the angles of the ribs; by means of these the Ilio-costalis is continued upward to the upper ribs and cervical portion of the spine. The accessory portions form two additional muscles, the **Musculus accessorius** and the **Cervicalis ascendens**.

The **Musculus accessorius ad ilio-costalem** (*m. iliocostalis dorsi*) arises, by separate flattened tendons, from the upper borders of the angles of the six lower ribs: these become muscular, and are finally inserted, by separate tendons, into the upper borders of the angles of the six upper ribs and into the back of the transverse processes of the seventh cervical vertebra.

The **Cervicalis ascendens** (*m. iliocostalis cervicis*) is the continuation of the Accessorius upward into the neck; it is situated on the inner side of the tendons of the Accessorius, arising from the angles of the four or five upper ribs, and is inserted by a series of slender tendons into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebrae.

The **Longissimus dorsi** is the middle and largest portion of the Erector spinae. In the lumbar region, where it is as yet blended with the Ilio-costalis, some of the fibres are attached to the whole length of the posterior surface of the transverse processes and the accessory processes of the lumbar vertebrae, and to the middle layer of the lumbar fascia. In the thoracic region the Longissimus dorsi is inserted, by long, thin tendons, into the tips of the transverse processes of all the thoracic vertebrae, and into from seven to eleven of the lower ribs between their tubercles and angles. This muscle is continued upward to the cranial and cervical portion of the spine by means of two additional muscles, the **Transversalis cervicis** and **Trachelo-mastoid**.

The **Transversalis cervicis** or **Transversalis colli** (*m. longissimus cervicis*), placed on the inner side of the Longissimus dorsi, arises by long, thin tendons from the summits of the transverse processes of the six upper thoracic vertebrae, and is inserted by similar tendons into the posterior tubercles of the transverse processes of the cervical vertebrae, from the second to the sixth inclusive.

The **Trachelo-mastoid** (*m. longissimus capitis*) lies on the inner side of the preceding, between it and the Complexus muscle. It arises, by tendons, from the transverse processes of the five or six upper thoracic vertebrae, and the articular processes of the three or four lower cervical. The fibres form a small muscle, which ascends to be inserted into the posterior margin of the mastoid process, beneath the Splenius and Sternoc-mastoid muscles. This small muscle is almost always crossed by a tendinous intersection near its insertion into the mastoid process.

The **Spinalis dorsi** connects the spinous processes of the upper lumbar and the thoracic vertebrae together by a series of muscular and tendinous slips which are

This muscle is sometimes called "Cervicalis descendens." The student should remember that these long muscles take their fixed point from above or from below, according to circumstances.—Ed. of 15th English edition.

*These two muscles (Transversalis cervicis and Trachelo-mastoid) are sometimes described as one, having a common origin, but dividing above at their insertion. The Trachelo-mastoid is then termed the Transversalis capitis.—Ed. of 15th English edition.*
intimately blended with the Longissimus dorsi. It is situated at the inner side of the Longissimus dorsi, arising, by three or four tendons, from the spinous processes of the first two lumbar and the last two thoracic vertebrae; these, uniting, form a small muscle, which is inserted, by separate tendons, into spinous processes of the thoracic vertebrae, the number varying from four to eight. It is intimately united with the Semispinalis dorsi, which lies beneath it.

The Spinalis colli (m. spinalis cervicis) is a small muscle, connecting together the spinous processes of the cervical vertebrae, and analogous to the Spinalis dorsi in the thoracic region. It varies considerably in its size and in its extent of attachment to the vertebrae, not only in different bodies, but on the two sides of the same body. It usually arises by fleshy or tendinous slips, varying from two to four in number, from the spinous processes of the fifth, sixth, and seventh cervical vertebrae, and occasionally from the first and second thoracic, and is inserted into the spinous process of the axis, and occasionally into the spinous processes of the two vertebrae below it. This muscle was found absent in five cases out of twenty-four.

Relations.—The Erector spinae and its prolongations are bound down to the vertebrae and ribs in the lumbar and thoracic regions by the lumbar fascia and the vertebral aponeurosis. The inner part of these muscles covers the muscles of the fifth layer. In the neck they are in relation, by their superficial surface, with the Trapezius and Splenius; by their deep surface, with the Semispinalis dorsi et colli and the Recti and Obliqui.

The Complexus (m. semispinalis capitis) is a broad thick muscle, situated at the upper and back part of the neck, beneath the Splenius, and internal to the Transversalis cervicis and Tracheo-mastoid. It arises, by a series of tendons, from the tips of the transverse processes of the upper six or seven thoracic and the last cervical vertebrae, and from the articular processes of the three cervical above this. The tendons, uniting, form a broad muscle, which passes obliquely upward and inward, and is inserted into the innermost depression between the two curved lines of the occipital bone. This muscle, about its middle, is traversed by a transverse tendinous intersection. The biventer cervicis is a small fasciculus, situated on the inner side of the preceding, and in the majority of cases blended with it; it has received its name from having a tendon intervening between two fleshy bellies. It is sometimes described as a part of the Complexus. It arises, by from two to four tendinous slips, from the transverse processes of as many of the upper thoracic vertebrae, and is inserted, on the inner side of the Complexus, into the superior curved line of the occipital bone.

Relations.—The Complexus is covered by the Splenius and the Trapezius. It lies on the Rectus capitis posticus major and minor, the Obliquus capitis superior and inferior, and on the Semispinalis colli, from which it is separated by the profunda cervicis artery, the princeps cervicis artery, and branches of the posterior primary divisions of the cervical nerves. The Biventer cervicis is separated from its fellow of the opposite side by the ligamentum nuchae.

The Fifth Layer (Fig. 282).

Semispinalis dorsi. Extensor coccygis.
Semispinalis colli. Intertransversales.
Multifidus spinae. Rectus capitis posticus major.
Rotatores spinae. Rectus capitis posticus minor.
Supraspinales. Obliquus capitis inferior.
Interspinales. Obliquus capitis superior.

Dissection.—Remove the muscles of the preceding layer by dividing and turning aside the Complexus; then detach the Spinalis and Longissimus dorsi from their attachments, divide the Erector spinae at its connection below to the sacral and lumbar spines and turn it outward. The muscles filling up the interval between the spinous and transverse processes are then exposed.
The **Semispinalis Dorsi** consists of thin, narrow, fleshy fasciculi interposed between tendons of considerable length. It *arises* by a series of small tendons from the transverse processes of the lower thoracic vertebrae, from the tenth or eleventh to the fifth or sixth; and is *inserted*, by five or six tendons, into the spinous processes of the upper four thoracic and lower two cervical vertebrae.

The **Semispinalis Colli** (*m. semispinalis cervicis*), thicker than the preceding, *arises* by a series of tendinous and fleshy fibres from the transverse processes of the upper five or six thoracic vertebrae, and is *inserted* into the spinous processes of four cervical vertebrae, from the axis to the fifth cervical. The fasciculus connected with the axis is the largest, and chiefly muscular in structure.

**Relations.**—By their *superficial surface*, from below upward, with the Spinalis dorsi, Longissimus dorsi, Splenius, Complexus, the profunda cervicis artery, the princeps cervicis artery, and the internal branches of the posterior divisions of the first, second, and third cervical nerves; by their *deep surface*, with the Multifidus spine.

The **Multifidus Spinae** (*m. multifidus*) consists of a number of fleshy and tendinous fasciculi which fill up the groove on either side of the spinous processes of the vertebrae, from the sacrum to the axis. In the sacral region these fasciculi *arise* from the back of the sacrum, as low as the fourth sacral foramen, and from the aponeurosis of origin of the Erector spinae; from the inner surface of the posterior superior spine of the ilium and posterior sacro-iliac ligaments; in the lumbar regions, from the articular processes; in the thoracic region, from the transverse processes; and in the cervical region, from the articular processes of the three or four lower vertebrae. Each fasciculus, passing obliquely upward and inward, is *inserted* into the whole length of the spinous process of one of the vertebrae above. These fasciculi vary in length: the most superficial, the longest, pass from one vertebra to the third or fourth above; those next in order pass from one vertebra to the second or third above; whilst the deepest connect two contiguous vertebrae.

**Relations.**—By its *superficial surface*, with the Longissimus dorsi, Spinalis dorsi, Semispinalis dorsi, and Semispinalis colli; by its *deep surface*, with the laminae and spinous processes of the vertebrae, and with the Rotatores spinae in the thoracic region.

The **Rotatores Spinae** (*mm. rotatores*) are found only in the thoracic region of the spine, beneath the Multifidus spine; they are eleven in number on each side. Each muscle is small and somewhat quadrilateral in form; it *arises* from the upper and back part of the transverse process, and is *inserted* into the lower border and outer surface of the lamina of the vertebra above, the fibres extending as far inward as the root of the spinous process. The first is found between the first and second thoracic; the last, between the eleventh and twelfth. Sometimes the number of these muscles is diminished by the absence of one or more from the upper or lower end.

The **Supraspinales** consist of a series of fleshy bands which lie on the spinous processes in the cervical region of the spine.

The **Interspinales** are short muscular fasciculi, placed in pairs between the spinous processes of the contiguous vertebrae, one on each side of the interspinous ligament. In the *cervical region* they are most distinct, and consist of six pairs, the first being situated between the axis and third vertebra, and the last between the last cervical and the first thoracic. They are small narrow bundles, attached, above and below, to the apices of the spinous processes. In the *thoracic region* they are found between the first and second vertebrae; and occasionally between the second and third; and below, between the eleventh and twelfth. In the *lumbar region* there are four pairs of these muscles in the intervals between the five lumbar vertebrae. There is also occasionally one in the interspinous space between the last thoracic and first lumbar, and between the fifth lumbar and the sacrum.
The Extensor Coccygis is a slender muscular fasciculus, occasionally present, which extends over the lower part of the posterior surface of the sacrum and coccyx. It arises by tendinous fibres from the last bone of the sacrum or first piece of the coccyx, and passes downward to be inserted into the lower part of the coccyx. It is a rudiment of the Extensor muscle of the caudal vertebrae of the lower animals.

The Intertransversales (mm. intertransversarii) are small muscles placed between the transverse processes of the vertebrae. In the cervical region they are most developed, consisting of rounded muscular and tendinous fasciculi, which are placed in pairs, passing between the anterior and the posterior tubercles of the transverse processes of two contiguous vertebrae, separated from one another by the anterior division of the cervical nerve, which lies in the groove between them. In this region there are seven pairs of these muscles, the first pair being between the atlas and axis, and the last pair between the seventh cervical and first thoracic vertebrae. In the thoracic region they are least developed, consisting chiefly of rounded tendinous cords in the intertransverse spaces of the upper thoracic vertebrae; but between the transverse processes of the lower three thoracic vertebrae, and between the transverse processes of the last thoracic and the first lumbar, they are muscular in structure. In the lumbar region they are arranged in pairs, on either side of the spine, one set occupying the entire interspace between the transverse processes of the lumbar vertebrae, the intertransversales laterales (mm. intertransversarii laterales); the other set, intertransversales mediales (mm. intertransversarii mediales), passing from the accessory process of one vertebra to the mammillary process of the next.

The Rectus Capitis Posticus Major (m. rectus capitis posterior major) arises by a pointed tendinous origin from the spinous process of the axis, and, becoming broader as it ascends, is inserted into the inferior curved line of the occipital bone and the surface of bone immediately below it. As the muscles of the two sides pass upward and outward, they leave between them a triangular space, in which are seen the Recti capitis postici minores muscles.

Relations.—By its superficial surface, with the Complexus, and, at its insertion, with the Superior oblique; by its deep surface, with part of the Rectus capitis posticus minor, the posterior arch of the atlas, the posterior occipito-atlantal ligament, and part of the occipital bone.

The Rectus Capitis Posticus Minor (m. rectus capitis posterior minor), the smallest of the four muscles in this region, is of a triangular shape; it arises by a narrow pointed tendon from the tubercle on the posterior arch of the atlas, and, becoming broader as it ascends, is inserted into the rough surface beneath the inferior curved line, nearly as far as the foramen magnum, nearer to the middle line than the preceding.

Relations.—By its superficial surface, with the Complexus and the Rectus capitis posticus major; by its deep surface, with the posterior occipito-atlantal ligament.

The Obliquus Capitis Inferior, the larger of the two Oblique muscles, arises from the apex of the spinous processes of the axis, and passes outward and slightly upward, to be inserted into the lower and back part of the transverse process of the atlas.

Relations.—By its superficial surface, with the Complexus and with the posterior division of the second cervical nerve, which crosses it; by its deep surface, with the vertebral artery and posterior atlanto-axial ligament.

The Obliquus Capitis Superior, narrow below, wide and expanded above, arises by tendinous fibres from the upper surface of the transverse process of the atlas, joining with the insertion of the preceding, and, passing obliquely upward and inward, is inserted into the occipital bone, between the two curved lines, external to the Complexus.
Relations.—By its superficial surface, with the Complexus and Trachelo-mastoid and occipital artery. By its deep surface, with the posterior occipito-atlantal ligament.

Between the two oblique muscles and the Rectus capitis posticus major a triangular interval exists, the suboccipital triangle. This triangle is bounded, above and internally, by the Rectus capitis posticus major; above and externally, by the Obliquus capitis superior; below and externally, by the Obliquus capitis inferior. It is covered in by a layer of dense fibro-fatty tissue, situated beneath the Complexus muscle. The floor is formed by the posterior occipito-atlantal ligament and the posterior arch of the atlas. It contains the vertebral artery, as it runs in a deep groove on the upper surface of the posterior arch of the atlas, and the posterior division of the suboccipital nerve.

Nerves.—The third, fourth, and fifth layers of the muscles of the back are supplied by the posterior primary divisions of the spinal nerves.

Actions.—When both the Spinales dorsi contract, they extend the thoracic region of the spine; when only one muscle contracts, it helps to bend the thoracic portion of the spine to one side. The Erector spinae, comprising the Ilio-costalis and the Longissimus dorsi with their accessory muscles, serves, as its name implies, to maintain the spine in the erect posture; it also serves to bend the trunk backward when it is required to counterbalance the influence of any weight at the front of the body, as, for instance, when a heavy weight is suspended from the neck, or when there is any great abdominal distention, as in pregnancy or dropsy; the peculiar gait under such circumstances depends upon the spine being drawn backward by the counterbalancing action of the Erector spinae muscles. The muscles which form the continuation of the Erector spinae upward steady the head and neck, and fix them in the upright position. If the Ilio-costalis and Longissimus dorsi of one side act, they serve to draw down the chest and spine to the corresponding side. The Cervicales ascendens, taking their fixed points from the cervical vertebrae, elevate those ribs to which they are attached; taking their fixed points from the ribs, both muscles help to extend the neck; while one muscle bends the neck to its own side. The Transversalis cervicis, when both muscles act, taking their fixed point from below, bend the neck backward. The Trachelo-mastoid, when both muscles act, taking their fixed point from below, bend the head backward; while, if only one muscle acts, the face is turned to the side on which the muscle is acting, and then the head is bent to the shoulder. The two Recti muscles draw the head backward. The Rectus capitis posticus major, owing to its obliquity, rotates the cranium, with the atlas, round the odontoid process, turning the face to the same side. The Multifidus spine acts successively upon the different parts of the spine; thus, the sacrum furnishes a fixed point from which the fasciculi of this muscle act upon the lumbar region; these then become the fixed points for the fasciculi moving the thoracic region, and so on throughout the entire length of the spine; it is by the successive contraction and relaxation of the separate fasciculi of this and other muscles that the spine preserves the erect posture without the fatigue that would necessarily have been produced had this position been maintained by the action of a single muscle. The Multifidus spine, besides preserving the erect position of the spine, serves to rotate it, so that the front of the trunk is turned to the side opposite to that from which the muscle acts, this muscle being assisted in its action by the Obliquus externus abdominis. The Complexi draw the head directly backward: if one muscle acts, it draws the head to one side, and rotates it so that the face is turned to the opposite side. The Superior oblique draws the head backward, and, from the obliquity in the direction of its fibres, will slightly rotate the cranium, turning the face to the opposite side. The Obliquus capitis inferior rotates the atlas, and with it the cranium, round the odontoid process, turning the face to the same side. The Semispinales, when the muscles of the two sides act together, help to extend the
spine; when the muscles of one side only act, they rotate the thoracic and cervical parts of the spine, turning the body to the opposite side. The Suprspiniales and Interspiniales by approximating the spinous processes help to extend the spine. The Intertransversales approximate the transverse processes, and help to bend the spine to one side. The Rotatores spinæ assist the Multifidus spine to rotate the spine, so that the front of the trunk is turned to the side opposite to that from which the muscle acts.

Surface Forms.—The surface forms produced by the muscles of the back are numerous and difficult to analyze unless they are considered in systematic order. The most superficial layer, consisting of large strata of muscular substance, influences to a certain extent the surface form, and at the same time reveals the forms of the layers beneath. The Trapezius at the upper part of the back, and in the neck, covers over and softens down the outline of the underlying muscles. Its anterior border forms the posterior boundary of the posterior triangle of the neck. It forms a slight undulating ridge which passes downward and forward from the occiput to the junction of the middle and outer third of the clavicle. The tendinous ellipse formed by a part of the origin of the two muscles at the back of the neck is always to be seen as an oval depression, more marked when the muscle is in action. A slight dimple on the skin opposite the interval between the spinous processes of the third and fourth thoracic vertebra marks the triangular aponeurosis by which the inferior fibres are inserted into the root of the spine of the scapula. From this point the inferior border of the muscle may be traced as an undulating ridge to the spinous process of the twelfth thoracic vertebra. In like manner the Latissimus dorsi softens down and modulates the underlying structures at the lower part of the back and lower part of the side of the chest. In this way it modulates the outline of the Erector spine; of the Serratus posticus inferior, which is sometimes to be discerned through it, and is sometimes entirely obscured by it; of part of the Serratus magnus and Superior oblique, which it covers; and of the convex oblique ridges formed by the ribs with the intervening intercostal spaces. The anterior border of the muscle is the only part which gives a distinct surface form. This border may be traced, when the muscle is in action, as a rounded edge, starting from the crest of the ilium, and passing obliquely forward and upward to the posterior border of the axilla, where it combines with the Teres major in forming a thick rounded fold, the posterior boundary of the axillary space. The muscles in the second layer influence to a very considerable extent the surface form of the back of the neck and upper part of the trunk. The Levator anguli secpula reveals itself as a prominent divergent line, running downward and outward, from the transverse processes of the upper cervical vertebrae to the angle of the scapula, covered over and toned down by the overlying Trapezius. The Rhomboidei produce, when in action, a vertical eminence between the vertebral border of the scapula and the spinal furrow, varying in intensity according to the condition of contraction or relaxation of the Trapezius muscle, by which they are for the most part covered. The lowermost part of the Rhomboideus major is uncovered by the Trapezius, and forms on the surface an oblique ridge running upward and inward from the inferrior angle of the scapula. Of the muscles of the third layer of the back, the Serratus posticus superior does not in any way influence surface form. The Serratus posticus inferior, when in strong action, may occasionally be revealed as an elevation beneath the Latissimus dorsi. The Sploevii by their divergence serve to broaden out the upper part of the back of the neck and produce a local fulness in this situation, but do not otherwise influence surface form. Beneath all these muscles those of the fourth layer—the Erector spine and its continuations—influence the surface form in a decided manner. In the loins, the Erector spine, bound down by the lumbar fascia, forms a rounded vertical eminence, which determines the depth of the spinal furrow, and which below tapers to a point on the posterior surface of the sacrum and becomes lost there. In the back it forms a flattened plane which gradually becomes lost. In the neck the only part of this group of muscles which influences surface form is the Trapeziomastoid, which produces a short convergent line across the upper part of the posterior triangle of the neck, appearing from under cover of the posterior border of the Sterno-mastoid and being lost below beneath the Trapezius.

II. MUSCLES AND FASCIAE OF THE THORAX.

The muscles belonging exclusively to this region are few in number. They are the

- Intercostales externi.
- Intercostales interni.
- Infracostales.
- Triangularis sterni.
- Levatores costarum.
- Diaphragm.

Intercostal Fascia.—A thin but firm layer of fascia covers the outer surface of the External intercostal and the inner surface of the Internal intercostal muscles;
and a third layer, more delicate, is interposed between the two planes of muscular fibres. These are the intercostal fasciae, external, middle, and internal; they are best marked in those situations where the muscular fibres are deficient, as between the External intercostal muscles and sternum, in front, and between the Internal intercostals and spine, behind.

The **Intercostal Muscles** (Figs. 290 and 314) are two thin planes of muscular and tendinous fibres, placed one over the other, filling up the intercostal spaces, and being directed obliquely between the margins of the adjacent ribs. They have received the name external and internal from the position they bear to one another. The tendinous fibres are longer and more numerous than the muscular; hence the walls of the intercostal spaces possess very considerable strength, to which the crossing of the muscular fibres materially contributes.

The **External Intercostals** (*mm. intercostales externi*) are eleven in number on each side. They extend from the tubercles of the ribs, behind, to the commencement of the cartilages of the ribs, in front, where they terminate in a thin membrane, the anterior intercostal membrane, which is continued forward to the sternum. They arise from the lower border of the rib above, and are inserted into the upper border of the rib below. In the two lowest spaces they extend to the ends of the cartilages, and in the upper two or three spaces they do not quite extend to the ends of the ribs. Their fibres are directed obliquely downward and forward, in a similar direction with those of the External oblique muscle of the abdomen. They are thicker than the Internal intercostals.

**Relations.**—By their outer surface, with the muscles which immediately invest the chest—viz., the Pectoralis major and minor, Serratus magnus, and Rhomboideus major, Serratus posticus superior and inferior, Scalenus posticus, Iliocostalis, Longissimus dorsi, Cervicalis ascendens, Transversalis cervicis, Levatores costarum, Obliquus externus abdominis, and the Latissimus dorsi; by their internal surface, with the middle intercostal fascia, which separates them from the intercostal vessels and nerve and the Internal intercostal muscles, and, behind, from the pleura.

The **Internal Intercostals** (*mm. intercostales interni*) are also eleven in number on each side. They commence anteriorly at the sternum in the interspaces between the cartilages of the true ribs, and from the anterior extremities of the cartilages of the false ribs, and extend backward as far as the angles of the ribs, whence they are continued to the vertebral column by a thin aponeurosis, the posterior intercostal membrane. They arise from the ridge on the inner surface of the rib above, as well as from the corresponding costal cartilage, and are inserted into the upper border of the rib below. Their fibres are directed obliquely downward and backward, passing in the opposite direction to the fibres of the External intercostal muscle.

**Relations.**—By their external surface, with the intercostal vessels and nerves and the External intercostal muscles; near the sternum, with the anterior intercostal membrane and the Pectoralis major. By their internal surface, with the pleura costalis, Triangularis sterni, and Diaphragm.

The **Infracostales** (*mm. subcostales*) consist of muscular and aponeurotic fasciculi, which vary in number and length; they are placed on the inner surface of the ribs, where the Internal intercostal muscles cease; they arise from the inner surface of one rib, and are inserted into the inner surface of the first, second, or third rib below. Their direction is most usually oblique, like the Internal intercostals. They are most frequent between the lower ribs.

The **Triangularis Sterni** (*m. transversus thoracis*) (Fig. 283) is a thin plane of muscular and tendinous fibres, situated upon the inner wall of the front of the chest. It arises from the lower third of the posterior surface of the sternum, from the posterior surface of the ensiform cartilage, and from the sternal ends of the costal
cartilages of the three or four lower true ribs. Its fibres diverge upward and outward, to be inserted by digitations into the lower borders and inner surfaces of the costal cartilages of the second, third, fourth, fifth, and sixth ribs. The lowest fibres of this muscle are horizontal in their direction, and are continuous with those of the Transversalis; those which succeed are oblique, whilst the superior fibres are almost vertical. This muscle varies much in its attachment, not only in different bodies, but on opposite sides of the same body.

**Relations.**—In front, with the sternum, ensiform cartilage, costal cartilages, Internal intercostal muscles, and internal mammary vessels; behind, with the pleura, pericardium, and anterior mediastinum.

The **Levatores Costarum** (Fig. 282), twelve in number on each side, are small tendinous and fleshy bundles which arise from the extremities of the transverse processes of the seventh cervical and eleven upper thoracic vertebrae, and, passing obliquely downward and outward, are inserted into the upper border of the rib below them, between the tubercle and the angle. The Inferior levatores divide into two fasciculi, one of which is inserted as above described; the other fasciculus passes down to the second rib below its origin; thus, each of the lower ribs receives fibres from the transverse processes of two vertebrae.

**Nerves.**—The muscles of this group are supplied by the intercostal nerves.
The Diaphragm (diaphragma, from διάφραγμα, a partition wall) (Figs. 284, 285, and 286) is a thin, musculo-fibrous septum, consisting of muscular fibres externally, which arise from the circumference of the thoracic cavity and pass upward and inward to converge to a central tendon. It is placed obliquely at the junction of the upper with the middle third of the trunk, and separates the thorax from the abdomen, forming the floor of the former cavity and the roof of the latter. It is elliptical, its longest diameter being from side to side; is somewhat fan-shaped, the broad elliptical portion being horizontal, the narrow part, the crura, which represents the handle of the fan, vertical, and joined at right angles to the former. It is from this circumstance that some anatomists describe it as consisting of two portions, the upper or great muscle of the Diaphragm, and the lower or lesser muscle. It arises from the whole of the internal circumference of the thorax, being attached, in front, by fleshy fibres to the ensiform cartilage, sternal portion of the Diaphragm (pars sternalis); on either side, to the inner surface of the cartilages and bony portions of the six or seven inferior ribs, costal portion (pars costalis), interdigitating with the Transversalis; and behind, to two aponeurotic arches, named the ligamentum arcuatum externum and the ligamentum arcuatum internum, and by the crura, to the lumbar vertebrae, lumbar portion (pars lumbalis). The fibres from these sources vary in length: those arising from the ensiform appendix are very short and occasionally aponeurotic; those from the ligamenta arcuata, and more especially those from the cartilages of the ribs at the side of the chest, are longer, describe well-marked curves as they ascend, and finally converge to be inserted into the circumference of the central tendon. Between the sides of the muscular slip from the ensiform appendix and the cartilages of the adjoining ribs the fibres of the Diaphragm are deficient, the interval being filled by areolar tissue, covered on the thoracic side by the pleura; on the abdominal, by the peritoneum. This is, consequently, a weak point, and a portion of the contents of the abdomen may protrude through it into the chest, forming a phrenic or diaphragmatic hernia, or a collection of pus in the mediastinum may descend through it, so as to point at the epigastrium. A triangular gap is sometimes seen between the fibres springing from the internal and those arising from the external arcuate ligament. When it exists, the kidney is separated from the pleura only by fatty and areolar tissue.

A congenital deficiency in the Diaphragm may produce diaphragmatic hernia; in deficiency of the central tendon the hernia passes into the pericardial sac; in deficiency of one of the lateral portions the hernia passes into the pleural sac.

There are five arcuate ligaments, two internal, two external, and one middle.

The Ligamentum Arcuatum Internum (arcus lumbocostalis medialis) is a tendinous arch, thrown across the upper part of the Psoas magnus muscle, on each side of the spine. It is connected, by one end, to the outer side of the body of the first or second lumbar vertebra, being continuous with the outer side of the tendon of the corresponding crus; and, by the other end, to the front of the transverse process of the first, and sometimes also to that of the second, lumbar vertebra.

The Ligamentum Arcuatum Externum (arcus lumbocostalis lateralis) is the thickened upper margin of the anterior lamella of the lumbar fascia; it arches across the upper part of the Quadratus lumbarum, being attached, by one extremity, to the front of the transverse process of the first lumbar vertebra, and, by the other, to the apex and lower margin of the last rib.

The arch of fibrous tissue which connects the crura of the diaphragm in front of the aorta is sometimes called the middle arcuate ligament. The Diaphragm is connected to the spine by two crura or pillars, which are situated on the bodies of lumbar vertebrae, on each side of the aorta. The crura, at their origin, are tendinous in structure; the right crus, larger and longer than the left, arising from the anterior common ligament and intervertebral substances of the three or four
upper lumbar vertebrae; the left, from the two upper lumbar vertebrae. These tendinous portions of the crura pass forward and inward, and gradually con-

 verge to meet in the middle line, forming an arch, beneath which passes the aorta, vena azygos major, and thoracic duct. From this tendinous arch muscular fibres arise, which diverge, the outermost portion being directed upward and
outward to the central tendon; the innermost decussating in front of the aorta and then diverging, so as to surround the oesophagus before ending in the central tendon. The fibres derived from the right crus are the most numerous and pass in front of those derived from the left. His and Spalteholz teach that three crura exist on each side—viz., the crus mediale, arising from the third and fourth lumbar vertebrae; the crus intermedium, from the second and third lumbar vertebrae; and the crus laterale, from the second or first lumbar vertebrae, and from the band of fascia which is stretched between the lateral part of the body of the first lumbar vertebra and the transverse process of the second lumbar vertebra in front of the Psoas muscle.

The Central or Cordiform Tendon of the Diaphragm (centrum tendineum) is a thin but strong tendinous aponeurosis, situated at the centre of the vault formed by the muscle, immediately below the pericardium, with which it is partly blended. It is shaped somewhat like a trefoil leaf, consisting of three divisions, or leaflets,

Fig. 286.—The Diaphragm, viewed from below. (Testut.)

separated from one another by slight indentations. The right leaflet is the largest; the middle one, directed toward the ensiform cartilage, the next in size; and the left, the smallest. In structure, the tendon is composed of several planes of fibres which intersect one another at various angles, and unite into straight or curved bundles—an arrangement which affords it additional strength.

The Openings.—The openings connected with the Diaphragm are three large and several smaller apertures. The former are the aortic, the oesophageal, and the opening for the vena cava.

The Aortic Opening (hiatus aorticus) is the lowest and the most posterior of the three large apertures connected with this muscle, being at the level of the first lumbar vertebra. It is situated slightly to the left of the middle line, immediately in front of the bodies of the vertebrae; and is, therefore, behind the Diaphragm, not in it. It is an osseo-aponeurotic aperture, formed by a tendinous arch thrown across the front of the bodies of the vertebrae, from the crus on one side to that on the other, and transmits the aorta, vena azygos major, and thoracic duct. Sometimes the vena azygos major is transmitted upward through the right crus.
Occasionally some tendinous fibres are prolonged across the bodies of the vertebrae from the inner part of the lower end of the crura, passing behind the aorta, and thus converting the opening into a fibrous ring.

The \textit{oesophageal opening} (\textit{hiatus oesophageus}) is situated at the level of the tenth thoracic vertebra; it is elliptical in form, oblique in direction, muscular in structure, and, formed by the decussating fibres of the two crura, is placed above, and, at the same time, anterior, and a little to the left of the preceding. It transmits the esophagus and vagus nerves and some small oesophageal arteries. The anterior margin of this aperture is occasionally tendinous, being formed by the margin of the central tendon. The posterior and lateral margins are thick and the gullet is in contact with them for about half an inch. The right margin of the oesophageal opening is particularly prominent and lies in the \textit{oesophageal groove} on the posterior surface of the left lobe of the liver.

The \textit{opening for the Vena Cava} or the \textit{Foramen Quadratum} (\textit{foramen venae cavae}) is the highest opening, being about on the level of the disk between the eighth and ninth thoracic vertebrae; it is quadrilateral in form, tendinous in structure, and placed at the junction of the right and middle leaflets of the central tendon, its margins being adherent to the wall of the inferior vena cava (\textit{postcava}).

The \textit{right crus} transmits the greater and lesser splanchnic nerves of the right side; the \textit{left crus} transmits the greater and lesser splanchnic nerves of the left side, and the vena azygos minor. The gangliated cords of the sympathetic usually enter the abdominal cavity by passing behind the internal arcuate ligaments.

\textbf{Serous Membranes}.—The serous membranes in relation with the Diaphragm are four in number: three lining its upper or thoracic surface; one, its abdominal. The three serous membranes on its upper surface are the pleura on either side and the pericardium, which covers the middle portion of the tendinous centre. The serous membrane covering the under surface of the Diaphragm is a portion of the general peritoneal membrane of the abdominal cavity.

The Diaphragm is arched, being convex toward the chest and concave toward the abdomen. The \textit{right portion} forms a complete arch from before backward, being accurately moulded over the convex surface of the liver, and having resting upon it the concave base of the right lung. The \textit{left portion} is arched from before backward in a similar manner; but the arch is narrower in front, being encroached upon by the pericardium, and lower than the right, at its summit, by about three-quarters of an inch. It supports the base of the left lung, and covers the great end of the stomach, the spleen, and left kidney. At its circumference the Diaphragm is higher in the median line of the body than at either side; but in the middle of the thorax the central portion, which supports the heart, is on a lower level than the two lateral portions.

\textbf{Nerves}.—The Diaphragm is supplied by the phrenic nerves, the lower intercostal nerves and the phrenic plexus of the sympathetic.

\textbf{Actions}.—The Intercostals are the chief agents in the movement of the ribs in ordinary respiration. When the first rib is elevated and fixed by the Scaleni, the External intercostals raise the other ribs, especially their forepart, and so increase the capacity of the chest from before backward; at the same time they evert their lower borders, and so enlarge the thoracic cavity transversely. The Internal intercostals, at the side of the thorax, depress the ribs and invert their lower borders, and so diminish the thoracic cavity; but at the forepart of the chest these muscles assist the External intercostals in raising the cartilages.\textsuperscript{1} The Levatores

\textsuperscript{1} The view of the action of the Intercostal muscles given in the text is that which is taught by Hutchinson (Cycl. of Anat. and Phys., art. Thorax), and is usually adopted in our schools. It is, however, much disputed. Hamberger believed that the External intercostals act as elevators of the ribs, or muscles of inspiration, while the internal act in expiration. Haller taught that both sets of muscles act in common—viz., as muscles of inspiration—and this view is adopted by many of the best anatomists of the Continent, and appears sup-
costarum assist the External intercostals in raising the ribs. The Triangularis sterni draws down the costal cartilages; it is therefore an expiratory muscle.

The Diaphragm is the principal muscle of inspiration. When in a condition of rest the muscle presents a domed surface, concave toward the abdomen; and consists of a circumferential muscular and a central tendinous part. When the muscular fibres contract, they become less arched, or nearly straight, and thus cause the central tendon to descend, and in consequence the level of the chest-wall is lowered, the vertical diameter of the chest being proportionally increased. In this descent the different parts of the tendon move unequally. The left leaflet descends to the greatest extent; the right to a less extent, on account of the liver; and the central leaflet the least, because of its connection to the pericardium. In descending the Diaphragm presses on the abdominal viscera, and so to a certain extent causes a projection of the abdominal wall; but in consequence of these viscera not yielding completely, the central tendon becomes a fixed point, and enables the circumferential muscular fibres to act from it, and so elevate the lower ribs and expand the lower part of the thoracic cavity; and Duchenne has shown that the Diaphragm has the power of elevating the ribs, to which it is attached, by its contraction, if the abdominal viscera are in situ, but that if these organs are removed, this power is lost. When at the end of inspiration the Diaphragm relaxes, the thoracic walls return to their natural position in consequence of their elastic reaction and of the elasticity and weight of the displaced viscera.1

In all expulsive acts the Diaphragm is called into action, to give additional power to each expulsive effort. Thus, before sneezing, coughing, laughing, and crying, before vomiting, previous to the expulsion of the urine and faces, or of the fœtus from the womb, a deep inspiration takes place.

The height of the Diaphragm is constantly varying during respiration, the muscle being carried upward or downward from the average level; its height also varies according to the degree of distention of the stomach and intestines, and the size of the liver. After a forced expiration, the right arch is on a level, in front, with the fourth costal cartilage; at the side, with the fifth, sixth, and seventh ribs; and behind, with the eighth rib, the left arch being usually from one to two ribs' breadth below the level of the right one. In a forced inspiration, it descends from one to two inches; its slope would then be represented by a line drawn from the ensiform cartilage toward the tenth rib. Prof. Wm. S. Forbes2 is of the opinion that the Diaphragm is an appendage of the circulatory apparatus rather than the chief agent in respiration. He maintains that the opening in the vena cava is stationary and holds a constant relation to the ninth thoracic vertebra. He emphasizes the fact that the base of the pericardium is attached to the central tendon of the Diaphragm, and on the anterior and left side. The muscular fibres of the Diaphragm ascend upon and are attached to the pericardium. Prolongations of the fibrous pericardium pass upward as the pericardial ligaments. These ligaments form fibrous planes reaching from each side of the central tendon of the Diaphragm to the "bony apex of the thoracic line" and to the fascia stretched across the thoracic apex, and they may be called the "superior tendinous crura." It is thus evident that the deep cervical fascia is connected to the lateral and superior parts of the pericardium. At birth the muscular

1 For a detailed description of the general relations of the Diaphragm, and its action, refer to Dr. Sibson's Medical Anatomy.—Ed. of 15th English edition.

fibres of the Diaphragm contract at the first inspiration. The ductus arteriosus is lodged in an elliptical opening of a tendinous scaffolding. The contractions of the Diaphragm cause the tendinous scaffolding to compress the ductus arteriosus "and eventually close it." The chief agents in the compression are the muscular fibres which pass from the Diaphragm to the pericardium. When the lateral wings of the Diaphragm descend they tend to form a vacuum in the thorax and thus assist the venous circulation.

"The descent of the Diaphragm is not necessary to respiration," but it "is necessary in order to protect the heart from the movement of surrounding viscera, and in order to promote the free circulation of the blood through the vessels forming the cardiac roots."

Muscles of Inspiration and Expiration.—The muscles which assist the action of the Diaphragm in ordinary tranquil inspiration are the Intercostals and the Levatores costarum, as above stated, and the Scaleni. When the need for more forcible action exists, the shoulders and the base of the scapula are fixed, and then the powerful muscles of forced inspiration come into play; the chief of these are the Trapezius, the Pectoralis minor, the Serratus posticus superior and inferior, and the Rhomboidei. The lower fibres of the Serratus magnus may possibly assist slightly in dilating the chest by raising and evertting the ribs. The Sterno-mastoid also, when the head is fixed, assists in forced inspiration by drawing up the sternum and by fixing the clavicle, and thus affording a fixed point for the action of the muscles of the chest. The Ilio-costalis and Quadratus lumborum assist in forced inspiration by fixing the last rib.

The ordinary action of expiration is hardly effected by muscular force, but results from a return of the walls of the thorax to a condition of rest, owing to their own elasticity and to that of the lungs. Forced expiratory actions are performed mainly by the flat muscles (Obliqui and Transversalis) of the abdomen, assisted by the Rectus. Other muscles of forced expiration are the Internal intercostals and Triangularis sterni (as above mentioned).

III. MUSCLES OF THE ABDOMEN.

The muscles of the abdomen may be divided into two groups: 1. The superficial muscles of the abdomen. 2. The deep muscles of the abdomen.

1. The Superficial Muscles of the Abdomen.

The Muscles in this region are, the

- External Oblique.
- Internal Oblique.
- Rectus.
- Transversalis.
- Pyramidalis.

Dissection (Fig. 287).—To dissect the abdominal muscles, make a vertical incision from the ensiform cartilage to the symphysis pubis; a second incision from the umbilicus obliquely upward and outward to the outer surface of the chest, as high as the lower border of the fifth or sixth rib; and a third, commencing midway between the umbilicus and pubes, transversely outward to the anterior superior iliac spine, and along the crest of the ilium as far as its posterior third. Then reflect the three flaps included between these incisions from within outward, in the lines of direction of the muscular fibres. If necessary, the abdominal muscles may be made tense by inflating the peritoneal cavity through the umbilicus.

Superficial Fascia.—The superficial fascia of the abdomen consists, over the greater part of the abdominal wall, of a single layer of fascia, which contains a variable amount of fat; but as this layer approaches the groin it is easily divisible into two layers, between which are found the superficial vessels and nerves and the superficial inguinal lymphatic glands. The superficial layer of the superficial
fascia, or the fascia of Camper, is thick, arcular in texture, containing adipose tissue in its meshes, the quantity of which varies in different subjects. Below it passes over Poupart’s ligament, and is continuous with the outer layer of the superficial fascia of the thigh. In the male this fascia is continued over the penis and outer surface of the cord to the scrotum, where it helps to form the dartos. As it passes to the scrotum it changes its character, becoming thin, destitute of adipose tissue, and of a pale hue, it has a reddish color, and in the scrotum it acquires some involuntary muscular fibres. From the scrotum it may be traced backward to be continuous with the superficial fascia of the perineum. In the female this fascia is continued into the labia majora. The deep layer of the superficial fascia or the fascia of Scarpa, is thinner and more membranous in character than the superficial layer. In the middle line it is intimately adherent to the linea alba and to the symphysis pubis, and is prolonged on to the dorsum of the penis, forming the suspensory ligament of the penis; above, it joins the superficial layer and is continuous with the superficial fascia over the rest of the trunk; below, it blends with the fascia lata of the thigh a little below Poupart’s ligament; and below and internally it is continued over the penis and spermatic cord to the scrotum, where it helps to form the dartos. From the scrotum it may be traced backward to be continuous with the deep layer of the superficial fascia of the perineum. In the female it is continued into the labia majora.

Deep Fascia.—The deep fascia invests the external oblique muscle, but is so thin over the aponeurosis of the muscle as to be scarcely recognizable.

The External or Descending Oblique Muscle (m. obliquus externus abdominis) (Fig. 288) is situated on the side and forepart of the abdomen; being the largest and the most superficial of the three flat muscles in this region. It is broad, thin, and irregularly quadrilateral, its muscular portion occupying the side, its aponeurosis the anterior wall, of the abdomen. It arises, by eight fleshy digitations, from the external surface and lower borders of the eight inferior ribs; these digitations are arranged in an oblique line running downward and backward; the upper ones being attached close to the cartilages of the corresponding ribs; the lowest, to the apex of the cartilage of the last rib; the intermediate ones, to the ribs at some distance from their cartilages. The five superior serrations increase in size from above downward, and are received between corresponding processes of the Serratus magnus; the three lower ones diminish in size from above downward, receiving between them corresponding processes from the Latisimus dorsi. From these attachments, the fleshy fibres proceed in various directions. Those from the lowest ribs pass nearly vertically downward, to be inserted into the anterior half of the outer lip of the crest of the ilium; the middle and upper fibres, directed downward and forward, terminate in an aponeurosis, opposite a line drawn from the prominence of the ninth costal cartilage to the anterior superior spinous process of the ilium.

Aponeurosis of External Oblique.—The aponeurosis of the external oblique is a thin, but strong membranous aponeurosis, the fibres of which are directed
obliquely downward and inward. It is joined with that of the opposite muscle along the median line, covers the whole of the front of the abdomen; above, it is connected with the lower border of the Pectoralis major; below, its fibres are closely aggregated together, and extend obliquely across from the anterior superior spine of the ilium to the spine of the os pubis and the linea ilio-pectinea. In the median line it interlaces with the aponeurosis of the opposite muscle, forming the linea alba, which extends from the ensiform cartilage to the symphysis pubis.

That portion of the aponeurosis which extends between the anterior superior spine of the ilium and the spine of the os pubis is a broad band, folded inward, and continuous below with the fascia lata; it is called Poupart's ligament or the ligament of Fallopius. The portion which is reflected from Poupart's ligament at the spine of the os pubis along the pectineal line is called Gimbernat's ligament. From the point of attachment of the latter to the pectineal line, a few fibres
pass upward and inward, behind the inner pillar of the ring, to the linea alba. They diverge as they ascend, and form a thin, triangular, fibrous layer, which is called the triangular fascia of the abdomen or Colles's ligament (ligamentum inguinale reflexum). The point of the triangle is at the origin of Colles's ligament; the base is at the linea alba. Colles's ligament is in front of the conjoined tendon, the Rectus muscle, and the Pyramidalis muscle.

In the aponeurosis of the External oblique, immediately above the crest of the os pubis, is a triangular opening, the external abdominal ring, formed by a separation of the fibres of the aponeurosis in this situation.

Relations.—By its external surface, with the superficial fascia, superficial epigastric and circumflex iliac vessels, and some cutaneous nerves; by its internal surface, with the Internal oblique, the lower part of the eight inferior ribs, and Intercostal muscles, the Cremaster, the spermatic cord in the male, and round ligament in the female. Its posterior border, extending from the last rib to the crest of the ilium, is fleshy throughout and free; it is occasionally overlapped by the Lattissimus dorsi, though generally a triangular interval exists between the two muscles near the crest of the ilium, in which is seen a portion of the internal oblique. This triangle, Petit's triangle (trigonum lumbale), is therefore bounded in front by the External oblique, behind by the Lattissimus dorsi, below by the crest of the ilium, while its floor is formed by the Internal oblique (Fig. 288).

The following parts of the aponeurosis of the External oblique muscle require to be further described—viz., the external abdominal ring, the intercolumnar fibres and fascia, Poupart's ligament, Gimbernat's ligament, and the triangular fascia of the abdomen.

The External Abdominal Ring (annulus inguinale subcutaneous) (Figs. 289 and 292).—Just above and to the outer side of the crest of the os pubis an interval is seen.
in the aponeurosis of the External oblique, called the external abdominal ring. The aperture is oblique in direction, somewhat triangular in form, and corresponds with the course of the fibres of the aponeurosis. It usually measures from base to apex about an inch, and transversely about half an inch. It is bounded below by the crest of the os pubis; above, by a series of curved fibres, the *external spermatic* or the *intercolumnar* fibres which pass across the upper angle of the ring, so as to increase its strength; and on each side, by the margins of the opening in the aponeurosis, which are called the *columns* or *pillars* of the ring.

The *External Pillar* or *inferior crus* (*crus inferius*) is inferior from the obliquity of its direction. It is stronger than the internal pillar; it is formed by that portion of Poupart's ligament which is inserted into the spine of the os pubis; it is curved so as to form a kind of groove, upon which the spermatic cord rests.

The *Internal Pillar* or *superior crus* (*crus superius*) is a broad, thin, flat band, which is attached to the front of the symphysis pubis, interlacing with its fellow of the opposite side.

The external abdominal ring gives passage to the *spermatic cord in the male* (*funiculus spermaticus*) and *round ligament in the female* (*ligamentum teres uteri*): it is much larger in men than in women, on account of the large size of the spermatic cord, and hence the greater frequency of inguinal hernia in men.

**Intercolumnar Fibres** (*fibræ intercrurales*) (Fig. 289).—The intercolumnar fibres are a series of curved tendinous fibres, which arch across the lower part of the aponeurosis of the External oblique. They have received their name from stretching across between the two pillars of the external ring, describing a curve with the convexity downward. They are much thicker and stronger at the outer margin of the external ring, where they are connected to the outer third of Poupart's ligament, than internally, where they are inserted into the linea alba. They are more strongly developed in the male than in the female. The intercolumnar fibres increase the strength of the lower part of the aponeurosis, and prevent the divergence of the pillars from one another.

These intercolumnar fibres as they pass across the external abdominal ring are themselves connected together by delicate fibrous tissue, thus forming a fascia, which as it is attached to the pillars of the ring covers it in, and is called the *intercolumnar fascia* or the *external spermatic fascia*. This intercolumnar fascia is continued down as a tubular prolongation around the outer surface of the cord and testis or of the round ligament, and encloses them in a distinct sheath.

The sac of an inguinal hernia, in passing through the external abdominal ring, receives an investment from the intercolumnar fascia.

If the finger is introduced a short distance into the external abdominal ring and the limb is then extended and rotated outward, the aponeurosis of the External oblique, together with the iliac portion of the fascia lata, will be felt to become tense, and the external ring much contracted; if the limb is, on the contrary, flexed upon the pelvis and rotated inward, this aponeurosis will become lax and the external abdominal ring sufficiently enlarged to admit the finger with comparative ease; hence the patient should always be put in the latter position when the taxis is applied for the reduction of an inguinal hernia in order that the abdominal walls may be relaxed as much as possible.

**Poupart's Ligament** (*ligamentum inguinale*).—The portion of Poupart's ligament in front of the crural ring is called the *superficial crural arch*. Poupart's ligament is the lower border of the aponeurosis of the External oblique muscle, and extends from the anterior superior spine of the ilium to the pubic spine. From this latter point it is reflected outward to be attached to the pectinal line for about half an inch, forming *Gimbernat's Ligament*. Its general direction is curved down-
ward toward the thigh, where it is continuous with the fascia lata. Its outer half is rounded and oblique in direction. Its inner half gradually widens at its attachment to the os pubis, is more horizontal in direction, and lies beneath the spermatic cord. Nearly the whole of the space included between the crural arch and the innominate bone is filled in by the parts which descend from the abdomen into the thigh (Fig. 297). These will be referred to again on a subsequent page.

Gimbernat’s Ligament (ligamentum lacunare) (Figs. 289 and 297).—Gimbernat’s ligament is that part of the aponeurosis of the External oblique muscle which is reflected upward and outward from the spine of the os pubis to be inserted into the pectineal line. It is about half an inch in length, larger in the male than in the female, almost horizontal in direction in the erect posture, and of a triangular form with the base directed outward. Its base, or outer margin, is concave, thin, and sharp, and lies in contact with the crural sheath, forming the inner boundary of the femoral or crural ring (annulus femoralis). Its apex corresponds to the spine of the os pubis. Its posterior margin is attached to the pectineal line, and is continuous with the pubic portion of the fascia lata. Its anterior margin is continuous with Poupart’s ligament. Its surfaces are directed upward and downward.

Triangular Fascia or Colles’s Ligament (ligamentum inguinal reflexum).—The triangular fascia of the abdomen is a layer of tendinous fibres of a triangular shape, which is attached by its apex to the pectineal line, where it is continuous with Gimbernat’s ligament. It passes inward beneath the spermatic cord, and expands into a somewhat fan-shaped fascia, lying behind the inner pillar of the external abdominal ring, and in front of the conjoined tendon, and interlaces with the ligament of the other side at the linea alba.

Ligament of Cooper (Fig. 297).—This is a strong ligamentous band, which was first described by Sir Astley Cooper. It extends upward and backward from the base of Gimbernat’s ligament along the ilio-pectineal line, to which it is attached. It is strengthened by the fascia transversalis, by the pectineal aponeurosis, and by a lateral expansion from the lower attachment of the linea alba (adminiculum linear alba).

Suspensory Ligament of the Penis (ligamentum fundiforme penis).—The suspensory ligament of the penis arises from the linea alba, the anterior portion of the sheath of the Rectus muscle, and the superficial fascia. It splits into two portions, blends with the inserting fascia of the penis, and passes into the scrotum.

Suspensory Ligament of the Clitoris (ligamentum fundiforme clitoridis).—The suspensory ligament of the clitoris corresponds in the female to the suspensory ligament of the penis in the male.

Dissection.—Detach the External oblique by dividing it across, just in front of its attachment to the ribs, as far as its posterior border, and separate it below from the crest of the ilium as far as the anterior superior spine; then separate the muscle carefully from the Internal oblique, which lies beneath, and turn it toward the opposite side.

The Internal or Ascending Oblique Muscle (m. obliquus internus abdominis) (Fig. 290), thinner and smaller than the preceding, beneath which it lies, is of an irregularly quadrilateral form, and is situated at the side and forepart of the abdomen. It arises, by fleshy fibres, from the outer half of Poupart’s ligament, being attached to the groove on its upper surface; from the anterior two-thirds of the middle lip of the crest of the ilium, and from the posterior lamella of the lumbar fascia (Fig. 294). From this origin the fibres diverge: those from Poupart’s ligament, few in number and paler in color than the rest, arch downward and inward across the spermatic cord in the male and the round ligament in the female, and, becoming tendinous, are inserted, conjointly with those of the Transversalis, into the crest of the os pubis and pectineal line, to the extent of half an inch or more, forming what is known as the conjoined tendon of the Internal oblique and
Transversalis; those from the anterior third of the iliac origin are horizontal in their direction, and, becoming tendinous along the lower fourth of the linea semilunaris, pass in front of the Rectus muscle to be inserted into the linea alba; those which arise from the middle third of the origin from the crest of the ilium pass obliquely upward and inward, and terminate in an aponeurosis which divides at the outer border of the Rectus muscle into two lamellae (Fig. 295), which are continued forward, in front and behind this muscle, to the linea alba, the posterior lamella being also connected to the cartilages of the seventh, eighth, and ninth ribs; the most posterior fibres pass almost vertically upward, to be inserted into the lower borders of the cartilages of the three lower ribs, being continuous with the Internal intercostal muscles.

![Image of the internal oblique muscle](image_url)

**Fig. 290.**—The Internal oblique muscle.

The **conjoined tendon of the Internal oblique and Transversalis** is inserted into the crest of the os pubis and pectineal line, immediately behind the external abdominal ring, serving to protect what would otherwise be a weak point in the abdominal wall. Sometimes this tendon is insufficient to resist the pressure from within, and is carried forward in front of a protrusion through the external ring, forming one of the coverings of direct inguinal hernia; or the hernia forces its way through the fibres of the conjoined tendon. The conjoined tendon is sometimes divided into an outer and an inner portion—the former being termed the ligament of Hesselbach; the latter, the ligament of Henle (Fig. 291). See pages 444 and 446.
Aponeurosis of Internal Oblique.—The aponeurosis of the Internal oblique is continued forward to the middle line of the abdomen, where it joins with the aponeurosis of the opposite muscle at the linea alba, and extends from the margin of the thorax to the os pubis. At the outer margin of the Rectus muscle this aponeurosis, for the upper three-fourths of its extent, divides into two lamellae, which pass, one in front and the other behind the muscle, enclosing it in a kind of sheath, and reuniting on its inner border of the linea alba; the anterior layer is blended with the aponeurosis of the External oblique muscle; the posterior layer with that of the Transversalis. Along the lower fourth the aponeurosis passes altogether in front of the Rectus without any separation. Where the aponeurosis ceases to split, and passes altogether in front of the Rectus muscle, a deficiency is left in the sheath of the muscle behind; this is marked above by a sharp lunated margin having its concavity downward. This is known as the semilunar fold of Douglas (linea semicircularis) (Fig. 292).

Relations.—By its external surface, with the External oblique, Latissimus dorsi, spermatic cord, and external ring; by its internal surface, with the Transversalis muscle, the lower intercostal vessels and nerves, the ilio-hypogastric and the ilioinguinal nerves. Near Poupart's ligament it lies on the fascia transversalis, internal ring, and spermatic cord. Its lower border forms the upper boundary of the inguinal canal.

The Cremaster muscle (Fig. 290) is a thin, muscular layer, composed of a number of fasciculi which arise from the inner part of Poupart's ligament, where its fibres are continuous with those of the Internal oblique and also occasionally with the Transversalis. It passes along the outer side of the spermatic cord, descends with it through the external abdominal ring upon the front and sides of the cord, and forms a series of loops which differ in thickness and length in different subjects. Those at the upper part of the cord are exceedingly short, but they become in succession longer and longer, the longest reaching down as low as the testicle, where a few are inserted into the tunica vaginalis. These loops are united together by areolar tissue, and form a thin covering over the cord and testis, the middle
spermatic fascia \((fascia cremasterica)\). The fibres ascend along the inner side of the cord, and are inserted by a small pointed tendon into the crest of the os pubis and front of the sheath of the Rectus muscle.

![Diagram of muscles and fasciae](image)

**Fig. 292.**—The muscles of the abdomen, showing the semilunar fold of Douglas. Viewed from in front. (Spalteholz.)

It will be observed that the origin and insertion of the Cremaster is precisely similar to that of the lower fibres of the Internal oblique. This fact affords an easy explanation of the manner in which the testicle and cord are invested by this muscle. At an early period of foetal life the testis is placed at the lower and back part of the abdominal cavity, but during its descent toward the scrotum, which takes place before birth, it passes beneath the arched fibres of the Internal oblique. In its passage beneath this muscle some fibres are derived from its lower part which accompany the testicle and cord into the scrotum. It occasionally happens
that the loops of the Cremaster surround the cord, some lying behind as well as in front. It is probable that under these circumstances the testis, in its descent, passed through instead of beneath the fibres of the Internal oblique.

In the descent of an oblique inguinal hernia, which takes the same course as the spermatic cord, the Cremaster muscle forms one of its coverings. This muscle becomes largely developed in cases of hydrocele and large old scrotal hernia. The Cremaster muscle is found only in the male, but almost constantly in the female

![Diagram of the abdominal muscles](image)

**Fig. 293.**—The Transversalis, Rectus, and Pyramidalis muscles.

a few muscular fibres may be seen on the surface of the round ligament, which correspond to this muscle, and in cases of oblique inguinal hernia in the female a considerable amount of muscular fibre may be found covering the sac.

**Dissection.**—Detach the Internal oblique in order to expose the Transversalis beneath. This may be effected by dividing the muscle, above, at its attachment to the ribs; below, at its connection with Poupart’s ligament and the crest of the ilium; and behind, by a vertical incision
extending from the last rib to the crest of the ilium. The muscle should previously be made tense by drawing upon it with the fingers of the left hand, and if its division is carefully effected, the cellular interval between it and the Transversalis, as well as the direction of the fibres of the latter muscle, will afford a clear guide to their separation; along the crest of the ilium the circumflex iliac vessels are interposed between them, and form an important guide in separating them. The muscle should then be thrown inward toward the linea alba.

The Transversalis Muscle (m. transversus abdominis) (Fig. 293), so called from the direction of its fibres, is the most internal flat muscle of the abdomen, being placed immediately beneath the Internal oblique. It arises by fleshy fibres from the outer third of Poupart's ligament; from the inner lip of the crest of the ilium for its anterior three-fourths; from the inner surface of the cartilages of the six lower ribs, interdigitating with the Diaphragm; and from the lumbar fascia (Fig. 294), which may be regarded as the posterior aponeurosis of the muscle. The muscle terminates in front in a broad aponeurosis, the lower fibres of which curve downward and inward, and are inserted, together with those of the Internal oblique, into the lower part of the linea alba, the crest of the os pubis and pectineal line forming what is known as the conjointed tendon of the Internal oblique and Transversalis. The lowermost fibres help to form the posterior wall of the inguinal canal. Throughout the rest of its extent the aponeurosis passes horizontally inward, and is inserted into the linea alba, its upper three-fourths passing behind the Rectus muscle, blending with the posterior lamella of the Internal oblique; its lower fourth passing in front of the Rectus. The external portion of the lower fibres of the conjointed tendon is known as the ligament of Hesselbach (Fig. 291) (ligamentum interfoveolare); the internal portion as the ligament of Henle (Fig. 291) (falc inguinalis).

Relations.—By its external surface, with the Internal oblique, the lower intercostal nerves, and the inner surface of the cartilages of the lower ribs; by its internal surface, with the fascia transversalis, which separates it from the peritoneum. Its lower border forms the upper boundary of the inguinal canal.

Dissection.—To expose the Rectus muscle, open its sheath by a vertical incision extending from the margin of the thorax to the os pubis, and then reflect the two portions from the surface of the muscle, which is easily done, excepting at the linea transverse, where so close an adhesion exists that the greatest care is requisite in separating them. Now raise the outer edge of the muscle, in order to examine the posterior layer of the sheath. By dividing the muscle in the centre, and turning its lower part downward, the point where the posterior wall of the sheath terminates in a thin curved margin will be seen.

The Rectus Abdominis (Figs. 291, 293 and 295) is a long flat muscle, which extends along the whole length of the front of the abdomen, being separated from its fellow of the opposite side by the linea alba. It is much broader, but thinner, above than below, and arises by two tendons, the external or larger being attached to the crest of the os pubis, the internal, smaller portion interlacing with its fellow of the opposite side, and being connected with the ligaments covering the front of the symphysis pubis. The fibres ascend, and the muscle is inserted by three portions of unequal size into the cartilages of the fifth, sixth, and seventh ribs. The upper portion, attached principally to the cartilage of the fifth rib, usually has some fibres of insertion into the anterior extremity of the rib itself. Some fibres are occasionally connected with the costo-xiphoideal ligaments and side of the ensiform cartilage. The Rectus muscle is traversed by tendinous intersections, three in number, which have received the name of lineae transverse. One of these is usually situated opposite the umbilicus, and two above that point; of the latter, one corresponds to the extremity of the ensiform cartilage, and the other to the interval between the ensiform cartilage and the umbilicus. These intersections pass transversely or obliquely across the muscle in a zigzag course; they rarely extend completely through its substance, sometimes they pass only half-way across it, and are intimately adherent in front to the sheath in which the muscle is enclosed.
Sometimes one or two additional lines may be seen, one usually below the umbilicus; the position of the other, when it exists, is variable. These additional lines are for the most part incomplete.

The Rectus is enclosed in a sheath, the rectus sheath (*vagina m. recti abdominis*) (Figs. 294 and 295), formed by the aponeurosis of the Oblique and Transversalis muscles, which are arranged in the following manner. When the aponeurosis of the Internal oblique arrives at the outer margin of the Rectus it divides into two lamellae,
of which passes in front of the Rectus, blending with the aponeurosis of the External oblique; the other, behind it, blending with the aponeurosis of the Transversalis; and these, joining again at its inner border, are inserted into the linea alba. This arrangement of the aponeuroses exists along the upper three-fourths of the muscle: at the commencement of the lower fourth, the posterior wall of the sheath terminates in a thin curved margin, the semilunar fold of Douglas (linea semicircularis) (Fig. 292), the concavity of which looks downward toward the pubes; the aponeuroses of all three muscles passing in front of the Rectus without any separation. A very thin aponeurotic layer does pass behind the lower one-fourth of the muscle, but it is trivial as compared with the thickness of the layer behind the upper three-fourths of the muscle. This sudden thinning causes the semilunar fold of Douglas. The extremities of the fold of Douglas descend as pillars to the os pubis. The inner pillar is attached to the symphysis pubis; the outer pillar passes downward as a distinct band on the inner side of the internal abdominal ring to join with the outer fibres of the conjoined tendon, and assist to form the ligament of Hesselbach (ligamentum interfoveolare) (Fig. 291). There its fibres divide into two sets, internal and external; the internal fibres are attached to the ascending ramus of the os pubis and the pectineal fascia; the external ones pass to the Psoas fascia, to the deep surface of Poupart's ligament, and to the tendon of the Transversalis on the outer side of the ring. The Rectus muscle, in the situation where its sheath is deficient, is separated from the peritoneum by the transversalis fascia. The convex outer border of the Rectus muscle corresponds to the linea semilunaris.

The Pyramidalis is a small muscle, triangular in shape, placed at the lower part of the abdomen, in front of the Rectus, and contained in the same sheath with that muscle. It arises by tendinous fibres from the front of the os pubis and the anterior pubic ligament; the fleshy portion of the muscle passes upward, diminishing in size as it ascends, and terminates by a pointed extremity, which is inserted into the linea alba, midway between the umbilicus and the os pubis. This muscle is sometimes found wanting on one or both sides; the lower end of the Rectus then becomes proportionately increased in size. Occasionally it has been found double on one side, or the muscles of the two sides are of unequal size. Sometimes its length exceeds what is stated above.

Besides the Rectus and Pyramidalis muscles, the sheath of the Rectus contains the superior and deep epigastric arteries, the terminations of the lumbar arteries and of the lower intercostal arteries and nerves.

Nerves.—The abdominal muscles are supplied by the lower intercostal nerves. The Transversalis and Internal oblique also receive filaments from the hypogastric branch of the ilio-hypogastric and sometimes from the ilio-inguinal. The Cremaster is supplied by the genital branch of the genito-femoral.

In the description of the abdominal muscles mention has frequently been made of the linea alba, lineae semilunares, and lineae transversae; when the dissection of the muscles is completed these structures should be examined.

The Linea Alba (Figs. 292, 293, and 294).—The linea alba is a tendinous raphe seen along the middle line of the abdomen, extending from the ensiform cartilage to the symphysis pubis, to the superior pubic ligament of which it is attached. It is placed between the inner borders of the Recti muscles, and is formed by the blending of the aponeuroses of the Obliqui and Transversales muscles. It is narrow below, corresponding to the narrow interval existing between the Recti; but broader above, as these muscles diverge from one another in their ascent, becoming of considerable breadth when there is great distention of the abdomen from pregnancy or ascites. It presents numerous apertures for the passage of vessels and nerves: the largest of these is the umbilicus (Fig. 296). The umbilicus is a fibrous ring formed by the fibres of the aponeurosis of the linea alba, is filled with scar tissue; in the fetus transmits the umbilical vein, the two hypogas-
tric arteries, the allantoic duct, and the vitello-intestinal duct; but in the adult is obliterated, the cicatrix being stronger than the neighboring parts; hence umbilical hernia occurs in the adult near the umbilicus, whilst in the foetus it occurs at the umbilicus. The remains of the foetal structures are cord-like in character, and they diverge from the umbilicus within the abdomen. The remains of the umbilical vein constitute the round ligament of the liver, and this cord passes upward (Fig. 296). The remains of the hypogastric arteries pass downward (Fig. 296). The remains of the allantois become the urachus, which passes to the summit of the bladder (Fig. 296). The depression of the umbilicus was created by the urachus. The linea alba is in relation, in front, with the integument, to which it is adherent, especially at the umbilicus; behind, it is separated from the peritoneum by the transversalis fascia; and below, by the urachus, and the bladder when that organ is distended.

The Lineæ Semilunares (Figs. 288 and 292).—The lineæ semilunares are two curved tendinous lines placed one on each side of the linea alba. Each corresponds with the outer border of the Rectus muscle, extends from the cartilage of the ninth rib to the pubic spine, and is formed by the aponeurosis of the Internal oblique at its point of division to enclose the Rectus, where it is reinforced in front by the External oblique and behind by the Transversalis.

The Lineæ Transverse (inscriptiones tendineae) (Fig. 288).—The lineæ transverse are narrow transverse lines which intersect the Recti muscles, as already mentioned; they connect the lineæ semilunares with the linea alba.

Actions.—The abdominal muscles perform a threefold action:

When the pelvis and thorax are fixed, they compress the abdominal viscera, by constricting the cavity of the abdomen, in which action they are materially assisted by the descent of the Diaphragm. By these means the foetus is expelled from the uterus, the faeces from the rectum, the urine from the bladder, and the contents of the stomach in vomiting.

If the pelvis and spine are fixed, these muscles compress the lower part of the thorax, materially assisting expiration. If the pelvis alone is fixed, the thorax is bent directly forward when the muscles of both sides act, or to either side when those of the two sides act alternately, rotation of the trunk at the same time taking place to the opposite side.

If the thorax is fixed, these muscles, acting together, draw the pelvis upward, as in climbing; or, acting singly, they draw the pelvis upward, and bend the vertebral column to one side or the other. The Recti muscles, acting from below, depress the thorax, and consequently flex the vertebral column; when acting from above, they flex the pelvis upon the vertebral column. The Pyramidalis are tensors of the linea alba.

The Transversalis Fascia (fascia transversalis).—The fascia transversalis is a thin aponeurotic membrane which lies between the inner surface of the Transversalis muscle and the extra-peritoneal fat. It forms part of the general layer of fascia which lines the interior of the abdominal and pelvic cavities, and is directly continuous with the iliac and pelvic fasciae. In theinguinal region the transversalis fascia is thick and dense in structure, and joined by fibres from the aponeurosis of the Transversalis muscle, but it becomes thin and cellular as it ascends to the Diaphragm, and blends with the fascia covering this muscle. In front, it unites across the
middle line with the fascia on the opposite side of the body, and behind it becomes lost in the fat which covers the posterior surfaces of the kidneys. Below, it has the following attachments: posteriorly, it is connected to the whole length of the crest of the ilium, between the attachments of the Transversalis and Iliacus muscles; between the anterior superior spine of the ilium and the femoral vessels it is connected to the posterior margin of Poupart’s ligament, and is there continuous with the iliac fascia. Internal to the femoral vessels it is thin and attached to the os pubis and pectineal line, behind the conjoined tendon, with which it is united; and, corresponding to the point where the femoral vessels pass into the thigh, this fascia descends in front of them, forming the anterior wall of the crural sheath. Beneath Poupart’s ligament it is strengthened by a band of fibrous tissue, which is only loosely connected to Poupart’s ligament, and is specialized as the deep crural arch. The spermatic cord in the male and the round ligament in the female pass through this fascia; the point where they pass through is called the internal abdominal ring. This opening is not visible externally, owing to a prolongation of the transversalis fascia on these structures, forming the infundibuliform fascia.

The internal or deep abdominal ring (annulus inguinalis abdominis) (Figs. 291 and 297) is situated in the transversalis fascia, midway between the anterior

![Diagram](Fig. 297.—The relation of the femoral and internal abdominal rings, seen from within the abdomen after removal of the peritoneum. (Poirier and Charpy.)

superior spine of the ilium and the symphysis pubis, and about half an inch above Poupart’s ligament. It is of an oval form, the extremities of the oval directed upward and downward, varies in size in different subjects, and is much larger in the male than in the female. Its lower border is strengthened by the collection of fibres called Hesselbach’s ligament, lying directly in front of the deep epigastric artery. It is the outer portion of the conjoined tendon fused with the outer pillar of the semilunar fold of Douglas. The internal ring is bounded, above and externally, by the arched fibres of the Transversalis; below and internally, by the deep epigastric vessels. It transmits the spermatic cord in the male and the round ligament in the female. From its circumference a thin funnel-shaped membrane, the infundibuliform or internal spermatic fascia, is continued round the cord and testis, enclosing them in a distinct pouch.
The right inguinal canal in the male, second layer, viewed from in front. (The first layer is shown in Fig. 298.) (Spalteholz.)

The right inguinal canal in the male, third layer, viewed from in front. (Spalteholz.)
When the sac of an oblique inguinal hernia passes through the internal or deep abdominal ring, the infundibuliform process of the transversalis fascia forms one of its coverings.

The Inguinal or Spermatic Canal (canalis inguinalis) (Figs. 298 and 299).—The inguinal or spermatic canal contains the spermatic cord (funiculus spermaticus) in the male and the round ligament (ligamentum teres uteri) in the female. It is an oblique canal about an inch and a half in length, directed downward and inward, and placed parallel to and a little above Poupart’s ligament. It commences above at the internal or deep abdominal ring, which is the point where the cord enters the spermatic canal, and terminates below at the external ring. It is bounded in front by the integument and superficial fascia, by the aponeurosis of the External oblique throughout its whole length, and by the Internal oblique for its outer third; behind, by the triangular fascia, the conjoined tendon of the Internal oblique and Transversalis, transversalis fascia, and the subperitoneal fat and peritoneum; above, by the arched fibres of the Internal oblique and Transversalis; below, by Gimbernat’s ligament, and by the union of the fascia transversalis with Poupart’s ligament. The median aspect of the floor of the canal is strengthened by dense fibres which are attached to the pubis and to the Rectus muscle. These fibres constitute the falc inguinalis, or ligament of Henle. The deep epigastric artery passes upward and inward behind the canal lying close to the inner side of the internal abdominal ring (Fig. 291). The interval between this artery and the outer edge of the Rectus is named Hesselbach’s triangle, the base of which is formed by Poupart’s ligament.

That form of protrusion in which the intestine follows the course of the spermatic cord along the spermatic canal is called oblique inguinal hernia.

The Deep Crural Arch.—Curving over the vessels, just at the point where they become femoral, on the abdominal side of Poupart’s ligament and loosely connected with it, is a thickened band of fibres called the deep crural arch. It is apparently a thickening of the fascia transversalis, joining externally to the centre of Poupart’s ligament, and arching across the front of the crural sheath to be inserted by a broad attachment into the spine of the os pubis and ilio-pectineal line, behind the conjoined tendon. In some subjects this structure is not very prominently marked, and not infrequently it is altogether wanting.

Cooper’s Ligament or the Reflected Tendon of Cooper (Fig. 297) is a small reflexion from the tendon of the Transversalis which passes downward and outward behind Gimbernat’s ligament.

The External Abdominal Ring (annulus abdominalis subcutaneus).—See p. 437.

Surface Form.—The only two muscles of this group which have any considerable influence on surface form are the External oblique and Rectus muscles of the abdomen. With regard to the External oblique, the upper digitations of its origin from the ribs are well marked, intermingled with the serrations of the Serratus magnus; the lower digitations are not visible, being covered by the thick border of the Latissimus dorsi. Its attachment to the crest of the ilium, in conjunction with the Internal oblique, forms a thick oblique roll, which determines the iliac furrow. Sometimes on the front of the lateral region of the abdomen an undulating outline marks the spot where the muscular fibres terminate and the aponeurosis commences. The outer border of the Rectus is defined by the linea semilunaris, which may be exactly defined by putting the muscle into action. It corresponds with a curved line, with its convexity outward, drawn from the end of the cartilage of the ninth rib to the spine of the os pubis, so that the centre of the line, at or near the umbilicus, is three inches from the median line. The inner border of the Rectus corresponds to the linea alba, marked on the surface of the body by a groove, the abdominal furrow, which extends from the infrasternal fossa to, or a little below, the umbilicus, where it gradually becomes lost. The surface of the Rectus presents three transverse furrows, the linea transversa. The upper two of these, one opposite or a little below the tip of the ensiform cartilage, and another, midway between this point and the umbilicus, are usually well marked; the third, opposite the umbilicus, is not so distinct. The umbilicus, situated in the linea alba, varies very much in position as regards its level. It is always situated above a zone drawn round the body opposite the highest point of the crest of the ilium, generally being about three-quarters of an inch to an inch above this line. It usually corresponds, therefore, to the fibro-cartilage between the third and fourth lumbar vertebrae.
2. The Deep Muscles of the Abdomen.

Psoas magnus.
Psoas parvus.
Iliacus.
Quadratus lumborum.

The Psoas magnus, the Psoas parvus, and the Iliacus muscles, with the fascia covering them, will be described with the Muscles of the Lower Extremity.

The Fascia Covering the Quadratus Lumborum (Fig. 294).—This is the most anterior of the three layers of the lumbar fascia. It is a thin layer of fascia, which, passing over the anterior surface of the Quadratus lumborum, is attached, internally, to the bases of the transverse processes of the lumbar vertebrae; below, to the ilio-lumbar ligament; and above, to the apex and lower border of the last rib.

The portion of this fascia which extends from the transverse process of the first lumbar vertebra to the apex and lower border of the last rib constitutes the ligamentum arcuatum externum.

The Quadratus Lumborum (Fig. 282) is situated in the lumbar region. It is irregularly quadrilateral in shape, and broader below than above. It arises by aponeurotic fibres from the ilio-lumbar ligament and the adjacent portion of the crest of the ilium for about two inches, and is inserted into the lower border of the last rib for about half its length, and by four small tendons, into the apices of the transverse processes of the four upper lumbar vertebrae. Occasionally a second portion of this muscle is found situated in front of the preceding. This arises from the upper borders of the transverse processes of three or four of the lower lumbar vertebrae, and is inserted into the lower margin of the last rib. The Quadratus lumborum is contained in a sheath formed by the anterior and middle lamellae of the lumbar fascia.

Relations.—Its anterior surface (or rather the fascia which covers its anterior surface) is in relation with the colon, the kidney, the Psoas muscle, and the Diaphragm. Between the fascia and the muscle are the last thoracic, ilio-hypogastric, and ilio-inguinal nerves. Its posterior surface is in relation with the middle lamella of the lumbar fascia, which separates it from the Erector spinae. The Quadratus lumborum extends, however, beyond the outer border of the Erector spinae.

Nerve-supply.—The anterior branches of the last thoracic and first lumbar nerves; sometimes also a branch from the second lumbar nerve.

Actions.—The Quadratus lumborum draws down the last rib. It acts as a muscle of inspiration by helping to fix the origin of the Diaphragm. If the thorax and spine are fixed, it may act upon the pelvis, raising it toward its own side when only one muscle is put in action; and when both muscles act together, either from below or above, they flex the trunk.

IV. MUSCLES OF THE PELVIC OUTLET.

The muscles of this region are situated at the pelvic outlet in the ischio-rectal region and the perineum. They include the following:
1. Muscles of the ischio-rectal region.
2. Muscles of the perineum in the male.
3. Muscles of the perineum in the female.

1. The Muscles of the Ischio-rectal Region.

Corrugator cutis ani.
External sphincter ani.
Internal sphincter ani.
Levator ani.
Coccygeus.

The Corrugator Cutis Ani.—Around the anus is a thin stratum of involuntary muscular fibre, which radiates from the orifice. Internally, the fibres fade off.
into the submucous tissue, while externally they blend with the true skin. By its contraction it raises the skin into ridges around the margin of the anus.

The **External Sphincter Ani** (*m. sphincter ani externus*) (Figs. 300, 305, 306, and 307) is a thin, flat plane of muscular fibres, elliptical in shape and intimately adherent to the integument surrounding the margin of the anus. It measures about three or four inches in length from its anterior to its posterior extremity, being about an inch in breadth opposite the anus. It arises from the tip and back of the coccyx by a narrow tendinous band, and from the superficial fascia in front
of that bone; and is inserted into the raphé of the Accelerator urinæ muscle and into the central tendinous point of the perineum, joining with the two Superficial transverse perineal, the Levator ani, and the Accelerator urinæ muscles. Many of the fibres are continuous with the Accelerator urinæ in the male and with the sphincter vaginae in the female. Often some of the fibres are continuous with the Transverse perineal muscles. It is continuous above with the Levator ani. Like other sphincter muscles, it consists of two planes of muscular fibre, which surround the margin of the anus and join in a commissure in front and behind, some fibres crossing from side to side in front and behind the anus.

Nerve-supply.—A branch from the anterior division of the fourth sacral and the inferior hemorrhoidal branch of the internal pudic.

Actions.—The action of this muscle is peculiar: 1. It is, like other sphincter muscles, always in a state of tonic contraction, and having no antagonistic muscle, it keeps the anal orifice closed. 2. It can be put into a condition of greater contraction under the influence of the will, so as to occlude more firmly the anal aperture in expiratory efforts unconnected with defecation. 3. Taking its fixed point at the coccyx, it helps to fix the central point of the perineum, so that the Accelerator urinæ may act from this fixed point.

The Internal Sphincter Ani (m. sphincter ani internus) is a muscular ring which surrounds the lower extremity of the rectum for about an inch, its inferior border being contiguous to, but quite separate from, the External sphincter. This muscle is about two lines in thickness, and is formed by an aggregation of the involuntary circular fibres of the intestine. It is paler in color and less coarse in texture than the External sphincter.

Actions.—Its action is entirely involuntary. It helps the External sphincter to occlude the anal aperture.

The Levator Ani (Figs. 301, 302, 303, and 304) is a broad, thin muscle, situated on each side of the pelvis. It is attached to the inner surface of the
sides of the true pelvis, and, descending, unites with its fellow of the opposite side to form the floor of the pelvic cavity. It supports the visceræ in this cavity and surrounds the various structures which pass through it. It is usually possible to detect an interval between the fibres rising from the pubis and those rising from the pelvic fascia, and this interval marks the fact that the muscle described as one is really two. The pubic fibres constitute the Pubococcygeus muscle and the other fibres the Iliococcygeus muscle.1

The Pubococcygeus muscle takes origin from the posterior aspect of the ramus of the pubis and from the most anterior portion of the tendinous arch of the Levator ani muscle. The fibres of origin from the pubis surround anteriorly the origin of the Internal obturator muscle. The muscle is a band, about one inch in width, thickest at its outer border, where it overlaps the Iliococcygeus. It passes backward, downward, and inward, "near the prostate in the male, the urethra and vagina in the female,"2 and near to the rectum. Most of the fibres pass back of the rectum, where they meet and join with the corresponding fibres of the opposite side. These united fibres form a thick, tendinous aponeurosis. "This is continued upward in front of the coccyx for some distance, and finally divides into two lateral portions, which have been named the ligamenta sacro-coccygea anterior. They are situated on either side of the middle sacral artery, and are finally inserted into the last one or two pieces of the sacrum and the first piece of the coccyx."3

1 Peter Thompson. The Myology of the Pelvic Floor.
2 Spalteholz’s Atlas. Translated and edited by Barker.
3 Peter Thompson. The Myology of the Pelvic Floor.
central tendon of the perineum, come in contact with but do not terminate in the rectal wall, descend in front of and close to the anterior rectal wall, and terminate in the anterior portion of the sphincter ani and in the skin of the anus (Peter Thompson).

Luschka and others believe that these anterior fibres descend among the longitudinal fibres of the rectum. It is certain that the most anterior fibres of the

Pubococcygeus muscle pass to the central point of the perineum. They pass "backward and downward on the side of the prostate, and in some cases on the side of the urethra immediately it emerges from the prostate." These anterior fibres in the female descend upon the side of the vagina. The anterior fibres are the preanal fibres of the Levator ani. They constitute what Santorini named

1 Peter Thompson. The Myology of the Pelvic Floor.
the *levator prostate*, because he regarded them as constituting a distinct muscle, which surrounds the prostate as a sling. Krause calls these fibres the *levator urethrae*; Testut, the *fibres pré-rectales*, and Prout, the Recto-urethralis muscle.

The *Iliococcygeus muscle* arises from the tendinous arch of the Levator ani muscle (*arcus tendineus m. levatoris ani*). This arch is concave upward. The anterior end of the arch begins on the posterior surface of the superior ramus of the pubis. "The posterior end can be followed as far as the linea arcuata of the ilium, between these two points it descends for a variable distance, but always leaves the canalis obturatorius free." The fibres, coursing internally and downward, pass below the posterior portion of the Pubococcygeus. The anterior fibres join the fibres of the other side, between the anus and the tip of the coccyx in a median raphé.

The posterior fibres are inserted into the sides of the last two pieces and into the tip of the coccyx. Peter Thompson points out that the Iliococcygeus muscle is liable to variations. It is strongly developed in but few, is usually thin, the muscular bundles being separated by membranous intervals; it may be replaced by fibrous tissue and may even be absent.²

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**Relations of the Levator Ani.**—By its *inner* or *pelvic surface*, with the rectovesical fascia, which separates it from the viscera of the pelvis and from the peritoneum. By its *outer* or *perineal surface*, it forms the inner boundary of the ischio-rectal fossa, and is covered by a thin layer of fascia, the *ischio-rectal* or *anal fascia*, given off from the obturator fascia. Its *posterior border* is free and separated from the Coccygeus muscle by a cellular interspace. Its *anterior border* is separated from the muscle of the opposite side by a triangular space, through which the urethra, and in the female the vagina, passes from the pelvis.

**Nerve-supply.**—A branch from the anterior division of the fourth sacral nerve and a branch from the pudic nerve, which is sometimes derived from the perineal and sometimes from the inferior hemorrhoidal division.

**Actions.**—The entire Levator ani muscle enters into the formation of the diaphragm of the pelvis and aids in supporting the rectum, vagina, and bladder.

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1 Spalteholz's Atlas. Translated and edited by Barker.  
2 Myology of Muscles.
The two parts of the muscle have different functions. The Iliococcygei have no other function than that of supporting the viscera. In early life they flex the vertebræ of the coccyx on one another and flex the coccyx on the sacrum, but do not act directly at any age on the rectum or pelvic viscera (Peter Thompson). The Pubococcygei, especially in the female, have most important functions. They are the most influential supports of the pelvic floor and restore the pelvic floor to its proper position after the depression induced by parturition, defecation, and efforts at urination. Normally, they pull the perineum upward after the descending head has pulled it down. In some cases the contraction of the muscles actually obstructs the descent of the head (Peter Thompson). The muscles are strongly developed in females, and, acting with the Sphincter vaginae, they aid in contracting the vaginal canal. The muscles constrict the rectum and also lift the rectum with the pelvic floor. During defecation the position of the rectal contents is maintained by intra-abdominal pressure, the muscles lift the perineum over the fecal matter (Goffe). The Levator ani is also a muscle of forced expiration.

The Coccygeus is a flat, triangular muscle situated behind and parallel with the preceding. It is a triangular plane of muscular and tendinous fibres, arising, by its apex, from the spine of the ischium, the obturator fascia, the edge of the great sacro-sciatic notch, and from the lesser sacro-sciatic ligament, and inserted, by its base, into the side of the lower two vertebræ of the sacrum and the upper two vertebræ of the coccyx. It assists the Levator ani and Pyriformis in closing in the back part of the outlet of the pelvis.

Relations.—By its inner or pelvic surface, with the rectum. By its external surface, with the lesser sacro-sciatic ligament. The lower border is in relation with the posterior border of the Levator ani, but separated from it by a cellular interval: its upper border is in relation with the lower border of the Pyriformis, but separated from it by the sciatic and internal pudic vessels and nerve.

Nerve-supply.—A branch from the fourth and fifth sacral nerves.

Action.—The Coccygei muscles raise and support the coccyx, after it has been pressed backward during defecation or parturition.

2. The Muscles and Fasciae of the Perineum in the Male
(Figs. 300, 305, 306, 307).

Transversus perinei superficialis. Erector penis.
Accelerator urinae. Compressor urethrae.

Superficial Fascia (fascia superficialis perinei).—The superficial fascia of the perineum consists of two layers, superficial and deep, as in other regions of the body. The superficial fascia over the posterior portion of the perineum is arranged in fatty layers which fill the ischio-rectal fossa on each side of the rectum and anus. The superficial fascia over the anterior portion of the perineum (urethral region) requires fuller consideration.

The Superficial Layer is thick, loose, areolar in texture, and, except toward the scrotum, contains much adipose tissue in its meshes, the amount of which varies in different subjects. In front, it is continuous with the dartos of the scrotum; behind, it is continuous with the subcutaneous areolar tissue surrounding the anus; and, on either side, with the same fascia on the inner side of the thighs. In the middle line it is adherent to the skin of the raphé and to the deep layer of

1 Peter Thompson. The Myology of the Pelvic Floor.
the superficial fascia. This layer should be carefully removed after it has been examined, when the deep layer will be exposed.

The Deep Layer of Superficial Fascia or the Fascia of Colles is thin, aponeurotic in structure, and of considerable strength, serving to bind down the muscles of the root of the penis. It is continuous, in front, with the deep fascia of the penis, and the dartos of the scrotum, the fascia of the spermatic cord, and Scarpa’s fascia upon the anterior portion of the abdomen; on either side it is firmly attached to the margins of the rami of the os pubis and ischium, external to the crus penis, and as far back as the tuberosity of the ischium; posteriorly, it curves down behind the Superficial transverse perineal muscles (reflected portion of fascia) to join the lower margin of the triangular ligament, which structure is a prolongation of the deep layer of the superficial fascia. The deep layer is attached to the superficial layer in the median line and to the median septum of the Accelerator urinae muscle. At the central tendon of the perineum the reflected portion of the fascia becomes blended with the insertions of the External anal sphincter, the two Superficial transverse perineal muscles, and the Accelerator urinae. This fascia not only covers the muscles in this region, but sends upward a vertical septum from its deep surface, which separates the back part of the subjacent space into two, the septum being incomplete in front.

The Central Tendinous Point of the Perineum.—This is a fibrous point in the middle line of the perineum, between the urethra and the rectum, being about half an inch in front of the anus. At this point four muscles converge and are attached—viz., the External sphincter ani, the Accelerator urinae, and the two Superficial transverse perineal; so that by the contraction of these muscles, which extend in opposite directions, it serves as a fixed point of support.
The **Transversus Perinei Superficialis** is a narrow muscular slip, which passes more or less transversely across the back part of the perineal space. It arises by a small tendon from the inner and forepart of the tuberosity of the ischium, and, passing inward, is inserted into the central tendinous point of the perineum, joining in this situation with the muscle of the opposite side, the External sphincter ani behind, and the Accelerator urinae in front. The base of the triangular ligament lies just beneath this muscle.

**Nerve-supply.**—The perineal branch of the internal pudic.

**Actions.**—By their contraction they serve to fix the central tendinous point of the perineum.

The **Accelerator Urinae**, called also the **Ejaculator seminis** and the **Ejaculator urinae** (*m. bulbocavernosus*), is placed in the middle line of the perineum, immediately in front of the anus. It consists of two symmetrical halves, united along the median line by a tendinous raphe. It arises from the central tendon of the perineum, and from the median raphe in front. From this point its fibres diverge like the plumes of a pen; the most posterior form a thin layer, which is lost on the anterior surface of the triangular ligament; the middle fibres encircle the bulb and adjacent parts of the corpus spongiosum, and join with the fibres of the opposite side, on the upper part of the corpus spongiosum, in a strong aponeurosis; the anterior fibres, the longest and most distinct, spread out over the sides of the corpus cavernosum, to be inserted partly into that body, anterior to the Erector penis, occasionally extending to the os pubis; partly terminating in a tendinous expansion, which covers the dorsal vessels of the penis. The latter fibres are best seen by dividing the muscle longitudinally, and dissecting it outward from the surface of the urethra. Many fibres of the External sphincter ani and of the Superficial transverse perineal muscles pass into this muscle.

**Action.**—This muscle serves to empty the canal of the urethra, after the bladder has expelled its contents; during the greater part of the act of micturition.
its fibres are relaxed, and it only comes into action at the end of the process. The middle fibres are supposed, by Krause, to assist in the erection of the corpus spongiosum, by compressing the erectile tissue of the bulb. The anterior fibres, on each side, which are known as Houston’s muscles, according to Tyrrel, also contribute to the erection of the penis, as they are inserted into, and continuous with, the fascia of the penis, compressing the dorsal vein during the contraction of the muscle.

The **Erector Penis** (*m. ischiocavernosus*) covers part of the crus penis. It is an elongated muscle, broader in the middle than at either extremity, and situated on either side of the lateral boundary of the perineum. It *arises* by tendinous and fleshy fibres from the inner surface of the tuberosity of the ischium, behind the crus penis, from the surface of the crus, and from the adjacent portion of the ramus of the ischium. From these points fleshy fibres succeed, which end in an aponeurosis which is *inserted* into the sides and under surface of the crus penis.

**Nerve-supply.**—The perineal branch of the internal pudic.

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**Fig. 307.**—Triangular ligament or deep perineal fascia. On the left side the anterior layer has been removed.

**Actions.**—It compresses the crus penis and retards the return of the blood through the veins, and thus serves to maintain the organ erect.

Between the muscles just examined a triangular space exists, bounded internally by the Accelerator urinæ, externally by the Erector penis, and behind by the Transversus perinei superficialis. The floor of this space is formed by the triangular ligament of the urethra (deep perineal fascia), and running from behind forward in it are the superficial perineal vessels and nerves, the long pudendal nerve, and the transverse perineal artery coursing along the posterior boundary of the space on the Transversus perinei superficialis.

The **Triangular Ligament** or the **Deep Perineal Fascia** (*trigonum or diaphragma urogenitale*) (Figs. 304, 308, and 309) is stretched almost horizontally across the pubic arch, so as to close in the front part of the outlet of the pelvis. It con-
sists of two dense musculo-membranous laminae, which are united along their posterior borders, but are separated in front by intervening structures. The superficial of these two layers, the superficial, anterior, or inferior layer of the triangular ligament (fascia trigoni urogenitalis inferior), is triangular in shape and about an inch and a half in depth. Its apex is directed forward, and is separated from the subpubic ligament by an oval opening for the transmission of the dorsal vein of the penis. The apex of the triangular ligament is called the

transverse perineal or transverse pelvic ligament (ligamentum transversum pelvis). The lateral margins of the inferior layer of the triangular ligament are attached on each side to the rami of the ischium and os pubis, above the crura penis. The fusion of the two leaves posteriorly takes place beneath the Superficial transverse perineal muscles. The region of fusion of the two leaflets posteriorly is called the base. The base is directed toward the rectum, and connected to the central tendinous point of the perineum. It is continuous with the deep layer of the superficial fascia behind the Superficial transverse perineal muscles, and with a thin fascia which covers the cutaneous surface of the Levator ani muscle, the anal or ischio-rectal fascia.

This layer of the triangular ligament is perforated, about an inch below the symphysis pubis, by the urethra, the aperture for which is circular in form and

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**Fig. 308.**—The aponeurosis of the perineum. (Denonvilliers.)

**Fig. 309.**—The superficial layer of the triangular ligament. The Compressor urethrae muscle lies behind the superficial layer of the triangular ligament and is shown in the figure for convenience. (Poirier and Charpy.)
about three or four lines in diameter; by the arteries to the bulb and the ducts of Cowper’s glands close to the urethral orifice; by the arteries to the corpora cavernosa—one on each side, close to the pubic arch and about half-way along the attached margin of the ligament; by the dorsal arteries and nerves of the penis near the apex of the ligament. Its base is also perforated by the superficial perineal vessels and nerves, while between its apex and the subpubic ligament the dorsal nerve of the penis and the dorsal vein of the penis passes upward into the pelvis.

If this superficial or inferior layer of the triangular ligament is detached on either side, the following structures will be seen between it and the deeper layer: the dorsal vein of the penis; the membranous portion of the urethra, and the Compressor urethrae muscle; Cowper’s glands and their ducts; the pudic vessels and dorsal nerve of the penis; the artery and nerve of the bulb, and a plexus of veins. The two layers join the urethral wall and vagina medianward.

The deep, posterior, or superior layer (fascia trigoni urogenitalis superior) of the triangular ligament is derived from the obturator fascia and stretches across the pubic arch. If the obturator fascia is traced inward after covering the Obturator internus muscle, it will be found to be attached by some of its deeper or anterior fibres to the inner margin of the ischio-pubic ramus, while its superficial or posterior fibres pass over this attachment to become the superior layer of the triangular ligament. Behind, this layer of the fascia is continuous with the inferior layer and with the fascia of Colles, and in front it is separated from the apex of the prostate gland through the intervention of a prolongation of the recto-vesical fascia. It is pierced by the urethra, or rather consists of two halves which are separated in the middle line by the urethra passing between them.

The Compressor or Constrictor Urethrae (m. constrictor urethrae) in the male surrounds the whole length of the membranous portion of the urethra, and is contained between the two layers of the triangular ligament. It arises, by aponeurotic fibres, from the junction of the rami of the os pubis and ischium, to the extent of half or three-quarters of an inch: the point where the crura penis joins the transverse ligament of the perineum and the layers of the triangular ligament; each segment of the muscle passes inward, and divides into two fasciculi, which surround the membranous urethra and unite, at the upper and lower surfaces of this tube, with the muscle of the opposite side by means of a tendinous raphé. The Compressor urethrae is continuous posteriorly with the m. prostaticus and is continuous anteriorly with the circular fibres of the cavernous portion of the urethra. This muscle is frequently in two portions, an anterior and a posterior, separated by a distinct interval. In such cases the posterior fibres are called the transversus perinei profundus, and the anterior fibres are called the sphincter urethrae membranaceae.

Nerve-supply.—The perineal branch of the internal pudic.

Actions.—The muscles of both sides act together as a sphincter, compressing the membranous portion of the urethra. During the transmission of fluids they, like the Acceleratores urinae, are relaxed, and come into action only at the end of the process, to eject the last drops of the fluid.

3. The Muscles of the Perineum in the Female (Fig. 310).

Transversus perinei superficialis. Erector clitoridis. Compressor urethrae.

Sphincter vaginae.

The Transversus Perinei Superficialis in the female is a narrow muscular slip, which passes more or less transversely across the back part of the perineal space.
It arises by a small tendon from the inner and forepart of the tuberosity of the ischium, and, passing inward, is inserted into the central point of the perineum, joining in this situation with the muscle of the opposite side, the External sphincter ani behind, and the Sphincter vaginae in front.

_Nerve-supply._—The perineal branch of the internal pudic.

_Actions._—By their contraction they serve to fix the central tendinous point of the perineum.

The _Sphincter Vaginae_ (m. bulbocavernosus) surrounds the orifice of the vagina, and is analogous to the Accelerator urine in the male. It is attached posteriorly to the central tendinous point of the perineum, where it blends with the External sphincter ani. Its fibres pass forward on each side of the vagina, to be inserted into the corpora cavernosa of the clitoris, a fasciculus crossing over the body of the organ so as to compress the dorsal vein.

_Nerve-supply._—The perineal branch of the internal pudic.

_Actions._—It diminishes the orifice of the vagina. The anterior fibres contribute to the erection of the clitoris, as they are inserted into and are continuous with the fascia of the clitoris; compressing the dorsal vein during the contraction of the muscle.

The _Erector Clitoridis_ (m. ischiocavernosus) resembles the Erector penis in the male, but is smaller than it. It covers the unattached part of the crus clitoridis. It is an elongated muscle, broader at the middle than at either extremity, and situated on either side of the lateral boundary of the perineum. It arises by tendinous and fleshy fibres from the inner surface of the tuberosity of the ischium, behind the crus clitoridis from the surface of the crus, and from the adjacent portion of the ramus of the ischium. From these points fleshy fibres succeed,
which end in an aponeurosis, which is inserted into the sides and under surface of the crus clitoridis.

**Nerve-supply.**—The perineal branch of the internal pudic.

**Actions.**—It compresses the crus clitoridis and retards the return of blood through the veins, and thus serves to maintain the organ erect.

The **Triangular Ligament** (ligamentum urogenitale) in the female is not so strong as in the male. It is divided in the middle line by the aperture of the vagina, with the external coat of which it becomes blended, and in front of this is perforated by the urethra. Its posterior border is continuous, as in the male, with the deep layer of the superficial fascia around the Transversus perinei muscle.

Like the triangular ligament in the male, it consists of two layers, between which are to be found the following structures: the dorsal vein of the clitoris, a portion of the urethra and the Compressor urethrae muscle, the glands of Bartholin and their ducts; the pudic vessels and the dorsal nerve of the clitoris; the arteries of the bulb vestibuli, and a plexus of veins.

The **Compressor Urethrae** (m. constrictor urethrae) arises on each side from the margin of the descending ramus of the os pubis. The fibres, passing inward, divide into two sets: those of the forepart of the muscle are directed across the subpubic arch in front of the urethra to blend with the muscular fibres of the opposite side; while those of the hinder and larger part pass inward to blend with the wall of the vagina behind the urethra.

**Nerve-supply.**—The perineal branch of the internal pudic.

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**MUSCLES AND FASCIAE OF THE UPPER EXTREMITY.**

The muscles of the Upper Extremity are divisible into groups, corresponding with the different regions of the limb.

I. **OF THE THORACIC REGION.**

1. **Anterior Thoracic Region.**

2. **Lateral Thoracic Region.**
   Serratus magnus.

II. **OF THE SHOULDER AND ARM.**

3. **Acromial Region.**
   Deltoid.

4. **Anterior Scapular Region.**
   Subscapularis.

5. **Posterior Scapular Region.**

6. **Anterior Humeral Region.**

7. **Posterior Humeral Region.**
   Triceps. Subanconeus.

III. **OF THE FOREARM.**

8. **Anterior Radio-ulnar Region.**

9. **Radial Region.**
   Supinator longus. Extensor carpi radialis longior. Extensor carpi radialis brevior.
10. Posterior Radio-Ulnar Region.

**Superficial Layer.**
- Extensor communis digitorum.
- Extensor minimi digiti.
- Extensor carpi ulnaris.
- Anconeus.
- Supinator brevis.
- Extensor ossis metacarpi pollicis.
- Extensor brevis pollicis.
- Extensor longus pollicis.
- Extensor indicis.

**Deep Layer.**
- Flèxor brevis pollicis.
- Adductor obliquus pollicis.
- Adductor transversus pollicis.

12. Ulnar Region.

- Palmaris brevis.
- Abductor minimi digitii.
- Flexor brevis minimi digitii.
- Flexor ossis metacarpi minimi digitii (Opponens minimi digitii).

IV. Of the Hand.

11. Radial Region.

- Abductor pollicis.
- Flexor ossis metacarpi pollicis (Opponens pollicis).

13. Middle Palmar Region.

- Lumbricales.
- Interossei palmares.
- Interossei dorsales.

**Dissection of Pectoral Region and Axilla** (Fig. 311).—The arm being drawn away from the side nearly at right angles with the trunk and rotated outward, make a vertical incision through the integument in the median line of the chest, from the upper to the lower part of the sternum; a second incision along the lower border of the Pectoral muscle, from the ensiform cartilage to the inner side of the axilla; a third, from the sternum along the clavicle, as far as its centre; and a fourth, from the middle of the clavicle obliquely downward, along the interspace between the Pectoral and Deltoid muscles, as low as the fold of the armpit. The flap of integument is then to be dissected off in the direction indicated in the figure, but not entirely removed, as it should be replaced on completing the dissection. If a transverse incision is now made from the lower end of the sternum to the side of the chest, as far as the posterior fold of the armpit, and the integument reflected outward, the axillary space will be more completely exposed.

I. THE MUSCLES AND FASCIAE OF THE THORACIC REGION.

1. The Anterior Thoracic Region.

- Pectoralis major.
- Subclavius.
- Pectoralis minor.
- Latissimus dorsi.
- Anconeus.
- Supinator brevis.
- Extensor carpi ulnaris.

**Superficial Fascia.**—The superficial fascia of the thoracic region is a loose cellulo-fibrous layer enclosing masses of fat in its spaces. It is continuous with the superficial fascia of the neck and upper extremity above, and of the abdomen below. Opposite the mamma it divides into two layers, one of which passes in front, the other behind, that gland; and from both of these layers numerous septa pass into its substance, supporting its various lobes: from the anterior layer fibrous processes pass forward to the integument and nipple. These processes were called by Sir A. Cooper the suspensory ligaments (ligamenta suspensoria), from the support they afford to the gland in this situation.

**Deep Fascia.**—The deep thoracic fascia is a thin aponeurotic lamina, covering the surface of the great Pectoral muscle, and sending numerous prolongations between its fasciculi: it is attached, in the middle line, to the front of the sternum, and above to the clavicle; externally and below it becomes continuous with the fascia over the shoulder, axilla, and thorax. It is very thin over the upper part of the muscle, thicker in the interval between the Pectoralis major and Latissimus dorsi, where it closes in the axillary space, and is known as the axillary fascia (fascia axillaris). It passes behind into the fascia of the Latissimus dorsi and Teres major, in front into the fascia of the deltoid and outward into the brachial fascia. The fascia of the Latissimus dorsi divides at the outer margin of the muscle into two layers, one of which passes in front and the other behind it; these proceed as far as the spinous processes of the thoracic vertebrae, to which they are
THE MUSCLES AND FASCIA

attached. As the axillary fascia leaves the lower edge of the Pectoralis major to pass across the floor of the axilla it sends a layer upward under cover of the muscle, deep pectoral fascia; this lamina splits to envelop the Pectoralis minor, at the upper edge of which it becomes continuous with the costo-coracoid membrane, or the clavi-pectoral fascia. The hollow of the armpit, seen when the arm is abducted, is mainly produced by the traction of this fascia on the axillary floor, the axillary fascia (fascia axillaris), and hence it is sometimes named the suspensory ligament of the axilla. The axillary fascia (Fig. 312) is not a distinct and complete rigid floor of the axillary space. Like all other fasciae, it follows muscular planes, and splits to encompass vessels, nerves, and muscles. In it are numerous perforations. In this fascia is a curved arch which often contains muscular fibres and which passes from the tendon of the great Pectoral,

Fig. 311.—Dissection of the upper extremity.

the Coraco-brachialis or the fascia over the biceps to the tendon of the Latissimus dorsi. This is called the axillary arch (arcus axillaris). Langer showed many years ago that there is an opening in the centre of the dense axillary fascia, the foramen of Langer. Through this opening axillary glands not unusually protrude. The axillary arch is the inner margin of the foramen of Langer. At the lower part of the thoracic region the deep thoracic fascia is well developed, and is continuous with the fibrous sheath of the Recti muscles.

The Pectoralis Major (Fig. 313) is a broad, thick, triangular muscle, situated at the upper and forepart of the chest, in front of the axilla. It arises from the anterior surface of the sternal half of the clavicle; from half the breadth of the anterior surface of the sternum, as low down as the attachment of the cartilage of the sixth or seventh rib; this portion of its origin consists of aponeurotic fibres, which intersect with those of the opposite muscle; it also arises from the carti-
lages of all true ribs, with the exception, frequently, of the first or of the seventh, or both; and from the aponeurosis of the External oblique muscle of the abdomen. The fibres from this extensive origin converge toward its insertion, giving to the muscle a radiated appearance. Those fibres which arise from the clavicle pass obliquely outward and downward and are usually separated from the rest by a cellular interval: those from the lower part of the sternum, and the cartilages of the lower true ribs, pass upward and outward, whilst the middle fibres pass horizontally. They all terminate in a flat tendon, about two inches broad, which is inserted into the outer bicipital ridge of the humerus. This tendon consists of two laminae, placed one in front of the other, and usually blended together below. The anterior, the thicker, receives the clavicular and upper half of the sternal portion of the muscle; and its fibres are inserted in the same order as that in which they arise; that is to say, the outermost fibres of origin from the clavicle are

![Diagram of the right axilla](image)

**Fig. 312.**—The fascia of the right axilla, viewed from below. (Spalteholz.)

inserted at the uppermost part of the tendon; the upper fibres of origin from the sternum pass down to the lowermost part of this anterior lamina of the tendon and extend as low as the tendon of the Deltoid and join with it. The posterior lamina of the tendon receives the attachment of the lower half of the sternal portion and the deeper part of the muscle from the costal cartilages. These deep fibres, and particularly those from the lower costal cartilages, ascend, the higher, turning backward successively behind the superficial and upper ones, so that the tendon appears to be twisted. The posterior lamina reaches higher on the humerus than does the anterior one, and from it an expansion is given off which covers the bicipital groove and blends with the capsule of the shoulder-joint. From the deepest fibres of this lamina at its insertion an expansion is given off which lines the bicipital groove of the humerus, while from the lower border of the tendon a third expansion passes downward to the fascia of the arm. Between the poste-
rior surface of the tendon of the great pectoral and the anterior surface of the long head of the biceps there is usually a bursa (*bursa m. pectoralis majoris*).

**Relations.**—By its *anterior surface*, with the integument, the superficial fascia, the Platysma, some of the branches of the descending cervical nerves, the mammary gland, and the deep fascia; by its *posterior surface*: its thoracic portion, with the sternum, the ribs and costal cartilages, the costo-coracoid membrane, the Subclavius, Pectoralis minor, Serratus magnus, and the Intercostals; its *axillary por-

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**FIG. 313.**—Muscles of the chest and front of the arm. Superficial view.

*tion* forms the anterior wall of the axillary space, and covers the axillary vessels and nerves, the Biceps and Coraco-brachialis muscles. Its *upper border* lies parallel with the Deltoid, from which it is separated by a slight interspace in which lie the cephalic vein and humeral branch of the acromial thoracic artery. Its *lower border* forms the anterior margin of the axilla, being at first separated from the Latissimus dorsi by a considerable interval; but both muscles gradually converge toward the outer part of the space.
Dissection.—Detach the Pectoralis major by dividing the muscle along its attachment to the clavicle, and by making a vertical incision through its substance a little external to its line of attachment to the sternum and costal cartilages. The muscle should then be reflected outward, and its tendon carefully examined. The Pectoralis minor is now exposed, and immediately above it, in the interval between its upper border and the clavicle, a strong fascia, the costo-coracoid membrane.

The **Costo-coracoid Membrane** or the **Clavipectoral Fascia** is a strong fascia, situated under cover of the clavicular portion of the Pectoralis major muscle. It occupies the interval between the Pectoralis minor and Subclavius muscle, and protects the axillary vessels and nerves. Traced upward, it splits to enclose the Subclavius muscle, and its two layers are attached to the clavicle, one in front of and the other behind the muscle; the latter layer fuses with the deep cervical fascia and with the sheath of the axillary vessels. Internally, it blends with the fascia covering the first two intercostal spaces, and is attached also to the first rib internal to the origin of the Subclavius muscle. Externally it is very thick and dense, and is attached to the coracoid process. The portion extending from its attachment to the first rib to the coracoid process is often whiter and denser than the rest; this is sometimes called the **costo-coracoid ligament**. Below, it is thin, and at the upper border of the Pectoralis minor it splits into two layers to invest the muscle; from the lower border of the Pectoralis minor it is continued downward to join the axillary fascia, and outward to join the fascia over the short head of the Biceps. The costo-coracoid membrane is pierced by the cephalic vein, the acromial thoracic artery and vein, superior thoracic artery, and anterior thoracic nerves.
The Pectoralis Minor (Fig. 314) is a thin, flat, triangular muscle, situated at the upper part of the thorax, beneath the Pectoralis major. It arises by three tendinous digitations from the upper margin and outer surface of the third, fourth, and fifth ribs, near their cartilages, and from the aponeurosis covering the intercostal muscles; the fibres pass upward and outward, and converge to form a flat tendon, which is inserted into the inner border and upper surface of the coracoid process of the scapula.

Relations.—By its anterior surface, with the Pectoralis major and the thoracic branches of the acromial thoracic artery. By its posterior surface, with the ribs, intercostal muscles, Serratus magnus, the axillary space, and the axillary vessels and brachial plexus of nerves. Its upper border is separated from the clavicle by a triangular interval, broad internally, narrow externally, which is occupied by the costo-coracoid membrane. This space contains the first part of the axillary vessels and the axillary nerves. Running parallel to the lower border of the muscle is the long thoracic artery.

The costo-coracoid membrane should now be removed, when the Subclavius muscle will be seen.

The Subclavius is a small triangular muscle, placed in the interval between the clavicle and the first rib. It arises by a short, thick tendon from the first rib and its cartilage at their junction, in front of the rhomboid ligament; the fleshy fibres proceed obliquely upward and outward, to be inserted into a deep groove on the under surface of the clavicle. An extension from the aponeurosis of this muscle lies upon the subclavian vein.

Relations.—By its upper surface, with the clavicle. By its deep surface it is separated from the first rib by the subclavian vessels and brachial plexus of nerves. Its anterior surface is separated from the Pectoralis major by the costo-coracoid membrane, which, with the clavicle, forms an osseo-fibrous sheath in which the muscle is enclosed.

If the costal attachment of the Pectoralis minor is divided across, and the muscle reflected outward, the axillary vessels and nerves are brought fully into view, and should be examined.

Nerves.—The Pectoral muscles are supplied by the anterior thoracic nerves; the Pectoralis major through these nerves receives filaments from all the spinal nerves entering into the formation of the brachial plexus; the Pectoralis minor receives its fibres from the eighth cervical and first thoracic nerves. The Subclavius is supplied by a filament from the fifth cervical nerve.

Actions.—If the arm has been raised by the Deltoid, the Pectoralis major will, conjointly with the Latissimus dorsi and Teres major, depress it to the side of the chest. If acting alone, it adducts and draws forward the arm, bringing it across the front of the chest, and at the same time rotates it inward. The Pectoralis minor depresses the point of the shoulder, drawing the scapula downward and inward to the thorax, and throwing the inferior angle backward. The Subclavius depresses the shoulder, drawing the clavicle downward and forward. When the arms are fixed, all three muscles act upon the ribs, drawing them upward and expanding the chest, and thus becoming very important agents in forced inspiration. Asthmatic patients always assume an attitude which fixes the shoulders, so that all these muscles may be brought into action to assist in dilating the cavity of the chest.
2. The Lateral Thoracic Region.

Serratus magnus.

The Serratus Magnus (m. serratus anterior) (Fig. 314) is a thin, irregularly quadrilateral muscle, situated between the ribs and the scapula at the upper and lateral part of the chest. It arises by nine digitations or slips from the outer surface and upper border of the eight upper ribs (the second rib giving origin to two slips), and from the aponeurosis covering the corresponding intercostal muscles. From this extensive attachment the fibres pass backward, closely applied to the chest-wall, and reach the vertebral border of the scapula, and are inserted into its ventral aspect in the following manner. The upper two digitations—i.e., the one from the first rib and the higher of the two from the second rib—converge to be inserted into a triangular area on the ventral aspect of the superior angle. The next two digitations spread out to form a thin triangular sheet, the base of which is directed backward and is inserted into nearly the whole length of the ventral aspect of the vertebral border. The lower five digitations converge, as they pass backward from the ribs, to form a fan-shaped structure, the apex of which is inserted, partly by muscular and partly by tendinous fibres, into a triangular impression on the ventral aspect of the inferior angle. The lower four slips interdigitate at their origin with the upper five slips of the External oblique muscle of the abdomen.

Relations.—This muscle is partly covered, in front, by the Pectoral muscles; behind, by the Subscapularis. The axillary vessels and nerves lie upon its upper part, while its deep surface rests upon the ribs and intercostal muscles.

Nerve.—The Serratus magnus is supplied by the posterior thoracic nerve, which is derived from the fifth, sixth, and generally the seventh cervical nerves.

Actions.—The Serratus magnus, as a whole, carries the scapula forward, and at the same time raises the vertebral border of the bone. It is therefore concerned in the action of pushing. Its lower and stronger fibres move forward the lower angle and assist the Trapezius in rotating the bone round an axis through its centre, and thus assists this muscle in raising the acromion and supporting weights upon the shoulder. It is also an assistant to the Deltoid in raising the arm, inasmuch as during the action of this latter muscle it fixes the scapula and so steadies the glenoid cavity on which the head of the humerus rotates. After the Deltoid has raised the arm to a right angle with the trunk, the Serratus magnus and the Trapezius, by rotating the scapula, raise the arm into an almost vertical position. It is possible that when the shoulders are fixed the lower fibres of the Serratus magnus may assist in raising and evertting the ribs; but it is not the important inspiratory muscle which it was formerly believed to be.

Surgical Anatomy.—When the muscle is paralyzed, the vertebral border, and especially the lower angle of the scapula, leaves the ribs and stands out prominently on the surface, giving a peculiar "winged" appearance to the back. The patient is unable to raise the arm, and an attempt to do so is followed by a further projection of the lower angle of the scapula from the back of the thorax.

Dissection.—After completing the dissection of the axilla, if the muscles of the back have been dissected, the upper extremity should be separated from the trunk. Saw through the clavicle at its centre, and then cut through the muscles which connect the scapula and arm with the trunk—viz., the Pectoralis minor in front, Serratus magnus at the side, and the Levator anguli scapulae, the Rhomboïds, Trapezius, and Latissimus dorsi behind. These muscles should be cleaned and traced to their respective insertions. Then make an incision through the integument, commencing at the outer third of the clavicle, and extending along the margin of that bone, the acromion process, and spine of the scapula; the integument should be dissected from above downward and outward, when the fascia covering the Deltoid is exposed (Fig. 311, No. 3).
II. MUSCLES AND FASCIAE OF THE SHOULDER AND ARM.

Superficial Fascia.—The superficial fascia of the upper extremity is a thin cellulo-fibrous layer, containing the superficial veins and lymphatics, and the cutaneous nerves. It is most distinct in front of the elbow, and contains very large superficial veins and nerves; in the hand it is hardly demonstrable, the integument being closely adherent to the deep fascia by dense fibrous bands. Small subcutaneous bursae are found in this fascia over the acromion, the olecranon, and the knuckles.

Deep Fascia.—The deep fascia of the upper extremity comprises the aponeurosis of the shoulder, arm, and forearm, the anterior and posterior annular ligaments of the carpus, and the palmar fascia. These will be considered in the description of the muscles of the several regions.

3. The Acromial Region.

Deltoid.

Deep Fascia.—The deep fascia covering the Deltoid, and known as the deltoid aponeurosis, is a fibrous layer which covers the outer surface of the muscle, thick and strong behind, where it is continuous with the infraspinatus fascia, thinner over the rest of its extent. It sends down numerous prolongations between the fasciculi of the muscle. In front, it is continuous with the fascia covering the great Pectoral muscle; behind, with that covering the Infraspinatus; above, it is attached to the clavicle, the acromion, and spine of the scapula; below, it is continuous with the deep fascia of the arm.

The Deltoid (m. deltoideus) (Fig. 313) is a large, thick, triangular muscle, which gives the rounded outline to the shoulder, and has received its name from its resemblance to the Greek letter Δ reversed. It surrounds the shoulder-joint in the greater part of its extent, covering it on its outer side, and in front and behind. It arises from the outer third of the anterior border and upper surface of the clavicle; from the outer margin and upper surface of the acromion process, and from the lower lip of the posterior border of the spine of the scapula, as far back as the triangular surface at its inner end. From this extensive origin the fibres converge toward their insertion, the middle passing vertically, the anterior obliquely backward, the posterior obliquely forward; they unite to form a thick tendon, which is inserted into a rough triangular prominence on the middle of the outer side of the shaft of the humerus. At its insertion the muscle gives off an expansion to the deep fascia of the arm. This muscle is remarkably coarse in texture, and the arrangement of its muscular fibres is somewhat peculiar; the central portion of the muscle—that is to say, the part arising from the acromion process—consists of oblique fibres, which arise in a bipenniform manner from the sides of tendinous intersections, generally four in number, which are attached above to the acromion process and pass downward parallel to one another in the substance of the muscle. The oblique muscular fibres thus formed are inserted into similar tendinous intersections, generally three in number, which pass upward from the insertion of the muscle into the humerus and alternate with the descending septa. The portions of the muscle which arise from the clavicle and spine of the scapula are not arranged in this manner, but pass from their origin above, to be inserted into the margins of the inferior tendon.

Relations.—By its superficial surface, with the integument, the superficial and deep fasciae, Platysma, and supra-acromial nerves. Its deep surface is separated
from the head of the humerus by a large sacculated synovial bursa, the subdeltoid bursa (bursa subdeltoidae). It often communicates with the subacromial bursa (bursa subacromialis), which is between the acromial process and the coraco-acromial ligament above and the capsule of the shoulder-joint and the Supraspinatus muscle below. The deep surface of the deltoid covers the coraco-ideal process, coraco-acromial ligament, Pectoralis minor, Coraco-brachialis, both heads of the Biceps, the tendon of the Pectoralis major, the insertions of the Supraspinatus, Infraspinatus, and Teres minor, the scapular and external heads of the Triceps, the circumflex vessels and nerve, and the humerus. Its anterior border is separated at its upper part from the Pectoralis major by a cellular interspace, which lodges the cephalic vein and humeral branch of the acromial thoracic artery: lower down the two muscles are in close contact. Its posterior border rests on the Infraspinatus and Triceps muscles.

**Nerves.**—The Deltoid is supplied by the fifth and sixth cervical through the circumflex nerve.

**Actions.**—The Deltoid raises the arm directly from the side, so as to bring it at right angles with the trunk, but this act cannot be performed without the aid of the Serratus magnus, which muscle steadies the lower angle of the scapula. Its anterior fibres, assisted by the Pectoralis major, draw the arm forward; and its posterior fibres, aided by the Teres major and Latissimus dorsi, draw it backward.

**Surgical Anatomy.**—The Deltoid is very liable to atrophy, and when in this condition simulates dislocation of the shoulder-joint, as there is flattening of the shoulder and apparent prominence of the acromion process; upon examination, however, it will be found that the relative position of the great tuberosity of the humerus to the acromion and coracoideal process is unchanged. Atrophy of the Deltoid may be due to disuse or loss of trophic influence, either from injury to the circumflex nerve or cord lesions, as in infantile paralysis.

### 4. The Anterior Scapular Region.

**Subscapularis.**

**Dissection.**—Divide the Deltoid across, near its upper part, by an incision carried along the margin of the clavicle, the acromion process and spine of the scapula, and reflect it downward, when the structures under cover of it will be seen.

**The Subscapular Fascia** (fascia subscapularis).—The subscapular fascia is a thin membrane attached to the entire circumference of the subscapular fossa, and affording attachment by its inner surface to some of the fibres of the Subscapularis muscle: when this is removed, the Subscapularis muscle is exposed.

**The Subscapularis** (Fig. 314) is a large triangular muscle which fills up the subscapular fossa, arising from its internal two-thirds, with the exception of a narrow margin along the posterior border, and the surfaces at the superior and inferior angles which afford attachment to the Serratus magnus: it also arises from the lower two-thirds of the groove on the axillary border of the bone. Some fibres arise from tendinous lamæ, which intersect the muscle, and are attached to ridges on the bone; and others from an aponeurosis, which separates the muscles from the Teres major and the long head of the Triceps. The fibres pass outward, and, gradually converging, terminate in a tendon, which is inserted into the lesser tuberosity of the humerus. Those fibres which arise from the axillary border of the scapula are inserted into the neck of the humerus to the extent of an inch below the tuberosity. The tendon of the muscle is in close contact with the anterior part of the capsular ligament of the shoulder-joint, and glides over a large bursa, the bursa of the subscapularis muscle (bursa m. subscapularis), which separates it from the base of the coracoideal process. This bursa communicates with the cavity of the joint by an aperture in the capsular ligament.
Relations.—Its anterior surface forms a considerable part of the posterior wall of the axilla, and is in relation with the Serratus magnus, Coraco-brachialis, and Biceps, the axillary vessels and brachial plexus of nerves, and the subscapular vessels and nerves. By its posterior surface, with the scapula and the capsular ligament of the shoulder-joint. Its lower border is contiguous with the Teres major and Latissimus dorsi.

Nerves.—It is supplied by the fifth and sixth cervical nerves through the upper and lower subscapular nerves.

Actions.—The Subscapularis rotates the head of the humerus inward; when the arm is raised, it draws the humerus forward and downward. It is a powerful defence to the front of the shoulder-joint, preventing displacement of the head of the bone.

5. The Posterior Scapular Region (Fig. 315).

Supraspinatus. Teres minor.
Infraspinatus. Teres major.

Dissection.—To expose these muscles, and to examine their mode of insertion into the humerus, detach the deltoid and Trapezius from their attachment to the spine of the scapula and acromion process. Remove the clavicle by dividing the ligaments connecting it with the coraco-process, and separate it at its articulation with the scapula: divide the acromion process near its root with a saw. The fragments being removed, the tendons of the posterior Scapular muscles will be fully exposed, and can be examined. A block should be placed beneath the shoulder-joint, so as to make the muscles tense.

The Supraspinatus Fascia (fascia supraspinata).—The supraspinatus fascia is a thick and dense membranous layer, which completes the osseofibrous case in which the Supraspinatus muscle is contained, affording attachment, by its inner surface, to some of the fibres of the muscle. It is thick internally, but thinner externally under the coraco-acromial ligament. When this fascia is removed, the Supraspinatus muscle is exposed.

The Supraspinatus Muscle occupies the whole of the supraspinatus fossa, arising from its internal two-thirds and from the strong fascia which covers its surface. The muscular fibres converge to a tendon which passes across the upper part of the capsular ligament of the shoulder-joint, to which it is intimately adherent, and is inserted into the highest of the three facets on the great tuberosity of the humerus.

Relations.—By its upper surface, with the Trapezius, the clavicle, the acromion, the coraco-acromial ligament, and the Deltoid; by its under surface, with the scapula, the suprascapular vessels and nerve, and upper part of the shoulder-joint.

The Infraspinatus Fascia (fascia infraspinata).—The infraspinatus fascia is a dense fibrous membrane, covering in the Infraspinatus muscle and attached to the circumference of the infraspinatus fossa; it affords attachment, by its inner surface, to some fibres of that muscle. At the point where the Infraspinatus commences to be covered by the Deltoid, this fascia divides into two layers: one layer passes over the Deltoid muscle, helping to form the Deltoid fascia already described; the other passes beneath the Deltoid to the capsule of the shoulder-joint.

The Infraspinatus is a thick, triangular muscle, which occupies the chief part of the infraspinatus fossa, arising by fleshy fibres from its internal two-thirds, and by tendinous fibres from the ridges on its surfaces: it also arises from a strong fascia which covers it externally, and separates it from the Teres major and minor. The fibres converge to a tendon which glides over the external border of the spine of the scapula, and, passing across the posterior part of the capsular ligament of the shoulder-joint, is inserted into the middle facet on the great tuberosity of the humerus. The tendon of this muscle has interposed between it and the joint
capsule a synovial bursa, the bursa of the Infraspinatus muscle (bursa m. infraspinati), which communicates with the synovial cavity of the shoulder-joint.

Relations.—By its posterior surface, with the Deltoid, the Trapezius, Latissimus dorsi, and the integument; by its anterior surface, with the scapula, from which it is separated by the suprascapular and dorsalis scapulae vessels, and with the

capsular ligament of the shoulder-joint. Its lower border is in contact with the Teres minor, occasionally united with it, and with the Teres major.

The Teres Minor is a narrow, elongated muscle, which arises from the dorsal surface of the axillary border of the scapula for the upper two-thirds of its extent, and from two aponeurotic laminae, one of which separates this muscle from the Infraspinatus, the other from the Teres major; its fibres pass obliquely upward and outward, and terminate in a tendon which is inserted into the lowest of the three facets on the great tuberosity of the humerus, and, by fleshy fibres, into the humerus immediately below it. The tendon of this muscle passes across the posterior part of the capsular ligament of the shoulder-joint.

Relations.—By its posterior surface, with the Deltoid and the integument; by its anterior surface, with the scapula and dorsal branch of the subscapular artery, the long head of the Triceps, and the shoulder-joint; by its upper border, with the Infraspinatus; by its lower border, with the Teres major, from which it is separated anteriorly by the long head of the Triceps.

The Teres Major is a thick but somewhat flattened muscle, which arises from the oval surface on the dorsal aspect of the inferior angle of the scapula, and from the fibrous septa interposed between it and the Teres minor and Infraspinatus; the

Fig. 315.—Muscles on the dorsum of the Scapula and the Triceps.
fibres are directed upward and outward, and terminate in a flat tendon, about two inches in length, which is inserted into the inner bicipital ridge of the humerus. The tendon of this muscle, at its insertion into the humerus, lies behind that of the Latissimus dorsi, from which it is separated by a synovial bursa, the bursa of the Latissimus dorsi muscle (bursa m. latissimi dorsi), the two tendons being, however, united along their lower borders for a short distance. Between the tendon of the Teres major and the bone is the bursa m. teretis majoris.

Relations.—By its posterior surface, with the Latissimus dorsi below, and the long head of the Triceps above. By its anterior surface, with the Subscapularis, Latissimus dorsi, Coraco-brachialis, short head of the Biceps, the axillary vessels, and brachial plexus of nerves. Its upper border is at first in relation with the Teres minor, from which it is afterward separated by the long head of the Triceps. Its lower border forms, in conjunction with the Latissimus dorsi, part of the posterior boundary of the axilla. The Latissimus dorsi at first covers the origin of the Teres major, then wraps itself obliquely round its lower border, so that its tendon ultimately comes to lie in front of that of the Teres major.

Nerves.—The Supra- and Infraspinatus muscles are supplied by the fifth and sixth cervical nerves through the suprascapular nerve; the Teres minor, by the fifth cervical, through the circumflex; and the Teres major, by the fifth and sixth cervical, through the lower subscapular.

Actions.—The Supraspinatus assists the Deltoid in raising the arm from the side, and fixes the head of the humerus in the glenoid cavity. The Infraspinatus and Teres minor rotate the head of the humerus outward; when the arm is raised, they assist in retaining it in that position and carrying it backward. One of the most important uses of these three muscles is the great protection they afford to the shoulder-joint, the Supraspinatus supporting it above, and preventing displacement of the head of the humerus upward, while the Infraspinatus and Teres minor protect it behind, and prevent dislocation backward. The Teres major assists the Latissimus dorsi in drawing the humerus downward and backward, when previously raised, and rotating it inward; when the arm is fixed, it may assist the Pectoral and Latissimus dorsi muscles in drawing the trunk forward.

THE MUSCLES AND FASCIAE OF THE ARM.

6. The Anterior Humeral Region (Fig. 314).


Dissection.—The arm being placed on the table, with the front surface uppermost, make a vertical incision through the integument along the middle line, from the clavicle to about two inches below the elbow-joint, where it should be joined by a transverse incision, extending from the inner to the outer side of the forearm; the two flaps being reflected on either side, the fascia should be examined (Fig. 311).

Deep Fascia (fascia brachii).—The deep fascia of the arm is continuous with that covering the Deltoid and the great Pectoral muscles, by means of which it is attached, above, to the clavicle, acromion, and spine of the scapula, and is also continuous with the axillary fascia. It forms a thin, loose, membranous sheath investing the muscles of the arm, sending down septa between them, and composed of fibres disposed in a circular or spiral direction, and connected together by vertical and oblique fibres. It differs in thickness at different parts, being thin over the Biceps, but thicker where it covers the Triceps, and over the condyles of the humerus; it is strengthened by fibrous aponeuroses, derived from the Pectoralis major and Latissimus dorsi on the inner side, and from the Deltoid externally. On either side it gives off a strong intermuscular septum,
which is attached to the supracondylar ridge and condyle of the humerus. These septa serve to separate the muscles of the anterior from those of the posterior brachial region. The *external intermuscular septum* (*septum intermusculare laterale*) extends from the lower part of the anterior bicipital ridge, along the external supracondylar ridge, to the outer condyle; it is blended with the tendon of the Deltoid, gives attachment to the Triceps behind, to the Brachialis anticus, Supinator longus, and Extensor carpi radialis longior, in front, and is perforated by the musculo-spiral nerve and superior profunda artery. The *internal intermuscular septum* (*septum intermusculare mediale*), thicker than the preceding, extends from the lower part of the posterior lip of the bicipital groove below the Teres major, along the internal supracondylar ridge to the inner condyle; it is blended with the tendon of the Coraco-brachialis, and affords attachment to the Triceps behind, and the Brachialis anticus in front. It is perforated by the ulnar nerve and the inferior profunda and anastomotic arteries. At the elbow the deep fascia is attached to all the prominent points round the joint—viz., the condyles of the humerus and the olecranon process of the ulna—and is continuous with the deep fascia of the forearm. Just below the middle of the arm, on its inner side, in front of the intermuscular septum, is an oval opening in the deep fascia which transmits the basilic vein and some lymphatic vessels. On the removal of this fascia the muscles, vessels, and nerves of the anterior humeral region are exposed.

The *Coraco-brachialis*, the smallest of the three muscles in this region, is situated at the upper and inner part of the arm. It *arises* by fleshy fibres from the apex of the coracoid process, in common with the short head of the Biceps, and from the intermuscular septum between the two muscles; the fibres pass downward, backward, and a little outward, to be inserted by means of a flat tendon into an impression at the middle of the inner surface and internal border of the shaft of the humerus between the origins of the Triceps and Brachialis anticus. It is perforated by the musculo-cutaneous nerve. The inner border of the muscle forms a guide to the position of the brachial artery in tying the vessel in the upper part of its course. Between the tendon of the subscapularis, the coracoid process and the tendon of the Coraco-brachialis, is the *bursa of the Coraco-brachialis muscle* (*bursa m. coracobraehialis*).

**Relations.**—By its *anterior surface*, with the Pectoralis major above, and at its insertion with the brachial vessels and median nerve which cross it; by its *posterior surface*, with the tendons of the Subscapularis, Latissimus dorsi, and Teres major, the inner head of the Triceps, the humerus, and the anterior circumflex vessels; by its *inner border*, with the brachial artery, and the median and musculo-cutaneous nerves; by its *outer border*, with the short head of the Biceps and Brachialis anticus.

The *Biceps* or the *Biceps Flexor Cubiti* (*m. biceps brachii*) is a long fusiform muscle, occupying the whole of the anterior surface of the arm, and divided above into two portions or heads, from which circumstance it has received its name. The *short head* (*caput breve*) *arises* by a thick flattened tendon from the apex of the coracoid process, in common with the Coraco-brachialis. The *long head* (*caput longum*) *arises* from the upper margin of the glenoid cavity, and is continuous with the glenoid ligament. This tendon arches over the head of the humerus, being enclosed in a special sheath of the synovial membrane of the shoulder-joint; it then passes through an opening in the capsular ligament at its attachment to the humerus, and descends in the bicipital groove, in which it is retained by a fibrous prolongation from the tendon of the Pectoralis major. Each tendon is succeeded by an elongated muscular belly, and the two bellies, although closely applied to each other, can readily be separated until within about three inches of the elbow-joint. Here they end in a flattened tendon, which is inserted into the back part of the tuberosity of the radius, a synovial bursa (*bursa bicipitoradialis*), being interposed
between the tendon and the front of the tuberosity, and another bursa (bursa cubitalis interossea) is often interposed between the ulna and the tendon. As the tendon of the muscle approaches the radius it becomes twisted upon itself, so that its anterior surface becomes external and is applied to the tuberosity of the radius at its insertion: opposite the bend of the elbow the tendon gives off, from its inner side, a broad aponeurosis, the bicipital or semilunar fascia (lacertus fibrosus), which passes obliquely downward and inward across the brachial artery, and is continuous with the deep fascia of the forearm (Fig. 313). The inner border of this muscle forms a guide to the position of the vessel in tying the brachial artery in the middle of the arm.1

Relations.—Its anterior surface is overlapped above by the Pectoralis major and Deltoid; in the rest of its extent it is covered by the superficial and deep fasciae and the integument. Its posterior surface rests above on the shoulder-joint and upper part of the humerus; below it rests on the Brachialis anticus, with the musculo-cutaneous nerve intervening between the two, and on the Supinator brevis. Its inner border is in relation with the Coraco-brachialis, and overlaps the brachial vessels and median nerve; its outer border, with the Deltoid and Supinator longus.

The Brachialis Anticus (m. brachialis) is a broad muscle, which covers the elbow-joint and the lower half of the front of the humerus. It is somewhat compressed from before backward, and is broader in the middle than at either extremity. It arises from the lower half of the outer and inner surfaces of the shaft of the humerus, and commences above at the insertion of the Deltoid, which it embraces by two angular processes. Its origin extends below, to within an inch of the margin of the articular surface, and is limited on each side by the external and internal borders of the shaft of the humerus. It also arises from the intermuscular septa on each side, but more extensively from the inner than the outer, from which it is separated below by the Supinator longus and Extensor carpi radialis longior. Its fibres converge to a thick tendon, which is inserted into a rough depression on the anterior surface of the coronoid process of the ulna, being received into an interval between two fleshy slips of the Flexor profundus digitorum.

Relations.—By its anterior surface, with the Biceps, the brachial vessels, musculo-cutaneous, and median nerves; by its posterior surface, with the humerus and front of the elbow-joint; by its inner border, with the Triceps, ulnar nerve, and Pronator radii teres, from which it is separated by the intermuscular septum; by its outer border, with the musculo-spiral nerve, radial recurrent artery, the Supinator longus, and Extensor carpi radialis longior.

Nerves.—The muscles of this group are supplied by the musculo-cutaneous nerve. The Brachialis anticus usually receives an additional filament from the musculo-spiral. The Coraco-brachialis receives its supply primarily from the seventh cervical, the Biceps and Brachialis anticus from the fifth and sixth cervical nerves.

Actions.—The Coraco-brachialis draws the humerus forward and inward, and at the same time assists in elevating it toward the scapula. The Biceps is a flexor of the forearm; it is also a powerful supinator, and serves to render tense the deep fascia of the forearm by means of the broad aponeurosis given off from its tendon. The Brachialis anticus is a flexor of the forearm, and forms an important defence to the elbow-joint. When the forearm is fixed, the Biceps and Brachialis anticus flex the arm upon the forearm, as is seen in efforts at climbing.

1 A third head to the Biceps is occasionally found (Thelle says as often as once in eight or nine subjects), arising at the upper and inner part of the Brachialis anticus, with the fibres of which it is continuous, and inserted into the bicipital fascia and inner side of the tendon of the Biceps. In most cases this additional slip passes behind the brachial artery in its course down the arm. Occasionally the third head consists of two slips which pass down, one in front, the other behind the artery, concealing the vessel in the lower half of the arm.
7. The Posterior Humeral Region.

Triceps. Subanconeus.

The Triceps or the Triceps Extensor Cubiti (m. triceps brachii) (Fig. 315) is situated on the back of the arm, extending the entire length of the posterior surface of the humerus. It is of large size, and divided above into three parts; hence its name. These three portions have been named (1) the *middle*, *scapular*, or *long head*; (2) the *external* or *long humeral head*; and (3) the *internal* or *short humeral head*.

The Middle, Long, or Scapular Head (caput longum) arises, by a flattened tendon, from a rough triangular depression on the scapula, immediately below the glenoid cavity, being blended at its upper part with the capsular ligament; the muscular fibres pass downward between the two other portions of the muscle, and join with them in the common tendon of insertion.

The External Head (caput laterale) arises from the posterior surface of the shaft of the humerus, between the insertion of the Teres minor and the upper part of the musculo-spiral groove; from the external border of the humerus and the external intermuscular septum: the fibres from this origin converge toward the common tendon of insertion.

The Internal Head (caput mediale) arises from the posterior surface of the shaft of the humerus, below the groove for the musculo-spiral nerve; commencing above, narrow and pointed, below the insertion of the Teres major, and extending to within an inch of the trochlear surface: it also arises from the internal border of the humerus, and from the back of the whole length of the internal and lower part of the external intermuscular septum. The fibres of this portion of the muscle are directed, some downward to the olecranon, whilst others converge to the common tendon of insertion.

The Common Tendon of the Triceps commences about the middle of the back part of the muscle: it consists of two aponeurotic laminae, one of which is subcutaneous and covers the posterior surface of the muscle for the lower half of its extent; the other is more deeply seated in the substance of the muscle: after receiving the attachment of the muscular fibres, they join together above the elbow, and are inserted, for the most part, into the back part of the upper surface of the olecranon process; a band of fibres is, however, continued downward, on the outer side, over the Anconeus, to blend with the deep fascia of the forearm. A small bursa (bursa subtendinea olecrani) occasionally multilocular, is situated on the front part of this surface, beneath the tendon. The subcutaneous olecranont bursa (bursa subcutanea olecrani) is situated between the olecranon process and the skin. Within the tendon of the triceps is often found the bursa intratendinea olecrani.

The long head of the Triceps descends between the Teres minor and Teres major, dividing the triangular space between these two muscles and the humerus into two smaller spaces, one triangular, the other quadrangular (Fig. 315). The triangular space contains the dorsalis scapulae vessels; it is bounded by the Teres minor above, the Teres major below, and the scapular head of the Triceps externally: the quadrangular space transmits the posterior circumflex vessels and the circumflex nerve; it is bounded by the Teres minor above, the Teres major below, the scapular head of the Triceps internally, and the humerus externally.

Relations.—By its posterior surface, with the Deltoid above: in the rest of its extent it is subcutaneous; by its anterior surface, with the humerus, musculo-spiral nerve, superior profunda vessels, and back part of the elbow-joint. Its middle or long head is in relation, behind, with the Deltoid and Teres minor; in front, with the Subscapularis, Latissimus dorsi, and Teres major.
The Subanconeus (m. anconaeus) is a name given to a few fibres from the under surface of the lower part of the Triceps muscle, which are inserted into the posterior ligament of the elbow-joint. By some authors it is regarded as the analogue of the Subcureus in the lower limb, but it is not a separate muscle.

Nerves.—The Triceps is supplied by the seventh and eighth cervical nerves through the musculo-spiral nerve.

Actions.—The Triceps is the great extensor muscle of the forearm, serving, when the forearm is flexed, to extend the elbow-joint. It is the direct antagonist of the Biceps and Brachialis anticus. When the arm is extended the long head of the muscles may assist the Teres major and Latissimus dorsi in drawing the humerus backward and in adducting it to the thorax. The long head of the Triceps protects the under part of the shoulder-joint, and prevents displacement of the head of the humerus downward and backward. The Subanconeus draws up the posterior ligament during extension of the forearm.

Surgical Anatomy.—The existence of the band of fibres from the Triceps to the fascia of the forearm is of importance in excision of the elbow, and should always be carefully preserved from injury by the operator, as by means of these fibres the patient is enabled to extend the forearm, a movement which would otherwise mainly be accomplished by gravity; that is to say, allowing the forearm to drop from its own weight.

III. MUSCLES AND FASCIAE OF THE FOREARM.

Dissection.—To dissect the forearm, place the limb in the position indicated in Fig. 311, make a vertical incision along the middle line from the elbow to the wrist, and a transverse incision at the extremity of this; the superficial structures being removed, the deep fascia of the forearm is exposed.

Deep Fascia (fascia antibrachii).—The deep fascia of the forearm, continuous above with that enclosing the arm, is a dense, highly glistening aponeurotic investment, which forms a general sheath enclosing the muscles in this region; it is attached, behind, to the olecranon and posterior border of the ulna, and gives off from its inner surface numerous intermuscular septa, which enclose each muscle separately. Below, it is continuous in front with the anterior annular ligament (ligamentum carpi volare), and forms a sheath for the tendon of the Palmaris longus muscle, which passes over the annular ligament to be inserted into the palmar fascia. Behind, near the wrist-joint, it becomes much thickened by the addition of many transverse fibres, and forms the posterior annular ligament (ligamentum carpi dorsale). It consists of circular and oblique fibres, connected together by numerous vertical fibres. It is much thicker on the dorsal than on the palmar surface, and at the lower than at the upper part of the forearm, and is strengthened above by tendinous fibres derived from the Brachialis anticus and Biceps in front, and from the Triceps behind. Its deep surface gives origin to muscular fibres, especially at the upper part of the inner and outer sides of the forearm, and forms the boundaries of a series of conical-shaped cavities, in which the muscles are contained. Besides the vertical septa separating each muscle, transverse septa are given off on the anterior and posterior surfaces of the forearm, separating the deep from the superficial layer of muscles. Numerous apertures exist in the fascia for the passage of vessels and nerves; one of these, of large size, situated at the front of the elbow, serves for the passage of a communicating branch between the superficial and deep veins.

The muscles of the forearm may be subdivided into groups corresponding to the region they occupy. One group occupies the inner and anterior aspect of the forearm, and comprises the Flexor and Pronator muscles. Another group occupies its outer side, and a third its posterior aspect. The two latter groups include all the Extensor and Supinator muscles.
THE ANTERIOR RADIO–ULNAR REGION

8. The Anterior Radio-ulnar Region.

The muscles in this region are divided for convenience of description into two groups or layers, superficial and deep.

The Superficial Layer.


These muscles take origin from the internal condyle of the humerus by a common tendon.

The Pronator Radii Teres (m. pronator teres) arises by two heads. One, the larger and more superficial, humeral head (caput humerale), arises from the humerus, immediately above the internal condyle, and from the tendon common to the origin of the other muscles; also from the fascia of the forearm and the intermuscular septum between it and the Flexor carpi radialis. The other head, the ulnar head (caput ulnare), is a thin fasciculus which arises from the inner side of the coronoid process of the ulna, joining the preceding at an acute angle. Between the two heads the median nerve enters the forearm. The muscle passes obliquely across the forearm from the inner to the outer side, and terminates in a flat tendon, which turns over the outer margin of the radius, and is inserted into a rough impression at the middle of the outer surface of the shaft of that bone.

Relations.—By its anterior surface, throughout the greater part of its extent, with the deep fascia; at its insertion it is crossed by the radial vessels and nerve, and is covered by the Supinator longus; by its posterior surface, with the Brachialis anticus, Flexor sublimis digitorum, the median nerve, and ulnar artery, the small or deep head being interposed between the two latter structures. Its outer border forms the inner boundary of a triangular space in which are placed the brachial artery, median nerve, and tendon of the Biceps muscle. Its inner border is in contact with the Flexor carpi radialis.

Surgical Anatomy.—This muscle, when suddenly brought into very active use, as in the game of lawn tennis, is apt to be strained, producing slight swelling and tenderness, and pain on putting the muscle into action. This is known as lawn-tennis arm.

The Flexor Carpi Radialis lies on the inner side of the preceding muscle. It arises from the internal condyle by the common tendon, from the fascia of the forearm, and from the intermuscular septa between it and the Pronator radii teres, on the outside, the Palmaris longus internally, and the Flexor sublimis digitorum beneath. Slender and aponeurotic in structure at its commencement, it increases in size, and terminates in a tendon which forms rather more than the lower half of its length. This tendon passes through a canal on the outer side of the annular ligament, runs through a groove in the os trapezium (which is converted into a canal by a fibrous sheath, and is lined by a synovial membrane), and is inserted into the base of the metacarpal bone of the index finger, and by a slip into the base of the metacarpal bone of the middle finger. The radial artery lies between the tendon of this muscle and the Supinator longus, and may easily be tied in this situation. In the hand a bursa (bursa m. flexoris carpi radialis) lies between the base of the second metacarpal bone and the tendon (Spalteholz).

Relations.—By its superficial surface, with the deep fascia and the integument; by its deep surface, with the Flexor sublimis digitorum, Flexor longus pollicis, and wrist-joint; by its outer border, with the Pronator radii teres and the radial vessels; by its inner border, with the Palmaris longus above and the median nerve below.
The Palmaris Longus (Fig. 316) is a slender, fusiform muscle lying on the inner side of the preceding. It arises from the inner condyle of the humerus by the common tendon, from the deep fascia, and the intermuscular septa between it and the adjacent muscles. It terminates in a slender flattened tendon, which passes over the upper part of the annular ligament, to end in the central part of the palmar fascia and lower part of the annular ligament, frequently sending a tendinous slip to the short muscles of the thumb. This muscle is often absent, and is subject to very considerable variations; it may be tendinous above and muscular below; or it may be muscular in the centre, with a tendon above and below; or it may present two muscular bundles with a central tendon; or finally it may consist simply of a mere tendinous band.

Relations.—By its superficial surface, with the deep fascia. By its deep surface, with the Flexor sublimis digitorum. Internally, with the Flexor carpi ulnaris. Externally, with the Flexor carpi radialis. The median nerve lies close to the tendon, just above the wrist, on its inner and posterior side.

The Flexor Carpi Ulnaris (Fig. 316) lies along the ulnar side of the forearm. It arises by two heads, connected by a tendinous arch, beneath which pass the ulnar nerve and posterior ulnar recurrent artery. One head arises from the inner condyle of the humerus, humeral head (caput humerae), by the common tendon; the other from the inner margin of the olecranon and from the upper two-thirds of the posterior border of the ulna, ulnar head (caput ulnare), by an aponeurosis, common to it and the Extensor carpi ulnaris and Flexor profundus digitorum; and from the intermuscular septum between it and the Flexor sublimis digitorum. The fibres terminate in a tendon which occupies the anterior part of the lower half of the muscle, and is inserted into the pisiform bone, and is prolonged from this to the fifth metacarpal and unciform bones, by the piso-metacarpal and piso-uncinate ligaments: it is also attached by a few fibres to the annular ligament. The ulnar artery lies on the outer side of the tendon of this muscle, in the lower two-thirds of the forearm, the tendon forming a guide in tying the vessel in this situation. A bursa (bursa m. flexoris carpi ulnaris) is placed between the tendon and a part of the pisiform bone.

Relations.—By its superficial surface, with the deep fascia, with which it is intimately connected for a considerable extent; by its deep surface, with the Flexor sublimis digitorum, the Flexor profundus digitorum, the Pronator quadratus, and the ulnar vessels and nerve; by its outer or radial border, with the Palmaris longus above and the ulnar vessels and nerve below.
The Flexor Sublimis Digitorum (m. flexor digitorum sublimis) (Fig. 316) is placed beneath the preceding muscles, which therefore must be removed in order to bring its attachment into view. It is the largest of the muscles of the superficial layer, and arises by three heads. One head, the humeral head (caput humerale), arises from the internal condyle of the humerus by the common tendon, from the internal lateral ligament of the elbow-joint, and from the intermuscular septum common to it and the preceding muscles. The second head, ulnar head (caput ulnare), arises from the inner side of the coronoid process of the ulna, above the ulnar origin of the Pronator radii teres (Fig. 134, p. 187). The third head, radial head (caput radiale), arises from the oblique line of the radius, extending from the tuberosity to the insertion of the Pronator radii teres. The fibres pass vertically downward, forming a broad and thick muscle, which speedily divides into two planes of muscular fibres, superficial and deep: the superficial plane divides into two parts which end in tendons for the middle and ring fingers; the deep plane also divides into two parts, which end in tendons for the index and little fingers, but previously to having done so it gives off a muscular slipp, which joins that part of the superficial plane which is intended for the ring finger. As the four tendons thus formed pass beneath the annular ligament into the palm of the hand, they are arranged in pairs, the superficial pair corresponding to the middle and ring fingers, the deep pair to the index and little fingers. The tendons diverge from one another as they pass onward. Opposite the bases of the first phalanges each tendon divides into two slips (chiasma tendinum) to allow of the passage of the corresponding tendon of the Flexor profundus digitorum; the two portions of the tendon then unite and form a grooved channel for the reception of the accompanying deep flexor tendon. Finally they subdivide a second time, to be inserted into the sides of the second phalanges about their middle. The insertion in the index finger is shown in Fig. 322. After leaving the palm the tendons of the superficial flexor, accompanied by the deep flexor tendons, lie in osseo-aponeurotic canals (Fig. 318). Each canal or theca extends from the metacarpo-phalangeal articulation to the proximal end of the distal phalanx (Fig. 232). It is formed by strong fibrous bands, which arch across the tendons, and are attached on each side to the margins of the phalanges. Opposite the middle of the proximal and second phalanges the sheath is very strong, and the fibres pass transversely; but opposite the joints it is much thinner, and the fibres pass obliquely. It is very thin over the metacarpo-phalangeal articulation. It is absent over the distal phalanx. Each sheath is lined by a synovial membrane, which is reflected on the contained tendons.

Relations.—In the forearm, by its superficial surface, with the deep fascia and all the preceding superficial muscles; by its deep surface, with the Flexor profundus digitorum, Flexor longus pollicis, the ulnar vessels and nerve, and the median nerve. In the hand its tendons are in relation, in front, with the palmar fascia, superficial palmar arch, and the branches of the median nerve; behind, with the tendons of the deep Flexor and the Lumbricales.
The Deep Layer (Fig. 318).

Flexor profundus digitorum. Flexor longus pollicis. Pronator quadratus.

**Dissection.**—Divide each of the superficial muscles at its centre, and turn either end aside; the deep layer of muscles, together with the median nerve and ulnar vessels, will then be exposed.

The Flexor Profundus Digitorum (*m. flexor digitorum profundus*) (Fig. 318) is situated on the ulnar side of the forearm, immediately beneath the superficial Flexors. It arises from the upper three-fourths of the anterior and inner surfaces of the shaft of the ulna, embracing the insertion of the Brachialis anticus above, and extending, below, to within a short distance of the Pronator quadratus. It also arises from a depression on the inner side of the coronoid process; by an aponeurosis from the upper three-fourths of the posterior border of the ulna, in common with the Flexor and Extensor carpi ulnaris; and from the ulnar half of the interosseous membrane. The fibres form a fleshy belly of considerable size, which divides into four tendons: these pass under the annular ligament beneath the tendons of the Flexor sublimis digitorum. Opposite the first phalanges the tendons pass through the openings in the two slips of the tendons of the Flexor sublimis digitorum, and are finally inserted into the bases of the last phalanges. The portion of the muscle for the index finger (Fig. 322) is usually distinct throughout, but the tendons for the three inner fingers are connected together by cellular tissue and tendinous slips as far as the palm of the hand. The tendons of this muscle and those of the Flexor sublimis digitorum, whilst contained in the osseo-aponeurotic canals of the fingers, are invested in a synovial sheath, and are connected to each other and to the phalanges by slender tendinous filaments, called vincula accessoria tendinum (*vinculum tendinum*). One of these connects the deep tendon to the bone before it passes through the superficial tendon; a second connects the two tendons together, after the deep tendons have passed through; and a third connects the deep tendon to the head of the second phalanx. This last consists largely of yellow elastic tissue, and may assist in drawing down the tendon after flexion of the finger.¹

Four small muscles, the Lumbricales, are connected with the tendons of the Flexor profundus in the palm. They will be described with the muscles in that region.

**Relations.**—By its superficial surface, in the forearm, with the Flexor sublimis digitorum, the Flexor carpi ulnaris, the ulnar vessels and nerve, and the median nerve; and in the hand, with the tendons of the superficial Flexor; by its deep surface, in the forearm, with the ulna, the interosseous membrane, the Pronator quadratus; and in the hand, with the Interossei, Adductor pollicis, and deep palmar arch; by its ulnar border, with the Flexor carpi ulnaris; by its radial border, with the Flexor longus pollicis, the anterior interosseous vessels and nerve being interposed.

The Flexor Longus Pollicis (*m. flexor pollicis longus*) (Fig. 318) is situated on the radial side of the forearm, lying on the same plane as the preceding. It arises from the grooved anterior surface of the shaft of the radius, commencing above, immediately below the tuberosity and oblique line, and extending below to within a short distance of the Pronator quadratus. It also arises from the adjacent part of the interosseous membrane and generally by a fleshy slip from the inner border of the coronoid process or from the internal condyle of the humerus. The fibres pass downward, and terminate in a flattened tendon which passes beneath the annular ligament, is then lodged in the interspace between the outer head of the Flexor brevis pollicis and the Adductor obliquus pollicis, and, entering an osseo-aponeurotic canal similar to those for the other flexor tendons, is inserted into the base of the last phalanx of the thumb.

Relations.—By its superficial surface, with the Flexor sublimis digitorum, Flexor carpi radialis, Supinator longus, and radial vessels; by its deep surface, with the radius, interosseous membrane, and Pronator quadratus; by its ulnar border, with the Flexor profundus digitorum, from which it is separated by the anterior interosseous vessels and nerve.

The Pronator Quadratus (Figs. 318 and 327) is a small, flat, quadrilateral muscle, extending transversely across the front of the radius and ulna, above their carpal extremities. It arises from the oblique or pronator ridge on the lower part of the anterior surface of the shaft of the ulna; from the lower fourth of the anterior surface and the anterior border of the ulna; and from a strong aponeurosis which covers the inner third of the muscle. The fibres pass outward and slightly downward, to be inserted into the lower fourth of the anterior surface and anterior border of the shaft of the radius.

Relations.—By its superficial surface, with the Flexor profundus digitorum, the Flexor longus pollicis, Flexor carpi radialis, and the radial vessels; by its deep surface, with the radius, ulna, and interosseous membrane.

Nerves.—All the muscles of the superficial layer are supplied by the median nerve, excepting the Flexor carpi ulnaris, which is supplied by the ulnar nerve. The Pronator radii teres and the Flexor carpi radialis derive their supply primarily from the sixth cervical; the Palmaris longus from the eighth cervical; the Flexor sublimis digitorum from the seventh and eighth cervical and first thoracic, and the Flexor carpi ulnaris from the eighth cervical and first thoracic nerves. Of the deep layer, the Flexor profundus digitorum is supplied by the eighth cervical and first thoracic through the ulnar and anterior interosseous branch of the median. The remaining two muscles, the

Fig. 318.—Front of the left forearm. Deep muscles.
Flexor longus pollicis and Pronator quadratus, are also supplied by the eighth cervical and first thoracic through the anterior interosseous branch of the median.

**Actions.**—These muscles act upon the forearm, the wrist, and hand. The Pronator radii teres helps to rotate the radius upon the ulna, rendering the hand prone: when the radius is fixed it assists the other muscles in flexing the forearm. The Flexor carpi radialis is one of the flexors of the wrist; when acting alone it flexes the wrist, inclining it to the radial side. It can also assist in pronating the forearm and hand, and, by continuing its action, in bending the elbow. The Flexor carpi ulnaris is one of the flexors of the wrist; when acting alone it flexes the wrist, inclining it to the ulnar side (adducts the wrist), and, by continuing to contract, it bends the elbow. The Palmaris longus is a tensor of the palmar fascia, and tension of this fascia protects the parts beneath it. It also assists in flexing the wrist and elbow. The Flexor sublimis digitorum flexes the middle phalanx and then assists in flexing the wrist and elbow. The Flexor profundus digitorum is the flexor of the distal phalanx. After the Flexor sublimis has bent the second phalanx, the Flexor profundus flexes the terminal one, but it cannot do so until after the contraction of the superficial muscle. After flexing the distal phalanx, it assists in flexing the middle phalanx, the proximal phalanx, and the wrist. The Flexor longus pollicis is the flexor of the distal phalanx of the thumb. When the thumb is fixed it also assists in flexing the wrist. The Pronator quadratus helps to rotate the radius upon the ulna, rendering the hand prone.

**Surgical Anatomy.**—When a finger is amputated so that the fibrous sheath of the flexor tendons is divided in a region in which it is firm and dense, the tendon contracts but the theca does not, and the rigid theca constitutes a permeable passage to the palm. If the parts should be infected the theca will draw pus toward the palm. Hence it is best to close the theca by sutures.

"Over the terminal phalanges, and over the joint between the middle and terminal phalanges, there is no fibrous sheath. In front of the metacarpo-phalangeal joint it is scarcely evident. Over the first and second (proximal and middle) phalanges, and in front of the joint between these bones, the fibrous sheath is well marked, and appears as a rigid tube when cut across. As the sheath crosses the metacarpo-phalangeal and first interphalangeal joints, it is adherent to the glenoid ligament, and is easily closed by two fine catgut sutures passed vertically—i.e., from the dorsal to the palmar wall. Opposite the shafts of the first and second phalanges, however, there is much difficulty in effecting closure, since the sheath is united to the periosteum, and that membrane is very thin. In these situations the periosteum should be stripped up a little from the palmar aspect of the bone, and the orifice of the tube secured by two fine sutures passed either vertically or transversely, as may appear the more convenient. This stripping off of periosteum should be effected before the bone is divided."

9. The Radial Region (Figs. 316, 319, 320).

**Supinator longus.**

**Extensor carpi radialis longior.**

**Extensor carpi radialis brevior.**

**Dissection.**—Divide the integument in the same manner as in the dissection of the anterior brachial region, and, after having examined the cutaneous vessels and nerves and deep fascia, remove all these structures. The muscles will then be exposed. The removal of the fascia will be considerably facilitated by detaching it from below upward. Great care should be taken to avoid cutting across the tendons of the muscles of the thumb, which cross obliquely the larger tendons running down the back of the radius.

The **Supinator Longus** (*m. brachioradialis*) (Fig. 316) is the most superficial muscle on the radial side of the forearm; it is fleshy for the upper two-thirds of its extent, tendinous below. It *arises* from the upper two-thirds of the external supracondylar ridge of the humerus, and from the external intermuscular septum, being limited above by the musculo-spiral groove. The fibres terminate above the middle of the forearm in a flat tendon, which is inserted into the outer side of the base of the styloid process of the radius.

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1 Operative Surgery. By Sir Frederick Treves.


Relations.—By its superficial surface, with the integument and fascia for the greater part of its extent; near its insertion it is crossed by the Extensor ossis metacarpi pollicis and the Extensor brevis pollicis; by its deep surface, with the humerus, the Extensor carpi radialis longior and brevior, the insertion of the Pronator radii teres, and the Supinator brevis; by its inner border, above the elbow, with the Brachialis anticus, the musculo-spiral nerve, and the radial recurrent artery; and in the forearm with the radial vessels and nerve.

The Extensor Carpi Radialis Longior \( (m.\ extensor\ carpi\ radialis\ longus) \) (Fig. 319) is placed partly beneath the preceding muscle. It arises from the lower third of the external supracondylar ridge of the humerus, and from the external intermuscular septum by a few fibres from the common tendon of origin of the Extensor muscles of the forearm. The fibres terminate at the upper third of the forearm in a flat tendon, which runs along the outer border of the radius, beneath the extensor tendons of the thumb; it then passes through a groove common to it and the Extensor carpi radialis brevior, immediately behind the styloid process, and is inserted into the base of the metacarpal bone of the index finger, on its radial side.

Relations.—By its superficial surface, with the Supinator longus and fascia of the forearm; its outer side is crossed obliquely by the extensor tendons of the thumb; by its deep surface, with the elbow-joint, the Extensor carpi radialis brevior, and back part of the wrist.

The Extensor Carpi Radialis Brevior \( (m.\ extensor\ carpi\ radialis\ brevis) \) (Fig. 319) is shorter, as its name implies, and thicker than the preceding muscle, beneath which it is placed. It arises from the external condyle of the humerus by a tendon common to it and the three following muscles; from the external lateral ligament of the elbow-joint, from a strong aponeurosis which covers its
surface, and from the internmuscular septa between it and the adjacent muscles. The fibres terminate about the middle of the forearm in a flat tendon which is closely connected with that of the preceding muscle, and accompanies it to the wrist, lying in the same groove on the posterior surface of the radius; it passes beneath the extensor tendons of the thumb, then beneath the annular ligament, and, diverging somewhat from its fellow, is inserted into the base of the metacarpal bone of the middle finger, on its radial side. There is often a bursa (bursa m. extensoris carpi radialis brevis) between a portion of the base of the bone and the tendon.

The tendons of the two preceding muscles pass through the same compartment of the annular ligament, and are lubricated by a single synovial membrane, but are separated from each other by a small vertical ridge of bone as they lie in the groove at the back of the radius.

Relations.—By its superficial surface, with the Extensor carpi radialis longior, and with the Extensor muscles of the thumb which cross it; by its deep surface, with the Supinator brevis, tendon of the Pronator radii teres, radius, and wrist-joint; by its ulnar border, with the Extensor communis digitorum.

10. The Posterior Radio-ulnar Region (Fig. 319).

The muscles in this region are divided for purposes of description into two groups or layers, superficial and deep.

The Superficial Layer.

<table>
<thead>
<tr>
<th>Extensor communis digitorum</th>
<th>Extensor carpi ulnaris</th>
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<tr>
<td>Extensor minimi digiti</td>
<td>Anconeus</td>
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The Extensor Communis Digitorum (m. extensor digitorum communis) is situated at the back part of the forearm. It arises from the external condyle of the humerus by the common tendon, from the deep fascia, and the internmuscular septa between it and the adjacent muscles. Just below the middle of the forearm it divides into three fleshy masses, from which tendons proceed; these pass, together with the Extensor indicis, through a separate compartment of the annular ligament, lubricated by a synovial membrane. The tendons then diverge, the innermost one dividing into two; and all, after passing across the back of the hand, are inserted into the second and third phalanges of the fingers in the following manner: the outermost tendon, accompanied by the Extensor indicis, goes to the index finger (Figs. 319, 321, and 322); the second tendon is sometimes connected to the first by a thin transverse band, and receives a slip from the third tendon (Fig. 319); it goes to the middle finger; the third tendon gives off the slip to the second (Fig. 319), and receives a very considerable part of the fourth tendon; the fourth, or innermost tendon, divides into two parts; one goes to join the third tendon; the other, reinforced by the Extensor minimi digiti, goes to the little finger. Each tendon opposite the metacarpo-phalangeal articulation becomes narrow and thickened, and gives off a thin fasciculus upon each side of the joint, which blends with the lateral ligaments and serves as the posterior ligament; after having passed the joint it spreads out into a broad aponeurosis, which covers the whole of the dorsal surface of the first phalanx, being reinforced, in this situation, by the tendons of the Interossei and Lumbricales. Opposite the first phalangeal joint this aponeurosis divides into three slips, a middle and two lateral: the former is inserted into the base of the second phalanx; and the two lateral, which are continued onward along the sides of the second phalanx, unite by their contiguous margins, and are inserted into the dorsal surface of the last phalanx. As the tendons cross the phalangeal joints they furnish them with posterior ligaments. The accessory slips or lateral vincula which join the tendon...
of the ring finger to the tendon of the little finger and the tendon of the middle finger are constant. If the middle and little fingers are held flexed the lateral vincula greatly limit the range of extension possible in the ring finger—a limitation which interferes with a piano-player (Prof. William S. Forbes).

Relations.—By its superficial surface, with the fascia of the forearm and hand, the posterior annular ligament, and integument; by its deep surface, with the Supinator brevis, the Extensor muscles of the thumb and index finger, the posterior interosseous vessels and nerve, the wrist-joint, carpus, metacarpus, and phalanges; by its radial border, with the Extensor carpi radialis brevior; by its ulnar border, with the Extensor minimi digiti and Extensor carpi ulnaris.

The Extensor Minimi Digiti (m. extensor digiti quinti proprius) is a slender muscle placed on the inner side of the Extensor communis, with which it is generally connected. It arises from the common tendon by a thin, tendinous slip, and from the intermuscular septa between it and the adjacent muscles. Its tendon runs through a separate compartment in the annular ligament behind the inferior radio-ulnar joint, then divides into two as it crosses the hand, the outermost division being joined by the slip from the innermost tendon of the common extensor. The two slips thus formed spread into a broad aponeurosis, which after receiving a slip from the Abductor minimi digiti is inserted into the second and third phalanges. The tendon is situated on the ulnar side of, and somewhat more superficial than, the common extensor.

The Extensor Carpi Ulnaris is the most superficial muscle on the ulnar side of the forearm. It arises from the external condyle of the humerus by the common tendon; by an aponeurosis from the posterior border of the ulna in common with the Flexor carpi ulnaris and the Flexor profundus digitorum; and from the deep fascia of the forearm. This muscle terminates in a tendon which runs through a groove behind the styloid process of the ulna, passes through a separate compartment in the annular ligament, and is inserted into the prominent tubercle on the ulnar side of the base of the metacarpal bone of the little finger.

Relations.—By its superficial surface, with the deep fascia of the forearm; by its deep surface, with the ulna and the muscles of the deep layer.

The Anconeus (m. anconaeus) is a small triangular muscle placed behind and below the elbow-joint, and appears to be a continuation of the external portion of the Triceps. It arises by a separate tendon from the back part of the external condyle of the humerus, and is inserted into the side of the olecranon and upper fourth of the posterior surface of the shaft of the ulna; its fibres diverge from their origin, the upper ones being directed transversely, the lower obliquely inward.

Relations.—By its superficial surface, with a strong fascia derived from the Triceps; by its deep surface, with the elbow-joint, the orbicular ligament, the ulna, and a small portion of the Supinator brevis.

The Deep Layer (Fig. 321).

Supinator radii brevis. Extensor brevis pollicis.
Extensor ossis metacarpi pollicis. Extensor longus pollicis.
Extensor indicis.

The Supinator Radii Brevis (m. supinator) (Figs. 320 and 321) is a broad muscle, of hollow cylindrical form, curved round the upper third of the radius. It consists of two distinct planes of muscular fibres, between which lies the posterior interosseous nerve (Fig. 320). The two planes arise in common: the superficial one by tendinous, and the deeper by muscular, fibres from the external condyle of the humerus, from the external lateral ligament of the elbow-joint and the orbicular ligament of the radius; from the ridge on the ulna, which runs obliquely downward from the
posterior extremity of the lesser sigmoid cavity; from the triangular depression in front of it; and from a tendinous expansion which covers the surface of the muscle.

The superficial fibres surround the upper part of the radius, and are inserted into the outer edge of the bicipital tuberosity and into the oblique line of the radius, as low down as the insertion of the Pronator radii teres. The upper fibres of the deeper plane form a sling-like fasciculus, which encircles the neck of the radius above the tuberosity and is attached to the back part of its inner surface: the greater part of this portion of the muscle is inserted into the posterior and external surface of the shaft, midway between the oblique line and the head of the bone. Between the insertion of the two planes the posterior interosseous nerve lies on the shaft of the bone (Fig. 320).
Relations.—By its superficial surface, with the superficial Extensor and Supinator muscles, and the radial vessels and nerve; by its deep surface, with the elbow-joint, the interosseous membrane, and the radius.

The Extensor Ossis Metacarpi Pollicis (*m. abductor pollicis longus*) is the most external and the largest of the deep extensor muscles; it lies immediately below the Supinator brevis, with which it is sometimes united. It arises from the outer part of the posterior surface of the shaft of the ulna below the insertion of the Anconeus, from the interosseous membrane, and from the middle third of the posterior surface of the shaft of the radius. Passing obliquely downward and outward, it terminates in a tendon which runs through a groove on the outer side of the styloid process of the radius, accompanied by the tendon of the Extensor brevis pollicis, and is inserted into the base of the metacarpal bone of the thumb. It occasionally gives off two slips near its insertion—one to the Trapeziun, and the other to blend with the origin of the Abductor pollicis.

Relations.—By its superficial surface, with the Extensor communis digitorum, Extensor minimi digiti, and fascia of the forearm, and with the branches of the posterior interosseous artery and nerve which cross it; by its deep surface, with the ulna, interosseous membrane, radius, the tendons of the Extensor carpi radialis longior and brevior, which it crosses obliquely, and, at the outer side of the wrist, with the radial vessels; by its upper border, with the Supinator brevis; by its lower border, with the Extensor brevis pollicis.

The Extensor Brevis Pollicis, often called the extensor primi internodii pollicis (*m. extensor pollicis brevis*), the smallest muscle of this group, lies on the inner side of the preceding. It arises from the posterior surface of the shaft of the radius, below the Extensor ossis metacarpi pollicis, and from the interosseous membrane. Its direction is similar to that of the Extensor ossis metacarpi pollicis, its tendon passing through the same groove on the outer side of the styloid process, to be inserted into the base of the first phalanx of the thumb.

Relations.—The same as those of the Extensor ossis metacarpi pollicis.

The Extensor Longus Pollicis, often called the extensor secundi internodii pollicis (*m. extensor pollicis longus*) is much larger than the preceding muscle, the origin of which it partly covers in. It arises from the outer part of the posterior surface of the shaft of the ulna, below the origin of the Extensor ossis metacarpi pollicis, and from the interosseous membrane. It terminates in a tendon which passes through a separate compartment in the annular ligament, lying in a narrow, oblique groove at the back part of the lower end of the radius. It then crosses obliquely the tendons of the Extensor carpi radialis longior and brevior, being separated from the other extensor tendons of the thumb by a triangular interval, in which the radial artery is found, and is finally inserted into the base of the last phalanx of the thumb.

Relations.—By its superficial surface, with the same parts as the Extensor ossis metacarpi pollicis; by its deep surface, with the ulna, interosseous membrane, the
posterior interosseous nerve, radius, the wrist, the radial vessels, and metacarpal bone of the thumb.

The Extensor Indicus (m. extensor indicis proprius) (Figs. 319, 321, and 322) is a narrow, elongated muscle placed on the inner side of, and parallel with, the preceding. It arises from the posterior surface of the shaft of the ulna, below the origin of the Extensor longus pollicis and from the interosseous membrane. Its tendon passes with the Extensor communis digitorum through the same canal in the annular ligament, and subsequently joins the tendon of the Extensor communis which belongs to the index finger, opposite the lower end of the corresponding metacarpal bone, lying to the ulnar side of the tendon from the common extensor.

Relations.—The relations are similar to those of the preceding muscles.

Nerves.—The Supinator longus is supplied by the sixth, the Extensor carpi radialis longior by the sixth and seventh, and the Anconeus by the seventh and eighth cervical nerves, all through the musculo-spiral nerve; the remaining muscles of the radial and posterior brachial region are supplied through the posterior interosseous nerve, the Supinator brevis being supplied by the sixth cervical, the Extensor carpi radialis brevior by the sixth and seventh cervical, and all the other muscles by the seventh cervical.

Actions.—The muscles of the radial and posterior brachial regions, which comprise all the extensor and supinator muscles, act upon the forearm, wrist, and hand; they are the direct antagonists of the pronator and flexor muscles. The Anconeus assists the Triceps in extending the forearm. The chief action of the Supinator longus is that of a flexor of the elbow-joint, but in addition to this it may act both as a supinator or a pronator; that is to say, if the forearm is forcibly pronated it will act as a supinator, and bring the bones into a position midway between supination and pronation; and vice versa, if the arm is forcibly supinated, it will act as a pronator, and bring the bones into the same position, midway between supination and pronation. The action of the muscle is therefore to throw the forearm and hand into the position they naturally occupy when placed across the chest. The Supinator brevis is a supinator; that is to say, when the radius has been carried across the ulna in pronation and the back of the hand is directed forward, this muscle carries the radius back again to its normal position on the outer side of the ulna, and the palm of the hand is again directed forward. The Extensor carpi radialis longior extends the wrist and abducts the hand. It may also assist in bending the elbow-joint; at all events, it serves to fix or steady this articulation. The Extensor carpi radialis brevior assists the Extensor carpi radialis longior in extending the wrist, and may also act slightly as an abductor of the hand. The Extensor carpi ulnaris helps to extend the hand, but when acting alone inclines it toward the ulnar side; by its continued action it extends the elbow-joint. The Extensor communis digitorum extends the phalanges, then the wrist, and finally the elbow. It acts principally on the proximal phalanges, the middle and terminal phalanges being extended by the Interossei and Lumbricales. It has also a tendency to separate the fingers as it extends them. The Extensor minimi digiti extends similarly the little finger, and by its continued action it assists in extending the wrist. It is owing to this muscle that the little finger can be extended or pointed whilst the others are flexed. The chief action of the Extensor ossis metacarpi pollicis is to carry the thumb outward and backward from the palm of the hand, and hence it has been called the abductor pollicis longus. By its continued action it helps to extend and abduct the wrist. The Extensor brevis pollicis extends the proximal phalanx of the thumb. By its continued action it helps to extend and abduct the wrist. The Extensor longus pollicis extends the terminal phalanx of the thumb. By its continued action it helps to extend and abduct the wrist. The Extensor indicis extends the index finger, and
by its continued action assists in extending the wrist. It is owing to this muscle that the index finger can be extended or pointed while the others are flexed.

**Surgical Anatomy.**—The tendons of the extensor muscles of the thumb are liable to become strained and their sheaths inflamed after excessive exercise, producing a sausage-shaped swelling along the course of the tendon, and giving a peculiar creaking sensation to the finger when the muscle acts. In consequence of its often being caused by such movements as wringing clothes, it is known as *washerwoman's sprain*. In piano-players the slips which join the tendons of the Extensor communis digitorum may limit freedom of motion in individual fingers. "When the middle finger and little finger of the hand are brought down by the flexor muscles, and their balls are held down firmly against the keys of a musical instrument, as in performing on a piano for the purpose of producing continuous sounds, and when at the same time it is necessary to extend and then to flex the ring-finger in order to produce accompanying sounds, it will be found that in the still-flexed position of the middle and little fingers, the ring finger can be but very slightly extended. Its complete extension, without operative interference, can only be brought about by long-continued exertion in practice, when elongation of certain accessory, but restricting, tendons is made by nutritive growth." If there is much limitation division of the hindering slips is proper. This was suggested by Prof. William S. Forbes in 1857.

**IV. MUSCLES AND FASCÆ OF THE HAND.**

The muscles of the hand are subdivided into three groups: 1. Those of the thumb, which occupy the radial side and produce the **thenar eminence**. 2. Those of the little finger, which occupy the ulnar side and give rise to the **hypothenar eminence**. 3. Those in the middle of the palm and within the interosseous spaces.

**Dissection** (Fig. 311).—Make a transverse incision across the front of the wrist, and a second across the heads of the metacarpal bones: connect the two by a vertical incision in the middle line, and continue it through the centre of the middle finger. The anterior and posterior annular ligaments and the palmar fascia should then be dissected.

The **Ligamentum Carpi Volare** is a thickening of the deep fascia of the forearm (*fascia antibrachii*) by deep fibres just above the wrist (Fig. 328). It covers the flexor muscles and joins the anterior annular ligament.

The **Anterior Annular Ligament** (*ligamentum carpi transversum*) (Fig. 323) is a strong, fibrous band which arches over the carpus, converting the deep groove on the front of the carpal bones into a canal, beneath which pass the flexor tendons of the fingers. It is attached, internally, to the pisiform bone and

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the hook of the unciniform bone (*eminencia carpi ulnaris*), and externally to the tuberosity of the scaphoid and to the inner part of the anterior surface and the ridge of the trapezium (*eminencia carpi radialis*). It is continuous, above, with the deep fascia of the forearm, of which it may be regarded as a thickened portion, and, below, with the palmar fascia. It is crossed by the ulnar vessels and nerve and the cutaneous branches of the median and ulnar nerves. At its outer extremity is the tendon of the Flexor carpi radialis, which lies in the groove on the trapezium between the attachments of the annular ligaments to the bone. It has inserted into its anterior surface a part of the tendon of the Palmaris longus and part of the tendon of the Flexor carpi ulnaris, and has arising from it, below, the small muscles of the thumb and little finger. Beneath it pass the tendons of the Flexor sublimis and Profundus digitorum, the Flexor longus pollicis, and the median nerve.

**The Synovial Membranes of the Flexor Tendons at the Wrist.**—There are two vaginal synovial membranes which enclose all the tendons as they pass beneath this ligament—one for the Flexor sublimis and Profundus digitorum, the other for the Flexor longus pollicis. They extend up into the forearm for about an inch above the annular ligament, and downward about half-way along the metacarpal bone, where they terminate in a blind diverticulum around each pair of tendons, with the exception of that of the thumb and those of the little finger—in each of these two digits the diverticulum is continued on, and communicates with the synovial sheath of the tendons in the fingers. In the other three fingers the synovial sheath of the tendons begins as a blind pouch without communication with the large synovial sac (Fig. 324).

**Surgical Anatomy.**—This arrangement of the synovial sheaths explains the fact that thecal abscess in the thumb and little finger is liable to be followed by abscesses in the forearm, from extension of the inflammation along the continuous synovial sheaths. Tuberculous inflammation is apt to occur in this situation, constituting *compound palmar ganglion*; it presents an hourglass outline, with a swelling in front of the wrist and in the palm of the hand, and a constriction corresponding to the annular ligament between the two. The fluid can be forced from the one swelling to the other under the ligament.

**Bursae about the Hand and Wrist.**—Bursae usually exist between the distal extremities of the metacarpal bones (*bursae intermetacarpophalangeae*), and a subcutaneous bursa often exists over the dorsal surface of the head of the fifth metacarpal bone. Subcutaneous digital dorsal bursae occur "almost constantly in the first finger-joints (between the first and second phalanx), occasionally in the second joint of the second and fourth fingers"¹ (*bursae subcutaneae digitorum dorsales*). A bursa exists between the tendon of the Extensor carpi radialis brevior and the base of the third metacarpal bone; another between the Flexor carpi ulnaris and the pisiform bone; another between the Flexor carpi radialis and the base of the second metacarpal bone.

The Posterior Annular Ligament (ligamentum carpi dorsale) is a strong fibrous band extending obliquely downward and inward across the back of the wrist, and consisting of the deep fascia of the back of the forearm, strengthened by the addition of some transverse fibres. It binds down the extensor tendons in their passage to the fingers, being attached, internally, to the styloid process of the ulna, the cuneiform and pisiform bones; externally, to the margin of the radius; and, in its passage across the wrist, to the elevated ridges on the posterior surface of the radius. It presents six compartments for the passage of tendons, each of which is lined by a separate synovial membrane (Fig. 325). These are, from without inward: 1. On the outer side of the styloid process, for the tendons of the Extensor ossis metacarpi and Extensor brevis pollicis. 2. Behind the styloid process, for the tendons of the Extensor carpi radialis longior and brevior. 3. About the middle of the posterior surface of the radius, for the tendon of the Extensor longus pollicis. 4. To the inner side of the latter, for the tendons of the Extensor communis digitorum and Extensor indicis. 5. Opposite the interval between the radius and ulna, for the Extensor minimi digitii. 6. Grooving the back of the ulna, for the tendon of the Extensor carpi ulnaris. The synovial membranes lining these sheaths are usually very extensive, reaching from above the annular ligament down upon the tendons for a variable distance on the back of the hand.

The Deep Palmar Fascia (aponeurosis palmaris).—The deep palmar fascia (Fig. 326) forms a common sheath which invests the muscles of the hand. It consists of a central and two lateral portions.

The Central Portion occupies the middle of the palm, is triangular in shape, of great strength and thickness, and binds down the tendons and protects the vessels and nerves in this situation. It is narrow above, where it is attached to the lower margin of the annular ligament, and receives the expanded tendon of the Palmaris longus muscle. Below, it is broad and expanded, and divides into four slips for the four fingers. Each slip gives off superficial fibres, which are inserted into the skin of the palm and finger, those to the palm joining the skin at the furrow corresponding to the metacarpo-phalangeal articulation, and those to the fingers passing into the skin at the transverse fold at the base of the fingers. The deeper part of each slip subdivides into two processes, which are inserted into the lateral margins of the anterior (glenoid) ligament of the metacarpo-phalangeal joint. From the sides of these processes offsets are sent backward, to be attached to the borders of the lateral surfaces of the metacarpal bones at their distal extremities. By this arrangement short channels are formed on the front of the lower ends of the metacarpal bones, through which the flexor tendons pass. Dr. W. W. Keen describes a fifth slip as frequently found passing to the thumb. The intervals left in the fascia between the four fibrous slips transmit the digital vessels and nerves and the tendons of the Lumbricales. At the points of division of the palmar fascia into the slips above mentioned numerous strong, transverse fibres bind the separate processes together. The palmar fascia is intimately adherent to the integument by dense fibro-areolar tissue, forming the superficial palmar fascia, and gives origin by its inner margin to the Palmaris brevis: it covers the superficial palmar arch, the tendons of the flexor muscles, and the branches of
the median and ulnar nerves, and on each side it gives off a vertical septum, which is continuous with the interosseous aponeurosis and separates the lateral from the middle palmar group of muscles.

The **Lateral Portions of the Palmar Fascia** are thin, fibrous layers, which cover, on the radial side, the muscles of the ball of the thumb, and, on the ulnar side, the muscles of the little finger; they are continuous with the dorsal fascia, and in the palm with the central portion of the palmar fascia.

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The **Superficial Transverse Ligament of the Fingers** is a thin, fibrous band which stretches across the roots of the four fingers, and is closely attached to the skin of the clefts, and internally to the fifth metacarpal bone, forming a sort of rudimentary web. Beneath it the digital vessels and nerves pass onward to their destination.

**Surgical Anatomy.**—The palmar fascia is liable to undergo contraction, producing a very inconvenient deformity known as *Dupuytren's contraction*. The ring and little fingers are most frequently implicated, but the middle, index, and the thumb may be involved. The proximal phalanx is drawn down and cannot be straightened, and the two distal phalanges become similarly flexed as the disease advances.
11. The Radial Region (Figs. 327, 328).

Abductor pollicis.
Opponens pollicis.
Adductor transversus pollicis.

Flexor brevis pollicis.
Adductor obliquus pollicis.

The Abductor Pollicis (m. abductor pollicis brevis) (Fig. 328) is a thin, flat muscle, placed immediately beneath the integument. It arises from the anterior annular ligament, the tuberosity of the scaphoid, and the ridge of the trapezium, frequently by two distinct slips; and, passing outward and downward, is inserted by a thin, flat tendon into the radial side of the base of the first phalanx of the thumb, sending a slip to join the tendon of the Extensor longus pollicis.
Relations.—By its superficial surface, with the palmar fascia and superficialis volae artery, which frequently perforates it. By its deep surface, with the Opponens pollicis, from which it is separated by a thin aponeurosis. Its inner border is separated from the Flexor brevis pollicis by a narrow cellular interval.

The Opponens Pollicis (Figs. 327 and 328), often called the flexor ossis metacarpi pollicis, is a small, triangular muscle, placed beneath the preceding. It arises from the palmar surface of the ridge on the trapezium and from the annular ligament, passes downward and outward, and is inserted into the whole length of the metacarpal bone of the thumb on its radial side.
Relations.—By its superficial surface, with the Abductor and Flexor brevis pollicis. By its deep surface, with the trapezio-metacarpal articulation. By its inner border, with the Adductor obliquus pollicis.

The Flexor Brevis Pollicis (m. flexor pollicis brevis) (Fig. 328) consists of two portions, outer and inner. The outer and more superficial portion arises from the outer two-thirds of the lower border of the anterior annular ligament, and passes along the outer side of the tendon of the Flexor longus pollicis; and, becoming tendinous, has a sesamoid bone developed in its tendon, and is inserted into the outer side of the base of the first phalanx of the thumb. The inner and deeper portion of the muscle is very small, and arises from the ulnar side of the first metacarpal bone beneath the Adductor obliquus pollicis, and is inserted into the inner side of the base of the first phalanx with this muscle.

Relations.—By its superficial surface, with the palmar fascia. By its deep surface, with the tendon of the Flexor longus pollicis. By its external surface, with the Opponens pollicis. Behind, with the Adductor obliquus pollicis.

The Adductor Obliquus Pollicis (m. adductor pollicis) (Figs. 327 and 328) arises by several slips from the os magnum, the bases of the second and third metacarpal bones, the anterior carpal ligaments, and the sheath of the tendon of the Flexor carpi radialis. From this origin the greater number of fibres pass obliquely downward and converge to a tendon, which, uniting with the tendons of the deeper portion of the Flexor brevis pollicis and the Adductor transversus, is inserted into the inner side of the base of the first phalanx of the thumb, a sesamoid bone being developed in the tendon of insertion. A considerable fasciculus, however, passes more obliquely outward beneath the tendon of the long flexor to join the superficial portion of the short flexor and the Adductor pollicis.

Relations.—By its superficial surface, with the Flexor longus pollicis and the outer head of the Flexor brevis pollicis. Its deep surface is in relation with the deep palmar arch, which passes between the two adductors.

The Adductor Transversus Pollicis (Figs. 327 and 328) is the most deeply seated of this group of muscles. It is of a triangular form, arising, by its broad base, from the lower two-thirds of the metacarpal bone of the middle finger on its palmar surface; the fibres, proceeding outward, converge to be inserted, with the inner part of the Flexor brevis pollicis, and the Adductor obliquus pollicis, into the ulnar side of the base of the first phalanx of the thumb. From the common tendon of insertion a slip is prolonged to the Extensor longus pollicis. The name adductor pollicis is frequently used to mean both of the adductors (Figs. 327 and 328).

Relations.—By its superficial surface, with the Adductor obliquus pollicis, the tendons of the Flexor profundus, and the Lumbricales. Its deep surface covers the first two interosseous spaces, from which it is separated by a strong aponeurosis.

Three of these muscles of the thumb, the Abductor, the Adductor transversus, and the Flexor brevis pollicis, at their insertions give off fibrous expansions which join the tendon of the Extensor longus pollicis. This permits of flexion of the proximal phalanx and extension of the terminal phalanx at the same time. These expansions, originally figured by Albinus, have been more recently described by M. Duchenne.

Nerves.—The Abductor, Opponens, and outer head of the Flexor brevis pollicis are supplied by the sixth cervical through the median nerve; the inner head of the Flexor brevis, and the Adductors, by the eighth cervical through the ulnar nerve.

1 This muscle is described by some as the deep portion of the Flexor brevis pollicis.
2 Physiologie des Mouvements.
Actions.—The actions of the muscles of the thumb are almost sufficiently indicated by their names. This segment of the hand is provided with three extensors—an extensor of the metacarpal bone, an extensor of the first, and an extensor of the second phalanx; these occupy the dorsal surface of the forearm and hand. There are also three flexors on the palmar surface—a flexor of the metacarpal bone, a flexor of the proximal, and a flexor of the terminal phalanx; there is also an Abductor and two Adductors. The Abductor pollicis moves the metacarpal bone of the thumb outward; that is, away from the index finger. The Flexor ossis metacarpi pollicis flexes the metacarpal bone—that is, draws it inward over the palm—and at the same time rotates the bone, so as to turn the ball of the thumb toward the fingers, thus producing the movement of opposition. The Flexor brevis pollicis flexes and adducts the proximal phalanx of the thumb. The Adductores pollicis move the metacarpal bone of the thumb inward; that is, toward the index finger. These muscles give to the thumb its extensive range of motion. It will be noticed, however, that in consequence of the position of the first metacarpal bone, these movements differ from the corresponding movements of the metacarpal bones of the other fingers. Thus extension of the thumb more nearly corresponds to the motion of abduction in the other fingers, and flexion to adduction.

12. The Ulnar Region (Fig. 328).

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Palmaris brevis</th>
<th>Abductor minimi digiti</th>
<th>Opponens minimi digiti</th>
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The Palmaris Brevis is a thin quadrilateral muscle placed beneath the integument on the ulnar side of the hand. It arises by tendinous fasciculi from the anterior annular ligament and palmar fascia; the fleshy fibres pass inward, to be inserted into the skin on the inner border of the palm of the hand.

Relations.—By its superficial surface, with the integument, to which it is intimately adherent, especially by its inner extremity; by its deep surface, with the inner portion of the palmar fascia, which separates it from the ulnar vessels and nerve, and from the muscles of the ulnar side of the hand.

The Abductor Minimi Digitii (m. abductor digitii quinti) is situated on the ulnar border of the palm of the hand. It arises from the pisiform bone and from the tendon of the Flexor carpi ulnaris, and terminates in a flat tendon, which divides into two slips; one is inserted into the ulnar side of the base of the first phalanx of the little finger. The other slip is inserted into the ulnar border of the aponeurosis of the Extensor minimi digiti.

Relations.—By its superficial surface, with the inner portion of the palmar fascia and the Palmaris brevis; by its deep surface, with the Opponens minimi digiti; by its outer border, with the Flexor brevis minimi digiti.

The Flexor brevis Minimi Digitii (m. flexor digitii quinti brevis) lies on the same plane as the preceding muscle, on its radial side. It arises from the convex aspect of the hook of the unciform bone and anterior surface of the annular ligament, and is inserted into the inner side of the base of the first phalanx of the little finger. It is separated from the Abductor at its origin by the deep branches of the ulnar artery and nerve. This muscle is sometimes wanting; the Abductor is then, usually, of large size.

Relations.—By its superficial surface, with the internal portion of the palmar fascia and the Palmaris brevis; by its deep surface, with the Opponens. The deep branch of the ulnar artery and the corresponding branch of the ulnar nerve pass between the Abductor and Flexor brevis minimi digiti muscles.

The Opponens Minimi Digitii (m. opponens digitii quinti).—This muscle is sometimes called the flexor ossis metacarpi (Fig. 318), is of a triangular form, and placed immediately beneath the preceding muscles. It arises from the convexity
of the hook of the unciform bone and the contiguous portion of the anterior annular ligament; its fibres pass downward and inward, to be inserted into the whole length of the metacarpal bone of the little finger, along its ulnar margin.

**Relations.**—By its superficial surface, with the Flexor brevis and Abductor minimi digitii; by its deep surface, with the Interossei muscles in the fourth metacarpal space, the metacarpal bone, and the Flexor tendons of the little finger.

**Nerves.**—All the muscles of this group are supplied by the eighth cervical nerve through the ulnar nerve.

**Actions.**—The Abductor minimi digitii abducts the little finger from the middle line of the hand. It corresponds to a dorsal interosseous muscle. It also assists in flexing the proximal phalanx and extending the second and third phalanges. The Flexor brevis minimi digitii abducts the little finger from the middle line of the hand. It also assists in flexing the proximal phalanges. The Opponens minimi digitii draws forward the fifth metacarpal bone, so as to deepen the hollow of the palm. The Palmaris brevis corrugates the skin on the inner side of the palm of the hand and probably serves to protect the ulnar nerve and artery from damage by the pressure of grasping a hard object.

**13. The Middle Palmar Region.**

Lumbricales.  
Interossei dorsales.

The **Lumbricales** (Fig. 328) are four small fleshy fasciculi, accessories to the deep Flexor muscle. They arise from the tendons of the deep Flexor: the first and second, from the radial side and palmar surface of the tendons of the index and middle fingers respectively; the third, from the contiguous sides of the tendons of the middle and ring fingers; and the fourth, from the contiguous sides of the tendons of the ring and little fingers. They pass to the radial side of the corresponding fingers and opposite the metacarpo-phalangeal articulation each tendon is inserted into the tendinous expansion of the Extensor communis digitorum, covering the dorsal aspect of each finger.

The **Interossei Muscles** (Figs. 329 and 330) are so named from occupying the intervals between the metacarpal bones, and are divided into two sets, dorsal and palmar.

The **Dorsal interossei** (mm. interossei dorsales) are four in number, larger than the palmar, and occupy the intervals between the metacarpal bones. They are bipenniform muscles, arising by two heads from the adjacent sides of the metacarpal bones, but more extensively from the metacarpal bone of the finger into which the muscle is inserted. They are inserted into the bases of the first phalanges and into the aponeurosis of the common Extensor tendon. Between the double origin of each of these muscles is a narrow triangular interval, through the first of which passes the radial artery; through each of the other three passes a perforating branch from the deep palmar arch.

The **First dorsal interosseous muscle** or Abductor indicis is larger than the others. It is flat, triangular in form, and arises by two heads, separated by a fibrous arch, for the passage of the radial artery from the dorsum to the palm of the hand. The outer head arises from the upper half of the ulnar border of the first metacarpal bone; the inner head, from almost the entire length of the radial border of the second metacarpal bone; the tendon is inserted into the radial side of the index finger. The second and third dorsal interossei are inserted into the middle finger, the former into its radial, the latter into its ulnar side. The fourth is inserted into the ulnar side of the ring finger.

The **Palmar interossei** (mm. interossei volares), three in number, are smaller than the Dorsal, and placed upon the palmar surface of the metacarpal bones, rather
than between them. Each muscle arises from the entire length of the metacarpal bone of one finger, and is inserted into the side of the base of the first phalanx and aponeurotic expansion of the common extensor tendon of the same finger. The first arises from the ulnar side of the second metacarpal bone, and is inserted into the same side of the first phalanx of the index finger. The second arises from the radial side of the fourth metacarpal bone, and is inserted into the same side of the ring finger. The third arises from the radial side of the fifth metacarpal bone, and is inserted into the same side of the little finger. From this account it may be seen that each finger is provided with two Interosseous muscles, with the exception of the little finger, in which the Abductor muscle takes the place of one of the pair.

Nerves.—The two outer Lumbricales are supplied by the sixth cervical nerve, through the third and fourth digital branches of the median nerve: the two inner Lumbricales and all the Interossei are supplied by the eighth cervical nerve, through the deep palmar branch of the ulnar nerve. Brooks states that the third lumbrical received a twig from the median in twelve out of twenty-one cases.

Actions.—The Palmar interossei muscles adduct the fingers to an imaginary line drawn longitudinally through the centre of the middle finger; and the Dorsal interossei abduct the fingers from that line. In addition to this, the Interossei, in conjunction with the Lumbricales, flex the first phalanges at the metacarpo-phalangeal joints, and extend the second and third phalanges in consequence of their insertion into the expansion of the extensor tendons. The Extensor communis digitorum is believed to act almost entirely on the first phalanges.

SURFACE FORM OF THE UPPER EXTREMIT Y.

The Pectoralis major muscle largely influences surface form and conceals a considerable part of the thoracic wall in front. Its sternal origin presents a festooned border which bounds and determines the width of the sternal furrow. Its clavicular origin is somewhat depressed and flattened, and between the two portions of the muscle is often an oblique depression which differentiates the one from the other. The outer margin of the muscle is generally well marked above, and bounds the infralavicular fossa, a triangular interval which separates the Pectoralis major
from the Deltoid. It gradually becomes less marked as it approaches the tendon of insertion, and becomes more closely blended with the Deltoid muscle. The lower border of the Pectoralis major forms the rounded anterior axillary fold, and corresponds with the direction of the fifth rib. The Pectoralis minor muscle influences surface form. When the arm is raised its lowest slip of origin produces a local fullness just below the border of the anterior fold of the axilla, and so serves to break the sharp line of the lower border of the Pectoralis major muscle, which is produced when the arm is in this position. The origin of the Serratus magnus muscle produces a very characteristic surface marking. When the arm is raised from the side in a well-developed subject, the five or six lower serrations are plainly discernible, forming a zigzag line, caused by the series of digitations, which diminish in size from above downward, and have their apices arranged in the form of a curve. When the arm is lying by the side, the first serration to appear, at the lower margin of the Pectoralis major, is the only one attached to the fifth rib. The Deltoid muscle, with the prominence of the upper extremity of the humerus, produces the rounded outline of the shoulder. It is rounder and fuller in front than behind, where it presents a somewhat flattened form. Its anterior border, above, presents a rounded, slightly curved eminence, which bounds externally the infraclavicular fossa; below, it is closely united with the Pectoralis major. Its posterior border is thin, flattened, and scarcely marked above; below, it is thicker and more prominent. When the muscle is in action, the middle portion becomes irregular, presenting alternate longitudinal elevations and depressions, the elevations corresponding to the fleshy portions, the depressions to the tendinous intersections of the muscle. The insertion of the Deltoid is marked by a depression on the outer side of the middle of the arm. Of the scapular muscles, the only one which materially influences surface form is the Teres major, which assist the Latissimus dorsi in forming the thick, rounded fold of the posterior boundary of the axilla. When the arm is raised, the Coraco-brachialis reveals itself as a long, narrow elevation which emerges from under cover of the anterior fold of the axilla and runs downward, internal to the shaft of the humerus. When the arm is hanging by the side, its front and inner part presents the prominence of the Biceps, bounded on either side by an intermuscular depression. This muscle determines the contour of the front of the arm, and extends from the anterior margin of the axilla to the bend of the elbow. Its upper tendons are concealed by the Pectoralis major and the Deltoid, and its lower tendon sinks into the space at the bend of the elbow. When the muscle is in a state of complete contraction—that is to say, when the forearm has been flexed and supinated—it presents a rounded convex form, bulged out laterally, and its length is diminished. On each side of the Biceps, at the lower part of the arm, the Brachialis anticus is discernible. On the outer side it forms a narrow eminence which extends some distance up the arm along the border of the Biceps. On the inner side it shows itself only as a little fullness just above the elbow. On the back of the arm the long head of the Triceps may be seen as a longitudinal eminence emerging from under cover of the Deltoid, and gradually merging into the longitudinal flattened plane of the tendon of the muscle on the lower part of the back of the arm. The tendon of insertion of the muscle extends about half-way up the back of the arm, where it forms an elongated flattened plane when the muscle is in action. Under similar conditions the surface forms produced by the three heads of the muscle are well seen. On the anterior aspect of the elbow are to be seen two muscular elevations, one on each side, separated above and converging below so as to form a triangular space. Of these, the inner elevation, consisting of the flexors and pronator, forms the prominence along the inner side and front of the forearm. It is a fusiform mass, pointed above at the internal condyle and gradually tapering off below. The Pronator radii teres, the innermost muscle of the group, forms the boundary of the triangular space at the bend of the elbow. It is shorter, less prominent, and more oblique than the outer boundary. The most prominent part of the eminence is produced by the Flexor carpi radialis, the muscle next in order on the inner side of the preceding one. It forms a rounded prominence above, and can be traced downward to its tendon, which can be felt lying on the front of the wrist, nearer to the radial than to the ulnar border, and to the inner side of the radial artery. The Palmaris longus presents no surface marking above, but below is the most prominent tendon on the front of the wrist, standing out, when the muscle is in action, as a sharp, tense cord beneath the skin. The Flexor sublimis digitorum does not directly influence surface form. The position of its four tendons on the front of the lower part of the forearm is indicated by an elongated depression between the tendons of the Palmaris longus and the Flexor carpi ulnaris. The Flexor carpi ulnaris occupies a small part of the posterior surface of the forearm, and is separated from the extensor and supinator group, which occupies the greater part of this surface, by the ulnar furrow, produced by the subcutaneous posterior border of the ulna. Its tendon can be perceived along the ulnar border of the front of the forearm, and is most marked when the hand is flexed and adducted. The deep muscles of the front of the forearm have no direct influence on surface form. The external group of muscles of the forearm, consisting of the extensors and supinators, occupy the outer side and correspond with the posterior surface of this region. It has a fusiform outline, which is altogether on a higher level than the pronato-flexor group. Its apex emerges from between the Triceps and Brachialis anticus muscles some distance above the
elbow-joint, and acquires its greatest breadth opposite the external condyle, and thence gradually shades off into a flattened surface. About the middle of the forearm it divides into two longitudinal eminences which diverge from each other, leaving a triangular interval between them. The outer of these two groups of muscles consists of the Supinator longus and the Extensor carpi radialis longior et brevior, which form a longitudinal eminence descending from the external condylar ridge in the direction of the styloid process of the radius. The other and more posterior group consists of the Extensor communis digitorum, the Extensor minimi digiti, and the Extensor carpi ulnaris. It commences above as a tapering form at the external condyle of the humerus, and is separated behind at its upper part from the Anconeus by a well-marked furrow, and below, from the pronato-flexor mass, by the ulnar furrow. In the triangular interval left between these two groups the extensors of the thumb and index finger are seen. The only two muscles of this region which require special mention as independently influencing surface form are the Supinator longus and the Anconeus. The inner border of the Supinator longus forms the outer boundary of the triangular space at the bend of the elbow. It commences as a rounded border above the condyle, and is longer, less oblique, and more prominent than the inner boundary. Lower down, the muscle forms a full fleshy mass on the outer side of the upper part of the forearm, and below tapers into a tendon, which may be traced down to the styloid process of the radius. The Anconeus presents a well-marked and characteristic surface form in the shape of a triangular, slightly elevated surface, immediately external to the subcutaneous posterior surface of the olecranon, and differentiated from the common extensor group by a well-marked oblique longitudinal depression. The upper angle of the triangle corresponds to the external condyle, and is marked by a depression or dipple in this situation. In the interval caused by the divergence from each other of the two groups of muscles into which the extensor and supinator group is divided at the lower part of the forearm an oblique elongated eminence is seen, caused by the emergence of two of the extensors of the thumb from their deep origin at the back of the forearm. This eminence, full above and becoming flattened out and partially subdivided below, runs downward and outward over the back and outer surface of the radius to the outer side of the wrist-joint, where it forms a ridge, especially marked when the thumb is extended, which passes onward to the posterior aspect of the thumb. The tendons of most of the extensor muscles are to be seen and felt at the level of the wrist-joint. Most externally are the tendons of the Extensor carpi radialis longior and the Extensor brevis pollicis, forming a vertical ridge over the outer side of the joint from the styloid process of the radius to the thumb. Internal to this is the oblique ridge produced by the tendon of the Extensor longus pollicis, very noticeable when the muscle is in action. The Extensor carpi radialis longior is scarcely to be felt, but the Extensor carpi radialis brevior can be distinctly perceived as a vertical ridge emerging from under the inner border of the tendon of the Extensor longus pollicis, when the hand is forcibly extended at the wrist. Internal to this, again, can be felt the tendons of the Extensor indicis, Extensor communis digitorum, and Extensor minimi digiti; the latter tendon being separated from those of the common extensor by a slight furrow. The muscles of the hand are principally concerned, as far as regards surface-form, in producing the thenar and hypothenar eminences, and individually are not to be distinguished, on the surface, from each other. The Adductor transversus pollicis is, however, an exception to this; its anterior border gives rise to a ridge across the web of skin connecting the thumb to the rest of the hand. The thenar eminence is much larger and rounder than the hypothenar one, which presents a longer and narrower eminence along the ulnar side of the hand. When the Palmatis brevis is in action it produces a wrinkling of the skin over the hypothenar eminence, and a deep dimple on the ulnar border of the hand. The anterior extremities of the Lumbrical muscles help to produce the soft eminences just behind the clefts of the fingers, separated from each other by depressions corresponding to the flexor tendons in their sheaths. Between the thenar and hypothenar eminences, at the wrist-joint, is a slight groove or depression, widening out as it approaches the fingers; beneath this we have the strong central part of the palmar fascia. Here we have some furrows which are pretty constant in their arrangement, and bear some resemblance to the letter M. One of these furrows passes obliquely outward from the groove between the thenar and hypothenar regions near the wrist to the head of the metacarpal bone of the index finger. A second passes inward, with a slight inclination upward, from the termination of the first to the ulnar side of the hand. A third runs nearly parallel with the second and about three-quarters of an inch below it. Lastly, crossing these two latter furrows, is an oblique furrow parallel with the first. The skin of the palm of the hand differs considerably from that of the forearm. At the wrist it suddenly becomes hard and dense, and covered with a thick layer of cuticle. The skin in the thenar region presents these characteristics less than elsewhere. In spite of this hardness and density, the skin of the palm is exceedingly sensitive and very vascular. It is destitute of hair, and no sebaceous follicles have been found in this region. Over the fingers the skin again becomes thinner, especially at the flexures of the joints, and over the terminal phalanges it is thrown into numerous ridges in consequence of the arrangement of the papillae in it. These ridges form, in different individuals, distinctive and permanent patterns, which may be used for purposes of identification. The superficial fascia in the palm
is made up of dense fibro-fatty tissue. This tissue binds down the skin so firmly to the deep palmar fascia that very little movement is permitted between the two. On the back of the hand the Dorsal interossei produce elongated swellings between the metacarpal bones. The first dorsal interosseous (Abductor indicis), when the thumb is closely adducted to the hand, forms a prominent fusiform bulging; the other interossei are not so marked.

**SURGICAL ANATOMY OF THE UPPER EXTREMITY.**

The student, having completed the dissection of the muscles of the upper extremity, should consider the effects likely to be produced by the action of the various muscles in fracture of the bones.

In considering the actions of the various muscles upon fractures of the upper extremity, the most common forms of injury have been selected both for illustration and description.

Fracture of the _middle of the clavicle_ (Fig. 331) is always attended with considerable displacement; the inner end of the outer fragment is displaced inward and backward, while the outer end of the same fragment is rotated forward. The whole outer fragment is somewhat depressed. The deformity is described by saying that the shoulder goes downward, forward, and inward.

The displacement is produced as follows: _inward_, by the muscles passing from the chest to the outer fragment of the clavicle, to the scapula, and to the humerus—viz., the Subclavius and the Pectoralis minor, and, to a less extent, the Pectoralis major and the Latissimus dorsi; _backward_, in consequence of the rotation of the outer fragment. The Serratus magnus causes the scapula to rotate on the wall of the chest; this carries the acromion and outer end of the outer fragment of the clavicle forward and causes the piece of bone to rotate round a vertical axis through its centre, and so carries the inner end of the outer portion backward. The depression of the whole outer fragment is produced by the weight of the arm and by the contraction of the Deltoid. The outer end of the inner fragment appears to be elevated, the skin being drawn tensely over it; this is owing to the depression of the outer fragment, as the inner fragment is usually kept fixed by the costo-clavicular ligament and by the antagonism between the Sternomastoid and Pectoralis major muscles. But it may be raised by an unusually strong Sterno-mastoid, or by the inner end of the outer fragment getting below and behind it. The causes of displacement having been ascertained, it is easy to apply the appropriate treatment. The outer fragment is to be drawn outward, and, together with the scapula, raised upward to a level with the inner fragment, and retained in that position. The formula for correcting the deformity is as follows: carry the shoulder upward, outward, and backward.

In fracture of the _acromial end of the clavicle_, between the conoid and trapezoid ligaments, only slight displacement occurs, as these ligaments, from their oblique insertion, serve to hold both portions of the bone in apposition. Fracture, also, of the _sternal end_, internal to the costoclavicular ligament, is attended with only slight displacement, this ligament serving to retain the fragments in close apposition.

Fracture of the _acromion process_ usually arises from violence applied to the upper and outer part of the shoulder; it is generally known by the rotundity of the shoulder being lost, from the Deltoid drawing the fractured portion downward and forward; and the displacement may easily be discovered by tracing the margin of the clavicle outward, when the fragment will be found resting on the front and upper part of the head of the humerus. In order to relax the anterior and outer fibres of the Deltoid (the opposing muscle), the arm should be drawn forward across the chest and the elbow well raised, so that the head of the bone may press the acromion process upward and retain it in its position.

Fracture of the _coraco-acromial process_ is an extremely rare accident, and is usually caused by a sharp blow on the point of the shoulder. Displacement is here produced by the combined action of the Pectoralis major, short head of the Biceps, and Coraco-brachialis, the former muscle drawing the fragment inward, and the latter muscles directly downward, the amount of displacement being limited by the connection of this process to the acromion by means of the coraco-acromial ligament. In many cases there appears to have been little or no displacement,
from the fact that the coraco-clavicular ligament has remained intact, and has kept the
separated fragment from displacement. In order to relax these muscles and replace the fragments in
close apposition, the forearm should be flexed so as to relax the Biceps, and the arm drawn
forward and inward across the chest, so as to relax the Coraco-brachialis; the humerus should
then be pushed upward against the coraco-acromial ligament, and the arm retained in that
position.

Fracture of the surgical neck of the humerus (Fig. 332) is very common, is attended with
considerable displacement, and its appearances correspond somewhat with those of dislocation
of the head of the humerus into the axilla. The upper fragment is slightly elevated under the
coraco-acromial ligament by the muscles attached to the greater and lesser tuberosities; the
lower fragment is drawn inward by the Pectoralis major, Latissimus dorsi, and Teres major; and
the humerus is thrown obliquely outward from the side by the Deltoïd, and occasionally elevated
so as to cause the upper end of the lower fragment to project beneath and in front of the coracoid process. The deformity
is reduced by fixing the shoulder, and drawing the arm outward and downward. To counteract the opposing muscles,
and to keep the fragments in position, a conical-shaped pad should be placed with the apex in the axilla; while the fore
arm is flexed to an angle of 90 degrees the shoulder is padded with cotton, a shoulder-cap of plaster-of-Paris is applied to
cover the shoulder, a portion of the chest and back, and the arm down to the external condyle (Scudder). The arm, with
the elbow slightly forward, is bandaged to the side. In some cases a splint is placed between the axillary pad and the
inner side of the arm.

In fracture of the shaft of the humerus below the insertion of the Pectoralis major, Latissimus dorsi, and Teres major,
and above the insertion of the Deltoïd, there is also considerable deformity, the upper fragment being drawn inward by
the first-mentioned muscles, and the lower fragment upward and outward by the Deltoïd, producing shortening of the limb
and a considerable prominence at the seat of fracture, from the fractured ends of the bone riding over one another, espe
pecially if the fracture takes place in an oblique direction. The fragments may be brought into apposition by extension from
the elbow, and are retained in that position by adopting the same means as in the preceding
injury, or by the use of an internal angular splint with three short humeral splints.

In fractures of the shaft of the humerus immediately below the insertion of the Deltoïd, the
amount of deformity depends greatly upon the direction of the fracture. If it occurs in a trans
verse direction, only slight displacement takes place, the upper fragment being drawn a little
forward; but in oblique fracture the combined actions of the Biceps and Brachialis anticus
muscles in front and the Triceps behind draw upward the lower fragment, causing it to glide
over the upper fragment, either backward or forward, according to the direction of the fracture.
Simple extension reduces the deformity, and the application of an internal angular splint and
three short humeral splints will retain the fragments in apposition. Care should be taken not
to raise the elbow, but the forearm and hand may be supported in a sling.

Fracture of the humerus (Fig. 333) above the condyle deserves very attentive considera
tion, as the general appearances correspond somewhat with those produced by separation
of the epiphysis of the humerus, and with those of dislocation of the radius and ulna back
ward. If the direction of the fracture is oblique from above, downward and forward, the
lower fragment is drawn upward by the Brachialis anticus and Biceps in front and the Triceps
behind; and at the same time is drawn backward behind the upper fragment by the Triceps.
This injury may be diagnosed from dislocation by the increased mobility in fracture, the
existence of crepitus, and the fact of the deformity being remedied by extension, on the discon
tinuance of which it is reproduced. The age of the patient is of importance in distinguishing
this form of injury from separation of the epiphysis. If fracture occurs in the opposite direc
tion to that shown in Fig. 333, the lower fragment is drawn upward and forward, causing a
considerable prominence in front, and the upper fragment projects backward beneath the
tendon of the Triceps muscle.

Fractures of the lower extremity of the humerus are spoken of as fractures in the neigh
borhood of the elbow-joint. The term includes fracture of the external condyle, of the internal condyle,
at the base of the condyles, and T- or Y-shaped fracture, the two condyles being separated
from each other and from the shaft of the humerus. Such injuries are followed by great and
rapid swelling. Whenever possible the x-rays are used to aid in diagnosis, and the patient is
placed under ether, to set and dress the fracture.

In fracture of the inner condyle the fragment with the ulna passes up and back, and when
the forearm is extended the ulna projects posteriorly. The "carrying function" of the arm is lost, because the forearm deviates to the ulnar side.

In all cases of fracture of the lower end of the humerus, except fracture at the base of the condyles, effect reduction by traction upon the forearm, and supination, extension, and bending the forearm slowly into acute flexion. In transverse fracture above the condyles draw the forearm and the lower fragment downward and forward and push the upper fragment back. A case can be treated by maintaining a position of acute flexion (Jones's position) or by using an anterior angular splint. Allis and others treat in extension.

Fracture of the olecranon process (Fig. 334) is a frequent accident. The detached fragment is displaced upward, by the action of the Triceps muscle, from half an inch to two inches; the prominence of the elbow is consequently lost, and a deep hollow is felt at the back part of the joint, which is much increased on flexing the limb. The patient at the same time loses, more or less, the power of extending the forearm. The treatment consists in relaxing the Triceps by extending the limb, and retaining it in the extended position by means of a long straight splint applied to the front of the arm; the fragments are thus brought into close apposition, and may be further approximated by drawing down the upper fragment. Union is generally ligamentous.

Fracture of the neck of the radius is an exceedingly rare accident, and is generally caused by direct violence. Its diagnosis is somewhat obscure, on account of the slight deformity visible, the injured part being surrounded by a large number of muscles; but the movements of pronation and supination are entirely lost. The upper fragment is drawn outward by the Supinator brevis, the extent of displacement being limited by the attachment of the orbicular ligament. The lower fragment is drawn forward and slightly upward by the Biceps, and inward by the Pronator radii teres, its displacement forward and upward being counteracted in some degree by the Supinator brevis. The treatment essentially consists in relaxing the Biceps, Supinator brevis, and Pronator radii teres muscles by flexing the forearm, and placing it in a position midway between pronation and supination, extension having been previously made so as to bring the parts in apposition.

In fracture of the radius below the insertion of the Biceps, but above the insertion of the Pronator radii teres, the upper fragment is strongly supinated by the Biceps and Supinator brevis, and at the same time drawn forward and flexed by the Biceps; the lower fragment is pronated and drawn inward toward the ulna by the pronators. Thus there is extreme displacement with very little deformity. In treating such a fracture the arm must be put up in a position of supination, otherwise union will take place with great impairment of the movements of the hand. In fractures of the radius below the insertion of the Pronator radii teres (Fig. 335), the upper fragment is drawn upward by the Biceps and inward by the Pronator radii teres, holding a position midway between pronation and supination, and a degree of fulness in the upper half of the forearm is thus produced; the lower fragment is drawn downward and inward toward the ulna by the Pronator quadratus, and thrown into a state of pronation by the same muscle; at the same time, the Supinator longus, by elevating the styloid process, into which

![Fig. 333.—Fracture of the humerus above the condyles.](image)

![Fig. 334.—Fracture of the olecranon.](image)
it is inserted, will serve to depress the upper end of the lower fragment still more toward the ulna. In order to relax the opposing muscles the forearm should be bent, and the limb placed in a position midway between pronation and supination; the fracture is then easily reduced by extension from the wrist and elbow: well-padded splints should be applied on both sides of the forearm from the elbow to the wrist; the hand being allowed to fall, will, by its own weight, counteract the action of the Pronator quadratus and Supinator longus, and elevate the lower fragment to the level of the upper one.

In fracture of the *shaft of the ulna* the upper fragment retains its usual position, but the lower fragment is drawn outward toward the radius by the Pronator quadratus, producing a well-marked depression at the seat of fracture and some fulness on the dorsal and palmar surfaces of the forearm. The fracture is easily reduced by extension from the wrist and forearm. The forearm should be flexed, and placed in a position midway between pronation and supination, and well-padded splints applied from the elbow to the ends of the fingers.

In fracture of the *shafts of the radius and ulna together* the lower fragments are drawn upward, sometimes forward, sometimes backward, according to the direction of the fracture, by the combined actions of the Flexor and Extensor muscles, producing a degree of fulness on the dorsal or palmar surface of the forearm; at the same time the two fragments are drawn into contact by the Pronator quadratus, the radius being in a state of pronation: the upper fragment of the radius is drawn upward and inward by the Biceps and Pronator radii teres to a higher level than the ulna; the upper portion of the ulna is slightly elevated by the Brachialis anticus. The fracture may be reduced by extension from the wrist and elbow, and the forearm should be placed in the same position as in fracture of the ulna.

In fracture of the *lower end of the radius* (Coles's fracture) (Fig. 336) the displacement which is produced is very considerable, and bears some resemblance to dislocation of the carpus backward, from which it should be carefully distinguished. The lower fragment is displaced backward and upward, but this displacement is probably due to the force of the blow driving the portion of the bone into this position and not to any muscular influence. The upper fragment projects forward, often lacerating the substance of the Pronator quadratus, and is drawn by this muscle into close contact with the lower end of the ulna, causing a projection on the anterior surface of the forearm, immediately above the carpus, from the flexor tendons being thrust forward. This fracture may be distinguished from dislocation by the deformity being removed on making sufficient extension, when crepitus may be occasionally detected; at the same time, on extension being discontinued, the parts immediately resume their deformed appearance. The age of the patient will also assist in determining whether the injury is fracture or separation of the epiphysis. Reduction is effected by hyperextension, longitudinal traction, and forced flexion. The posterior straight splint with suitable pads is the best dressing.

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1 R. J. Levis.
MUSCLES AND FASCIAE OF THE LOWER EXTREMITY.

The Muscles of the Lower Extremity are subdivided into groups corresponding with the different regions of the limb.

I. Iliac Region.

Psoas magnus.
Psoas parvus.
Iliacus.

II. Thigh.

1. Anterior Femoral Region.

Tensor fasciae Femoris.
Sartorius.
Rectus.
Quadiceps
Extensor.
Vastus externus.
Vastus internus.
Crureus.
Subcrureus.

2. Internal Femoral Region.

Gracilis.
Pectineus.
Adductor longus.
Adductor brevis.
Adductor magnus.

3. Gluteal Region.

Gluteus maximus.
Gluteus medius.
Gluteus minimus.
Pyriformis.
Obturator internus.
Gemellus superior.
Gemellus inferior.
Quadratus femoris.
Obturator externus.

4. Posterior Femoral Region.

Biceps.
Semitendinosus.
Semimembranosus.

III. Leg.

5. Anterior Tibio-fibular Region.

Tibialis anticus.
Extensor proprius hallucis.
Extensor longus digitorum.
Peroneus tertius.

6. Posterior Tibio-fibular Region.

Superficial Layer.
Gastrocnemius.
Soleus.
Plantaris.

Deep Layer.
Popliteus.
Flexor longus hallucis.
Flexor longus digitorum.
Tibialis posticus.

7. Fibular Region.

Peroneus longus.
Peroneus brevis.

IV. Foot.

8. Dorsal Region.

Extensor brevis digitorum.

9. Plantar Region.

First Layer.
Abductor hallucis.
Flexor brevis digitorum.
Abductor minimi digiti.

Second Layer.
Flexor accessorius.
Lumbricales.

Third Layer.
Flexor brevis hallucis.
Adductor obliquus hallucis.
Flexor brevis minimi digiti.
Adductor transversus hallucis.

Fourth Layer.
The Interossei.
I. MUSCLES AND FASCIAE OF THE ILIAC REGION.

Psoas magnus.  
Psoas parvus.  
Iliacus.

**Dissection.**—No detailed description is required for the dissection of these muscles. On the removal of the viscera from the abdomen they are exposed, covered by the peritoneum and a thin layer of fascia, the iliac fascia.

**Iliac Fascia** (*fascia iliaca*).—The iliac fascia¹ is the aponeurotic layer which lines the back part of the abdominal cavity, and covers the Psoas and Iliacus muscles throughout their whole extent. It is thin above, and becomes gradually thicker below as it approaches the crural arch.

The **Portion Covering the Psoas** is attached, above, to the ligamentum arcuatum internum; internally, by a series of arched processes to the intervertebral substances and prominent margins of the bodies of the vertebrae, and to the upper part of the sacrum, the intervals so left, opposite the constricted portions of the bodies, transmitting the lumbar arteries and veins and filaments of the sympathetic cord. Externally, above the crest of the ilium, this portion of the iliac fascia is continuous with the anterior lamella of the lumbar fascia, but below the crest of the ilium it is continuous with the fascia covering the Iliacus.

The **Portion Investing the Iliacus** is connected externally to the whole length of the inner border of the crest of the ilium, and internally to the brim of the true pelvis, where it is continuous with the periosteum; and at the ilio-pectineal eminence it receives the tendon of insertion of the Psoas parvus, when that muscle exists. External to the femoral vessels, this fascia is intimately connected to the posterior margin of Poupart’s ligament, and is continuous with the fascia transversalis. Immediately to the outer side of the femoral vessels the fascia iliaca is prolonged backward and inward from Poupart’s ligament as a band, the **ilio-pectineal**

¹ The student must not confound this fascia with the *iliac portion of the fascia lata* (see p. 517).
ligament, which is attached to the ilio-pectineal eminence. The ligament divides the space between Poupart’s ligament and the innominate bone into two parts, the inner of which (lacuna vasorum) transmits the femoral vessels, and contains the margin of Gimbernat’s ligament and also the femoral ring; the outer (lacuna musculorum) the ilio-psoas and the anterior crural nerve (Fig. 338). Internal to the vessels the iliac fascia is attached to the ilio-pectineal line behind the conjoined tendon, where it is again continuous with the transversalis fascia; and, corresponding to the point where the femoral vessels pass into the thigh, this fascia descends behind them, forming the posterior wall of the femoral sheath. This portion of the iliac fascia which passes behind the femoral vessels is also attached to the ilio-pectineal line beyond the limits of the attachment of the conjoined tendon; at this part it is continuous with the pubic portion of the fascia lata of the thigh. The external iliac vessels lie in front of the iliac fascia, but all the branches of the lumbar plexus behind it; it is separated from the peritoneum by a quantity of loose areolar tissue. The femoral or crural sheath (fascia cruris) is formed by the transversalis fascia in front of the vessels and the iliac fascia back of them. The fasciae join to the inner side of the femoral vein, a space, the femoral canal, intervening between the vein and their junction.

Between the femoral vein and the edge of Gimbernat’s ligament is the femoral or crural ring (annulus femoralis) (Fig. 340). The crural or femoral canal (canalis femoralis) is the interval between the femoral vein and the inner wall of the femoral (crural) sheath. This canal extends from the femoral ring to the saphenous opening. The femoral ring is closed by the septum crurale of Cloquet (septum femorale [Cloquet]), which is a process of transversalis fascia.
The Psoas Magnus (m. psoas major) (Fig. 341) is a long fusiform muscle placed on the side of the lumbar region of the spine and the margin of the pelvis. It arises from the front of the bases and lower borders of the transverse processes of the lumbar vertebrae by five fleshy slips; also from the sides of the bodies and the corresponding intervertebral substances of the last thoracic and all the lumbar vertebrae. The muscle is connected to the bodies of the vertebrae by five slips; each slip is attached to the upper and lower margins of two vertebrae, and to the intervertebral substance between them, the slips themselves being connected by the tendinous arches which extend across the constricted part of the bodies, and beneath which pass the lumbar arteries and veins and filaments of the sympathetic cord. These tendinous arches also give origin to muscular fibres, and protect the blood-vessels and nerves from pressure during the action of the muscle. The first slip is attached to the contiguous margins of the last thoracic and first lumbar vertebrae; the last to the contiguous margins of the fourth and fifth lumbar vertebrae, and to the intervertebral substance. From these points the muscle descends across the brim of the pelvis, and, diminishing gradually in size, passes beneath Poupart’s ligament, and terminates in a tendon which, after receiving nearly the whole of the fibres of the Iliacus, is inserted into the lesser trochanter of the femur.

Relations.—In the lumbar region: by its anterior surface, which is placed behind the peritoneum, with the iliac fascia, the ligamentum arcuatum internum, the kidney, Psoas parvus, renal vessels, ureter, spermatic vessels, genito-femoral nerve, and the colon. In many cases the vermiform appendix rests upon the Psoas muscle (page 513). By its posterior surface, with the transverse processes of the lumbar vertebrae and the Quadratus lumborum muscle, from which it is separated by the anterior lamella of the lumbar fascia. The lumbar plexus is situated in the posterior part of the substance of the muscle. By its inner side the muscle is in relation with the bodies of the lumbar vertebrae, the lumbar arteries, the ganglia of the sympathetic nerve, and their branches of communication with the spinal nerves; the lumbar glands; the vena cava inferior on the right and the aorta on the left side, and along the brim of the pelvis with the external iliac artery. In the thigh it is in relation, in front, with the fascia lata; behind, with the capsular ligament of the hip, from which it is separated by a synovial bursa (bursa iliopectinea), which frequently communicates with the cavity of the joint through an opening of variable size; between the tendon and part of the lesser trochanter is the bursa iliaca sub-tendinea; by its inner border, with the Pectineus and internal circumflex artery, and also with the femoral artery, which slightly overlaps it; by its outer border, with the anterior crural nerve and Iliacus muscle.

The Psoas Parvus (m. psoas minor) (Fig. 341) is a long slender muscle placed in front of the Psoas magnus. It arises from the sides of the bodies of the last thoracic and first lumbar vertebrae and from the intervertebral substance between them. It forms a small flat muscular bundle, which terminates in a long flat tendon inserted into the ilio-pectineal eminence, and, by its outer border, into the iliac fascia. This muscle is often absent, and, according to Cruveilhier, is sometimes double.

Relations.—It is covered by the peritoneum, and, at its origin, by the ligamentum arcuatum internum; it rests on the Psoas magnus.

The Iliacus (Fig. 341) is a flat, triangular muscle which fills up the whole of the iliac fossa. It arises from the upper two-thirds of this fossa and from the inner margin of the crest of the ilium; behind, from the ilio-lumbar ligament and base of the sacrum; in front, from the anterior superior and anterior inferior spinous processes of the ilium, from the notch between them. The fibres converge to be inserted into the outer side of the tendon of the Psoas, some of them being prolonged on to the shaft of the femur for about an inch below and in front of the
lesser trochanter. The most external fibres are inserted into the capsule of the hip-joint. If these fibres are separate they constitute the **Ilio-capsularis muscle** or the **Iliacus minor**.

**Relations.**—Within the **abdomen**: by its anterior surface, with the iliac fascia, which separates the muscle from the peritoneum, and with the external cutaneous nerve; on the right side, with the cecum; on the left side, with the sigmoid flexure of the colon; by its posterior surface, with the iliac fossa; by its inner border, with the Psoas magnus and femoral nerve. In the **thigh**, it is in relation, by its anterior surface, with the fascia lata, the Rectus and Sartorius muscles, and the profunda femoris artery; behind, with the capsule of the hip-joint, a synovial bursa common to it and the Psoas magnus being interposed.

**Nerves.**—The Psoas magnus is supplied by the anterior branches of the second and third lumbar nerves; the Psoas parvus, when it exists, is supplied by the anterior branch of the first lumbar nerve; and the Iliacus by the anterior branches of the second and third lumbar nerves through the femoral.

**Actions.**—The Psoas and Iliacus muscles, acting from above, flex the thigh upon the pelvis. Acting from below, the femur being fixed, the muscles of both sides bend the lumbar portion of the spine and pelvis forward. They also serve to maintain the erect position, by supporting the spine and pelvis upon the femur, and assist in raising the trunk when the body is in the recumbent posture.

The **Psoas parvus** is a tensor of the iliac fascia. It assists in flexing the lumbar spine laterally, the pelvis being its fixed point.

**Surgical Anatomy.**—There is no definite septum between the portions of the iliac fascia covering the Psoas and Iliacus respectively, and the fascia is only connected to the subjacent muscles by a quantity of loose connective tissue. When an abscess forms beneath this fascia, as it is very apt to do, the matter is contained in an osseo-fibrous cavity, which is closed on all sides within the abdomen, and is open only at its lower part, where the fascia is prolonged over the muscle into the thigh.

Abscess within the sheath of the Psoas muscle (psoas abscess) is generally due to tuberculous caries of the bodies of the lower thoracic or of the lumbar vertebrae. When the disease is in the thoracic region, the matter tracts down the posterior mediastinum, in front of the bodies of the vertebrae, and, passing beneath the ligamentum aequal tum internum, enters the sheath of the Psoas muscle, down which it passes as far as the pelvic brim; it then gets beneath the iliac portion of the fascia and fills up the iliac fossa. In consequence of the attachment of the fascia to the pelvic brim, it rarely finds its way into the pelvis, but passes by a narrow opening under Poupart’s ligament into the thigh, to the outer side of the femoral vessels. It thus follows that a Psoas abscess may be described as consisting of four parts: (1) a somewhat narrow channel at its upper part, in the Psoas sheath; (2) a dilated sac in the iliac fossa; (3) a constricted neck under Poupart’s ligament; and (4) a dilated sac in the upper part of the thigh. When the lumbar vertebrae are the seat of the disease, the matter finds its way directly into the substance of the muscle. If a Psoas abscess forms the muscular fibres are destroyed, and the nervous cords contained in the abscess are isolated and exposed in its interior; the femoral vessels which lie in front of the fascia remain intact, and the peritoneum seldom becomes complicated. All Psoas abscesses do not, however, pursue this course; the matter may leave the muscle above the crest of the ilium, and, tracking backward, may point in the loin (lumbar abscess); or it may point above Poupart’s ligament in the inguinal region; or it may follow the course of the iliac vessels into the pelvis, and, passing through the great sacro-sciatic notch, discharge itself on the back of the thigh; it may open into the bladder or find its way into the perineum, or it may pass down the thigh to the popliteal space or even lower.

*Strain* of the Psoas muscle is not unusual, and induces pain which may be mistaken for appendicitis. The *bursa* beneath the tendon of the Psoas and Iliacus and the hip-joint or that between the tendon and the lesser trochanter may greatly enlarge and produce pain and disablement. Byron Robinson pointed out that trauma of the Psoas muscle may be an important factor in the etiology of appendicitis, trauma may induce periappendicular adhesions and adhesions interfere with the circulation of blood and faeces. Robinson says, in the previously quoted article, that in 46 per cent. of men and in 20 per cent. of women the appendix rests on the Psoas muscle.

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1. The Psoas magnus, Psoas parvus, and Iliacus are regarded by His and others as a single muscle, the *Ilio-psoas* (Fig. 338).
II. MUSCLES AND FASCIAE OF THE THIGH.

1. The Anterior Femoral Region.

<table>
<thead>
<tr>
<th>Tensor fasciae femoris</th>
<th>Quadriceps extensor</th>
<th>Rectus.</th>
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<tr>
<td>Sartorius</td>
<td>Vastus externus</td>
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<td></td>
<td>Vastus internus</td>
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<tr>
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<td>Crureus</td>
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Subcureus.

Dissection.—To expose the muscles and fasciae in this region, make an incision along Poupart’s ligament, from the anterior superior spine of the ilium to the spine of the os pubis; a vertical incision from the centre of this, along the middle of the thigh to below the knee-joint; and a transverse incision from the inner to the outer side of the leg, at the lower end of the vertical incision. The flaps of integument having been removed, the superficial and deep fasciae should be examined. The more advanced student should commence the study of this region by an examination of the anatomy of femoral hernia and Scarpa’s triangle, the incisions for the dissection of which are marked out in Fig. 339.

Superficial Fascia.—The superficial fascia forms a continuous layer over the whole of the thigh. It consists of areolar tissue, containing in its meshes much fat, and is capable of being separated into two or more layers, between which are found the superficial vessels and nerves. It varies in thickness in different parts of the limb: in the groin it is thick, and the two layers are separated from one another by the superficial inguinal lymphatic glands, the internal saphenous vein, and several smaller vessels. One of these two layers, the superficial, is continuous above with the superficial fascia of the abdomen and the back. Internally it is continuous with the superficial fascia of the perineum. The deep layer of the superficial fascia is a very thin fibrous layer, best marked on the inner side of the long saphenous vein and below Poupart’s ligament. It is placed beneath the subcutaneous vessels and nerves and upon the surface of the fascia lata. It is intimately adherent to the fascia lata a little below Poupart’s ligament. It covers the saphenous opening (Fig. 340) in the fascia lata, being closely united to the margins of the opening, and is connected to the sheath of the femoral vessels by its under surface. The portion of the fascia covering this aperture is perforated by the internal saphenous vein and by numerous blood- and lymphatic vessels; hence it has been termed the cribriform fascia (fascia cribrosa), the openings for these vessels having been likened to the holes in a sieve. The cribriform fascia adheres closely both to the superficial fascia and to the fascia lata, so that it is described by some anatomists as part of the fascia lata, but is usually considered (as in this work) as belonging to the superficial fascia. It is not until the cribriform fascia has been cleared away that the saphenous opening is seen, so that this opening does not in ordinary cases exist naturally, but is the result of dissection. Mr.
Caliender, however, speaks of cases in which, probably as the result of pressure from enlarged inguinal lymphatic glands, the fascia has become atrophied, and a saphenous opening exists independent of dissection. A femoral hernia in passing through the saphenous opening receives the cribriform fascia as one of its coverings. A large subcutaneous bursa (bursa praepatellaris subcutanea) is found in the superficial fascia over the patella, and another (bursa trochanterica subcutanea) in the superficial fascia over the great trochanter.

Deep Fascia or Fascia Lata (Fig. 340).—The deep fascia of the thigh is exposed on the removal of the superficial fascia, and is named, from its great extent, the fascia lata; it forms a uniform investment for the whole of this region of the limb, but varies in thickness in different parts; thus, it is thicker in the upper and outer part of the thigh, where it receives a fibrous expansion from the Gluteus maximus muscle, and the Tensor fasciae latae is inserted between its layers: it is very thin behind, and at the upper and inner part where it covers the Adductor muscles, and again becomes stronger around the knee, receiving fibrous expansions from the tendon of the Biceps externally, from the Sartorius internally, and from the Quadriceps extensor in front. The fascia lata is attached, above and behind, to the back of the sacrum and coccyx; externally, to the crest of the ilium; in front, to Poupart's ligament and to the body of the os pubis; and internally, to the descending ramus of the os pubis, to the ramus and tuberosity of the ischium, and to the lower border of the great sacro-sciatic ligament. From its attachment to the crest of the ilium it passes down over the Gluteus medius muscle to the upper border of the Gluteus maximus, where it splits into two layers, one passing superficial to and the other beneath this muscle. At the lower border of the muscle the two layers reunite. Externally the fascia lata receives the greater part of the tendon of insertion of the Gluteus maximus, and becomes proportionately thickened. The portion of the fascia lata arising from the front part of the crest of the ilium, cor-
responding to the origin of the Tensor fasciae femoris, passes down the outer side of the thigh as two layers, one superficial to and the other beneath this muscle. The deep layer is a continuation of the tendinous fibres of the Gluteus maximus muscle and the superficial layer is chiefly a continuation of the tendinous fibres of the Tensor fasciae femoris, but receives some fibres from the fascia covering the Gluteus medius muscle. These layers at the lower end of the muscle become blended into a thick and strong band, having first received the insertion of the muscle. This band is continued downward, under the name of the ilio-tibial band (tractus ilirotibialis [Maissiat]), to be inserted into the external tuberosity of the tibia. A strengthening band of transverse fibres is placed in the gluteal groove or sulcus (sulcæ gluteæ) and another is placed across the roof of the popliteal space. Below, the fascia lata is attached to all the prominent points around the knee-joint—viz., the condyles of the femur, tuberosities of the tibia, and head of the fibula. On each side of the patella it is strengthened by transverse fibres given off from the lower part of the Vasti muscles, which are attached to and support this bone. Of these the outer fibres are the stronger, and are continuous with the ilio-tibial band. From the inner surface of the fascia lata are given off two strong intermuscular septa, which are attached to the whole length of the linea aspera and its prolongations above and below: the external intermuscular septum (septum intermusculare laterale) is the stronger. It extends from the insertion of the Gluteus maximus to the outer condyle, separates the Vastus externus in front from the short head of the Biceps behind, and gives partial origin to these muscles; the internal intermuscular septum (septum intermusculare mediale), the thinner of the two, separates the Vastus internus from the Adductor and Pectineus muscles. Besides these there are numerous smaller septa, separating the individual muscles and enclosing each in a distinct sheath. At the upper and inner part of the thigh, a little below Poupart's ligament, a large oval-shaped aperture is observed after the superficial fascia has been cleared off: it transmits the internal saphenous vein and other smaller vessels, and is termed the saphenous opening (fossa ovalis) (Fig. 340). This opening is covered by a portion of the deep layer of the

superficial fascia, the *cribriform fascia*. In order more correctly to consider the mode of formation of this aperture, the fascia lata in this part of the thigh is described as consisting of two portions—an iliac portion and a pubic portion.

**Iliac Portion.**—The iliac portion, the *superficial layer of the fascia lata* or the Sartorial portion of the fascia lata, is all that part of the fascia lata on the outer side of the saphenous opening. It is attached, externally, to the crest of the ilium and its anterior superior spine, to the whole length of Poupart’s ligament as far internally as the spine of the os pubis, and to the pectineal line in conjunction with Gimbernat’s ligament. From the spine of the os pubis it is reflected downward and outward, forming an arched margin, the *falciform process* or the *falciform margin of Burns* (*margo falciformis*), or the *superior cornu of the saphenous opening* (*cornu superior*). This margin overlies and is adherent to the anterior layer of the sheath of the femoral vessels: to its edge is attached the *cribriform fascia*; and, below, it is continuous with the pubic portion of the fascia lata. The *femoral ligament*, or the ligament of Hey, is the point at which the falciform process joins the base of Gimbernat’s ligament.

**Public Portion.**—The public portion, or the pectineal portion, or the *deep layer of the fascia lata*, is situated at the inner side of the saphenous opening: at the lower margin of this aperture it is continuous with the iliac portion. The lower concave margin of the saphenous opening where the two layers of fascia are continuous is called the *inferior cornu* (*cornu inferior*). Traced upward, the pubic portion covers the surface of the Pectineus, Adductor longus, and Gracilis muscles, and, passing behind the sheath of the femoral vessels, to which it is closely united, is continuous with the sheath of the Psoas and Iliacus muscles, and is attached above to the ilio-pectineal line, where it becomes continuous with the iliac fascia. From this description it may be observed that the iliac portion of the fascia lata passes in front of the femoral vessels, and the pubic portion behind them, so that an apparent aperture exists between the two, through which the internal saphenous joins the femoral vein.¹

**Surgical Anatomy.**—The *ilio-tibial* band at a point between the crest of the ilium and the great trochanter is so tense that it is impossible to sink the fingers in deeply in this region. Dr. Allis points out that in fracture of the neck of the femur the great trochanter mounts toward the iliac crest, the ilio-tibial band relaxes, and the fingers can be sunk deeply into the space between the great trochanter and the iliac crest—*Allis’s sign*. Allis’s sign indicates shortening. A *Psoas abscess* usually points at the termination of the Psoas muscle, but the tuberculous matter may be directed down the thigh beneath the fascia lata, and it may reach the popliteal space or even lower.

The fascia should now be removed from the surface of the muscles. This may be effected by pinching it up between the forceps, dividing it, and separating it from each muscle in the course of its fibres.

The *Tensor Fasciae Femoris* (*m. tensor fasciae latae, m. tensor vaginae femoris*) (Fig. 341) arises from the anterior part of the outer lip of the crest of the ilium, and from the outer surface of the anterior superior spinous process, and part of the outer border of the notch below it, between the Gluteus medius and Sartorius, and from the surface of the fascia covering the Gluteus medius. It is inserted between two layers of the fascia lata, about one-fourth down the outer side of the thigh. From the point of insertion the fascia is continued downward to the external tuberosity of the tibia as a thickened band, the *ilio-tibial band*.

**Relations.**—By its superficial surface, with the fascia lata and the integument; by its deep surface, with the Gluteus medius, Rectus femoris, and Vastus externus muscles, and the ascending branches of the external circumflex artery; by its anterior border, with the Sartorius, from which it is separated below by a triangular

¹ These parts will be again more particularly described with the anatomy of Hernia.
space, in which is seen the Rectus femoris; by its posterior border, with the Gluteus medius.

The Sartorius (Fig. 341), the longest muscle in the body, is flat, narrow, and ribbon-like; it arises by tendinous fibres from the anterior superior spinous process of the ilium and the upper half of the notch below it, passes obliquely across the upper and anterior part of the thigh, from the outer to the inner side of the limb, then descends vertically, as far as the inner side of the knee, passing behind the inner condyle of the femur, and terminates in a tendon which, curving obliquely forward, expands into a broad aponeurosis, inserted in front of the Gracilis and Semitendinosus, into the upper part of the inner surface of the shaft of the tibia, nearly as far forward as the crest. The upper part of the tendon is curved backward over the upper edge of the tendon of the Gracilis so as to be inserted behind it. An offset is derived from the upper margin of this aponeurosis, which blends with the fibrous capsule of the knee-joint, and another, given off from its lower border, blends with the fascia on the inner side of the leg.

The relations of this muscle to the femoral artery should be carefully examined, as it constitutes the chief guide in tying the vessel. In the upper third of the thigh it forms the outer side of a triangular space, Scarpa's triangle (trigonum femorale), the inner side of which is formed by the inner border of the Adductor longus, and the base, which is turned upward, by Poupard's ligament; the femoral artery passes perpendicularly through the middle of this space from its base to its apex. In the middle third of the thigh the femoral artery lies first along the inner border, and then behind the Sartorius.

Relations.—By its superficial surface, with the fascia lata and integument; by its deep surface, with the Rectus, Iliacus, Vastus internus, femoral nerve, sheath of the femoral vessels, Adductor longus, Adductor magnus, Gracilis, Semitendinosus, long saphenous nerve, and internal lateral ligament of the knee-joint. Frequently there is a bursa (bursa m. sartorii propria) between the tendon of the Sartorius and the tendons of the Gracilis and Semimembranosus. It may be in communication with the bursa anserina.

The Quadriceps Extensor (m. quadriceps femoris) (Fig. 341) includes the four remaining muscles on the front of the thigh. It is the great Extensor muscle of the leg, forming a large fleshy mass which covers the front and sides of the femur, being united below into a single tendon, attached to the patella, and above subdivided into separate portions, which have received distinct names. Of these, one occupying the middle of the thigh, connected above with the ilium, is called the Rectus femoris, from its straight course. The other divisions lie in immediate connection with the shaft of the femur, which they cover from the trochanters to the condyles. The portion on the outer side of the femur is termed the Vastus externus; that covering the inner side, the Vastus internus; and that covering the front of the femur, the Orureus.

The Rectus Femoris is situated in the middle of the anterior region of the thigh; it is fusiform in shape, and its superficial fibres are arranged in a bipenniform manner, the deep fibres running straight down to the deep aponeurosis. It arises by two tendons: one, the anterior or straight, from the anterior inferior spinous process of the ilium; the other, the posterior or reflected tendon, from a groove above the brim of the acetabulum; the two unite at an acute angle and spread into an aponeurosis, which is prolonged downward on the anterior surface of the muscle and from which the muscular fibres arise. The muscle terminates in a broad and thick aponeurosis, which occupies the lower two-thirds of its posterior surface, and, gradually becoming narrowed into a flattened tendon, is inserted

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1 Mr. W. R. Williams, in an interesting paper in the Journ. of Anat. and Phys., vol. xiii. p. 204, points out that the reflected tendon is the real origin of the muscle, and is alone present in early foetal life. The direct tendon is merely an accessory band of condensed fascia. The paper will well repay perusal, though in some particulars I think the description in the text more generally accurate.—Ed. of 15th English edition.
THE ANTERIOR FEMORAL REGION

Fig. 342.—Transverse section of the thigh below the trochanter minor. (After Braune.)

Fig. 343.—Transverse section at the middle of the leg. In front of the interosseous membrane are the anterior tibial vessels and nerve; in front of the soleus, the posterior tibial vessels and nerve; and close to the fibula, the peroneal vessels. (After Braune.)
into the patella in common with the Vasti and Crureus. Between the tendon of origin and the acetabulum there is often a bursa (bursa m. recti femoris).

**Relations.**—By its superficial surface, with the anterior fibres of the Gluteus minimus, the Tensor fasciae femoris, the Sartorius, and the Iliacus; by its lower three-fourths, with the fascia lata. By its posterior surface, with the hip-joint, the external circumflex vessels, branches of the femoral nerve, and the Crureus and Vasti muscles.

The **Vastus Externus** (*m. vastus lateralis*) is the largest part of the Quadriceps extensor. It arises by a broad aponeurosis, which is attached to the upper half of the anterior intertrochanteric line, to the anterior and inferior borders of the root of the great trochanter, to the outer lip of the gluteal ridge, and to the upper half of the outer lip of the linea aspera; this aponeurosis covers the upper three-fourths of the muscle, and from its inner surface many fibres take origin. A few additional fibres arise from the tendon of the Gluteus maximus, and from the external intermuscular septum between the Vastus externus and short head of the Biceps. The fibres form a large fleshy mass, which is attached to a strong aponeurosis, placed on the under surface of the muscle at its lower part: this becomes contracted and thickened into a flat tendon, which is inserted into the outer border of the patella, blending with the great Extensor tendon, and giving an expansion to the capsule of the knee-joint. Some of the fibres run down by the side of the patella to the condyle of the tibia, and are called the retinacula patellae laterale.

**Relations.**—By its superficial surface, with the Rectus, the Tensor fasciae femoris, the fascia lata, and the tendon of the Gluteus maximus, from which it is separated by a synovial bursa. By its deep surface, with the Crureus, some large branches of the external circumflex artery and femoral nerve being interposed.

The **Vastus Internus** and **Crureus** appear to be inseparably united, but when the Rectus femoris has been reflected, a narrow interval will be observed extending upward from the inner border of the patella between the two muscles. Here they can be separated, and the separation should be continued upward as far as the lower part of the anterior intertrochanteric line, where, however, the two muscles are frequently continuous.

The **Vastus Internus** (*m. vastus medialis*) arises from the lower half of the anterior intertrochanteric line, the spiral line, the inner lip of the linea aspera, the upper part of the internal supra-condylar line, and the tendon of the Adductor magnus and the internal intermuscular septum. Its fibres are directed downward and forward, and are chiefly attached to an aponeurosis which lies on the deep surface of the muscle and is inserted into the inner border of the patella and the Quadriceps extensor tendon, an expansion being sent to the capsule of the knee-joint. Some of the fibres run down by the side of the patella to the condyle of the tibia and are called the retinacula patellae mediale.

The **Crureus** (*m. vastus intermedius*) arises from the front and outer aspect of the shaft of the femur in its upper two-thirds and from the lower part of the external intermuscular septum. Its fibres end in a superficial aponeurosis, which forms the deep part of the Quadriceps extensor tendon.

**Relations.**—The inner edge of the Crureus is in contact with the anterior edge of the Vastus internus, but when separated from each other, as directed above, the latter muscle is seen merely to overlap the inner aspect of the femoral shaft without taking any fibres of origin from it. The Vastus internus is partly covered by the Rectus and Sartorius, but where these separate near the knee it becomes superficial, and produces a well-marked prominence above the inner aspect of the knee. In the middle third of the thigh it forms the outer wall of Hunter's canal (*canalis adductorius* [Hunteri]), which contains the femoral vessels and the long saphenous nerve—the roof of the canal being formed by a strong fascia which extends from
the Vastus internus to the Adductores longus and magnus. The Crureus is almost completely hidden by the Rectus femoris and Vastus externus. The deep surface of the two muscles is in relation with the femur and Subcrureus muscles. A synovial bursa (bursa suprapatellaris) is situated between the femur and the portion of the Quadriceps extensor tendon above the patella; in the adult it communicates with the synovial cavity of the knee-joint.

The tendons of the different portions of the Quadriceps extensor unite at the lower part of the thigh, so as to form a single strong tendon, which is inserted into the upper part of the patella, some few fibres passing over it to blend with the Ligamentum patellae. More properly, the patella may be regarded as a sesamoid bone, developed in the tendon of the Quadriceps; and the Ligamentum patellæ, which is continued from the lower part of the patella to the tuberosity of the tibia, as the proper tendon of insertion of the muscle. A synovial bursa, the deep patellar bursa (bursa infrapatellaris profunda), is interposed between the tendon and the upper part of the tuberosity of the tibia; and another, the pre-patellar bursa (bursa praepatellaris subcutanea), is placed over the patella itself. This latter bursa often becomes enlarged, constituting "housemaid's knee."

The Subcrureus (m. articularis genu) is a small muscle, usually distinct from the Crureus, but occasionally blended with it, which arises from the anterior surface of the lower part of the shaft of the femur, and is inserted into the upper part of the cul-de-sac of the capsular ligament which projects upward beneath the Quadriceps for a variable distance. It sometimes consists of several separate muscular bundles.

Nerves.—The Tensor fasciae latae is supplied by the fourth and fifth lumbar and first sacral nerves through the superior gluteal nerve; the other muscles of this region, by the second, third, and fourth lumbar nerves, through branches of the femoral.

Actions.—The Tensor fasciae latae is a tensor of the fascia lata; continuing its action, the oblique direction of its fibres enables it to abduct and to rotate the thigh inward. In the erect posture, acting from below, it will serve to steady the pelvis upon the head of the femur; and by means of the ilio-tibial band it steadies the condyles of the femur on the articular surfaces of the tibia, and assists the Gluteus maximus in supporting the knee in the extended position. The Sartorius flexes the leg upon the thigh, and, continuing to act, flexes the thigh upon the pelvis; it next rotates the thigh outward. It was formerly supposed to adduct the thigh, so as to cross one leg over the other, and hence received its name of Sartorius, or tailor's muscle (sartor, a tailor), because it was supposed to assist in crossing the legs in the squatting position. When the knee is bent the Sartorius assists the Semitendinosus, Semimembranosus, and Popliteus in rotating the tibia inward. Taking its fixed point from the leg, it flexes the pelvis upon the thigh, and, if one muscle acts, assists in rotating the pelvis. The Quadriceps extensor extends the leg upon the thigh. The Rectus muscle assists the Psoas and Iliacus in supporting the pelvis and trunk upon the femur. It also assists in flexing the thigh on the pelvis, or if the thigh is fixed it will flex the pelvis. The Vastus internus draws the patella inward as well as upward.

Surgical Anatomy.—A few fibres of the Rectus muscle are liable to be ruptured from severe strain. This accident is especially liable to occur during the games of football and cricket, and is sometimes known as cricket thigh. The patient experiences a sudden pain in the part, as if he had been struck, and the Rectus muscle stands out and is felt to be tense and rigid. The accident is often followed by considerable swelling from inflammatory effusion. Occasionally the Quadriceps extensor may be torn away from its insertion into the patella, or the tendon of the quadriceps may be ruptured about an inch above the bone. This accident is caused in the same manner that fracture of the patella by muscular action is produced—viz., by a violent muscular effort to prevent falling whilst the knee is in a position of semiflexion. A distinct gap can be
felt above the patella, and, owing to the retraction of the muscular fibres, union may fail to take place. Sudden and powerful contraction of the Quadriceps extensor femoris is the cause of transverse fracture of the patella.

2. The Internal Femoral Region.

<table>
<thead>
<tr>
<th>Gracilis</th>
<th>Adductor longus.</th>
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<tr>
<td>Pectineus</td>
<td>Adductor brevis.</td>
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<tr>
<td>Adductor magnus.</td>
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Dissection.—These muscles are at once exposed by removing the fascia from the forepart and inner side of the thigh. The limb should be abducted, so as to render the muscles tense and easier of dissection.

The Gracilis (Figs. 341, 346, and 349) is the most superficial muscle on the inner side of the thigh. It is thin and flattened, broad above, narrowing and tapering below. It arises by a thin aponeurosis from the lower half of the margin of the symphysis and the anterior half of the pubic arch. The fibres pass vertically downward, and terminate in a rounded tendon which passes behind the internal condyle of the femur, and, curving round the inner tuberosity of the tibia, becomes flattened, and is inserted into the upper part of the inner surface of the shaft of the tibia, below the tuberosity. A few of the fibres of the lower part of the tendon are prolonged into the deep fascia of the leg. The tendon of this muscle is situated immediately above that of the Semitendinosus, and its upper edge is overlapped by the tendon of the Sartorius, with which it is in part blended. As it passes across the internal lateral ligament of the knee-joint it is separated from it by a synovial bursa (bursa anserina) common to it and the Semitendinosus muscle.

Relations.—By its superficial surface, with the fascia lata and the Sartorius below: the internal saphenous vein crosses it obliquely near its lower part, lying superficial to the fascia lata; the internal saphenous nerve emerges between its tendon and that of the Sartorius; by its deep surface, with the Adductor brevis and the Adductor magnus and the internal lateral ligament of the knee-joint.

The Pectineus (Fig. 341) is a flat, quadrangular muscle, situated at the anterior part of the upper and inner aspect of the thigh. It arises from the linea ilipectine and, to a slight extent from the surface of the bone in front of it between the pectineal eminence and spine of the os pubis, and from the fascia covering the anterior surface of the muscle; the fibres pass downward, backward, and outward, to be inserted into a rough line leading from the lesser trochanter to the linea aspera.

Relations.—By its anterior surface, with the pubic portion of the fascia lata, which separates it from the femoral vessels and internal saphenous vein; by its posterior surface, with the capsular ligament of the hip-joint, the Adductor brevis and Obturator externus muscles, the obturator vessels and nerve being interposed; by its outer border, with the Psoas, a cellular interval separating them, through which pass the internal circumflex vessels; by its inner border, with the margin of the Adductor longus. There is usually a bursa (bursa m. pectinei) between the pectineus and the tendon of the psoas and iliacus.

The Adductor Longus (Figs. 341 and 344), the most superficial of the three Adductors, is a flat triangular muscle lying on the same plane as the Pectineus. It arises, by a flat narrow tendon, from the front of the os pubis, at the angle of junction of the crest with the symphysis; and soon expands into a broad fleshy belly, which, passing downward, backward, and outward, is inserted, by an aponeurosis, into the linea aspera, between the Vastus internus and the Adductor magnus, with both of which it is usually blended.

Relations.—By its anterior surface, with the fascia lata, the Sartorius, and, near its insertion, with the femoral artery and vein; by its posterior surface, with the Adductor brevis and magnus, the anterior branches of the obturator nerve, and
with the profunda artery and vein near its insertion; by its outer border, with the Pectineus; by its inner border, with the Gracilis.

The Pectineus and Adductor longus should now be divided near their origin, and turned downward, when the Adductor brevis and Obturator externus will be exposed.

The Adductor Brevis (Fig. 344) is situated immediately behind the two preceding muscles. It is somewhat triangular in form, and arises by a narrow origin from the outer surface of the body and descending ramus of the os pubis, between the Gracilis and Obturator externus. Its fibres passing backward, outward, and downward, are inserted, by an aponeurosis, into the lower part of the line leading from the lesser trochanter to the linea aspera and the upper part of the same line, immediately behind the Pectineus and upper part of the Adductor longus.

Relations.—By its anterior surface, with the Pectineus, Adductor longus, profunda femoris artery, and anterior branches of the obturator nerve; by its posterior surface, with the Adductor magnus and posterior branch of the obturator nerve; by its outer border, with the internal circumflex artery, the Obturator externus, and conjoined tendon of the Psoas and Iliacus; by its inner border, with the Gracilis and Adductor magnus. This muscle is pierced, near its insertion, by the second or by the first and second perforating branches of the profunda femoris artery.

The Adductor brevis should now be cut away near its origin, and turned outward, when the entire extent of the Adductor magnus will be exposed.

The Adductor Magnus (Fig. 344) is a large triangular muscle forming a septum between the muscles on the inner and those on the back of the thigh. It arises from a small part of the descending ramus of the os pubis, from the ramus of the ischium, and from the outer margin of the inferior part of the tuberosity of the ischium. Those fibres which arise from the ramus of the os pubis are very short, horizontal in direction, and are inserted into the rough line leading from the great trochanter to the linea aspera, internal to the Gluteus maximus. They are considered by some a distinct muscle and called the Adductor minimus. The fibres taking origin from the ramus of the ischium are directed downward and outward

FIG. 344.—Deep muscles of the internal femoral region.
with different degrees of obliquity, to be inserted, by means of a broad aponeurosis, into the linea aspera and the upper part of its internal prolongation below. The **internal portion** of the muscle, consisting principally of those fibres which arise from the tuberosity of the ischium, forms a thick fleshy mass consisting of coarse bundles which descend almost vertically, and terminate about the lower third of the thigh in a rounded tendon, which is inserted into the Adductor tubercle on the inner condyle of the femur, being connected by a fibrous expansion to the line leading upward from the tubercle to the linea aspera. Between the two portions of the muscle an interval is left, tendinous in front, fleshy behind, for the passage of the femoral vessels from Hunter's canal into the popliteal space. The **external portion** of the muscle at its attachment to the femur presents three or four osseo-aponeurotic openings, formed by tendinous arches attached to the bone, from which muscular fibres arise. The three superior of these apertures are for the three perforating arteries, and the fourth, when it exists, is for the terminal branch of the profunda.

**Relations.**—By its anterior surface, with the Pectineus, Adductor brevis, Adductor longus, and the femoral and profunda vessels and obturator nerve; by its posterior surface, with the great sciatic nerve, the Gluteus maximus, Biceps, Semitendinosus, and Semimembranosus. By its superior or shortest border it lies parallel with the Quadratus femoris, the internal circumflex artery passing between them; by its internal or longest border, with the Gracilis, Sartorius, and fascia lata; by its external or attached border it is inserted into the femur behind the Adductor brevis and Adductor longus, which separate it from the Vastus internus, and in front of the Gluteus maximus and short head of the Biceps, which separate it from the Vastus externus.

**Nerves.** The three Adductor muscles and the Gracilis are supplied by the third and fourth lumbar nerves through the obturator nerve; the Adductor magnus receiving an additional branch from the sacral plexus through the great sciatic. The Pectineus is supplied by the second, third, and fourth lumbar nerves through the femoral, and by the accessory obturator, from the third lumbar, when it exists. Occasionally it receives a branch from the obturator nerve.

**Actions.**—The Pectineus and three Adductors adduct the thigh powerfully; they are especially used in horse exercise, the flanks of the horse being grasped between the knees by the actions of these muscles. In consequence of the obliquity of their insertion into the linea aspera they rotate the thigh outward, assisting the external Rotators, and when the limb has been abducted they draw it inward, carrying the thigh across that of the opposite side. The Pectineus and Adductor brevis and longus assist the Psoas and Iliacus in flexing the thigh upon the pelvis. In progression, also, all these muscles assist in drawing forward the hinder limb. The Gracilis assists the Sartorius in flexing the leg and rotating it inward; it is also an adductor of the thigh. If the lower extremities are fixed, these muscles may take their fixed point from below and act upon the pelvis, serving to maintain the body in an erect posture, or, if their action is continued, to flex the pelvis forward upon the femur.

**Hunter's Canal** (canalis adductorius [Hunteri]) extends from the apex of Scarpa's triangle to the opening in the Adductor magnus muscle. The antero-internal boundary or roof of Hunter's canal is the Sartorius and the aponeurotic expansion from the Adductors to the Vastus internus. It is bounded externally by the Vastus internus. The Adductor longus and Magnus constitute its floor or the postero-internal boundary. The canal contains the femoral artery, femoral vein, the long saphenous nerve, and the nerve to the Vastus internus. The anterior opening of Hunter's canal is called the **hiatus tendineus**.

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1 Professor Paterson describes the Pectineus as consisting of two incompletely separated strata, of which the outer or dorsal stratum, which is constant, is supplied by the anterior crural nerve, or in its absence by the accessory obturator, with which it is intimately related; while the inner or ventral stratum, when present, is supplied by the obturator nerve.—Journ. of Anat. and Phys., vol. xxvi. p. 43.—Ed. of 15th English edition.
Surgical Anatomy.—The Adductor longus is liable to be severely strained in those who ride much on horseback, or its tendon to be ruptured by suddenly gripping the saddle. Occasionally, especially in cowboys and cavalry soldiers, the tendon of insertion of the Adductor magnus may become ossified, constituting the rider's bone.

THE MUSCLES AND FASCIAE OF THE HIP.

3. The Gluteal Region (Figs. 346, 347).

Gluteus maximus.  
Gluteus medius.  
Gluteus minimus.  
Pyriformis.  
Obturator internus.  
Gemellus superior.  
Gemellus inferior.  
Quadratus femoris.  
Obturator externus.

Dissection (Fig. 345).—The subject should be turned on its face, a block placed beneath the pelvis to make the buttocks tense, and the limbs allowed to hang over the end of the table, with the foot inverted and the thigh abducted. Make an incision through the integument along the crest of the ilium to the middle of the sacrum, and thence downward to the tip of the coccyx, and carry a second incision from that point obliquely downward and outward to the outer side of the thigh, four inches below the great trochanter. The portion of integument included between these incisions is to be removed in the direction shown in the figure.

The Gluteus Maximus (m.glutaeus maximus) (Fig. 346), the most superficial muscle in the gluteal region, is a very broad and thick, fleshy mass of a quadrilateral shape, which forms the prominence of the buttck. Its large size is one of the most characteristic points in the muscular system of man, connected as it is with the power he has of maintaining the trunk in the erect posture. In structure the muscle is remarkably coarse, being made up of muscular fasciculi lying parallel with one another, and collected together into large bundles, separated by deep cellular intervals. It arises from the superior curved line of the ilium and the portion of bone, including the crest, immediately above and behind it; from the posterior surface of the lower part of the sacrum, the side of the coccyx, the aponeurosis of the Erector spinae muscle, the great sacro-scatic ligament, and the fascia covering the Gluteus medius. The fibres are directed obliquely downward and outward; those forming the upper and large portion of the muscle, together with the superficial fibres of the lower portion, terminate in a thick tendinous lamina, which passes across the great trochanter and is inserted into the fascia lata covering the outer side of the thigh; the deeper fibres of the lower portion of the muscles are inserted into the rough, line leading from the great trochanter to the linea aspera between the Vastus externus and Adductor magnus.

Fig. 345.—Dissection of lower extremity. Posterior view.
Several synovial bursae are found in relation with this muscle. One of these (bursa trochanterica m. glutaei maximii), of large size, and generally multilocular, separates it from the great trochanter. A second (bursa ischiadica m. glutaei maximii), often wanting, is situated on the tuberosity of the ischium. A third bursa is found between the tendon of this muscle and the Vastus externus. Two or three small bursae (bursae glutaeofemorales) are placed between the tendon of the muscle and the gluteal ridge.

Relations.—By its superficial surface, with a thin fascia, which separates it from the subcutaneous tissue; by its deep surface, from above downward, with the ilium, sacrum, coccyx, and great sacro-sciatic ligament, part of the Gluteus medius, Pyriformis, Genelli, Obturator internus, Quadratus femoris, the tuberosity of the ischium, great trochanter, the origin of the Biceps, Semitendinosus, Semimembranosus, and Adductor magnus muscles. The superficial part of the gluteal artery reaches the deep surface of the muscle by passing between the Pyriformis and the Gluteus medius; the sciatic and internal pudic vessels and nerves and muscular branches from the sacral plexus issue from the pelvis below the Pyriformis. The first perforating artery and the terminal branches of the internal circumflex artery are also found under cover of the muscle. Its upper border is thin, and connected with the Gluteus medius by the fascia lata. Its lower border is free and prominent.

Dissection.—Divide the Gluteus maximus near its origin by a vertical incision carried from its upper to its lower border; a cellular interval will be exposed, separating it from the Gluteus medius and External rotator muscles beneath. The upper portion of the muscle is to be altogether detached, and the lower portion turned outward; the loose areolar tissue filling up the interspace between the trochanter major and tuberosity of the ischium being removed, the parts already enumerated as exposed by the removal of this muscle will be seen.

The Gluteus Medius (m. glutaeus medius) (Fig. 346) is a broad, thick, radiated muscle, situated on the outer surface of the pelvis. Its posterior third is covered by the Gluteus maximus; its anterior two-thirds by the fascia lata, which separates it from the integument. It arises from the outer surface of the ilium, between the superior and middle curved lines, and from the outer lip of that portion of the crest which is between them; it also arises from the dense fascia, the gluteal aponeurosis, covering its outer surface. The fibres converge to a strong flattened tendon which is inserted into the oblique line which traverses the outer surface of the great trochanter. A synovial bursa (bursa trochanterica m. glutaei medii anterior) separates the tendon of the muscle from the summit of the great trochanter. There is frequently a bursa (bursa trochanterica m. glutaei medii posterior) between the tendons of the Gluteus medius and Pyriformis.

Relations.—By its superficial surface, with the Gluteus maximus behind, the Tensor fasciae femoris and deep fascia in front; by its deep surface, with the Gluteus minimus and the gluteal vessels and superior gluteal nerve. Its anterior border is blended with the Gluteus minimus. Its posterior border lies parallel with the Pyriformis, the gluteal vessels intervening.

This muscle should now be divided near its insertion and turned upward, when the Gluteus minimus will be exposed.

The Gluteus Minimus (m. glutaeus minimus) (Fig. 346), the smallest of the three Glutei, is placed immediately beneath the preceding. It is fan-shaped, arising from the outer surface of the ilium, between the middle and inferior curved lines, and behind, from the margin of the great sacro-sciatic notch; the fibres converge to the deep surface of a radiated aponeurosis, which, terminating in a tendon, is inserted into an impression on the anterior border of the great trochanter.
Relations.—By its superficial surface, with the Gluteus medius and the gluteal vessels and superior gluteal nerve; by its deep surface, with the ilium, the reflected tendon of the Rectus femoris, and the capsular ligament of the hip-joint. Its anterior margin is blended with the Gluteus medius; its posterior margin is in contact and sometimes joined with the tendon of the Pyriformis. There is a synovial bursa (bursa m. glutaei minimi) between the tendon of the Gluteus minimus and the great trochanter.

The Pyriformis (m. piriformis) (Figs. 346 and 347) is a flat muscle, pyramidal in shape, lying almost parallel with the posterior margin of the Gluteus medius. It is situated partly within the pelvis at its posterior part and partly at the back of the hip-joint. It arises from the front of the sacrum by three fleshy digitations attached to the portions of bone between the first, second, third, and fourth anterior sacral foramina, and also from the groove leading from the foramina: a few fibres also arise from the margin of the great sacro-sciatic foramen and from the anterior surface of the great sacro-sciatic ligament. The muscle passes out of the pelvis through the great sacro-sciatic foramen, the upper part of which it fills, and is inserted by a rounded tendon into the upper border of the great trochanter, behind, but often partly blended with, the tendon of the Obturator internus and Gemelli muscles.

Relations.—By its anterior surface, within the pelvis, with the Rectum (especially on the left side), the sacral plexus of nerves, and the branches of the internal iliac vessels; external to the pelvis, with the posterior
surface of the ischium and the capsular ligament of the hip-joint; by its posterior surface, within the pelvis, with the sacrum, and external to it, with the Gluteus maximus; by its upper border, with the Gluteus medius, from which it is separated by the gluteal vessels and superior gluteal nerve; by its lower border, with the Gemellus superior and Coccygeus, the sciatic vessels and nerves, the internal pudic vessels and nerve, and muscular branches from the sacral plexus, passing from the pelvis in the interval between the two muscles. There is usually a bursa (bursa m. piriformis) between the tendon of the pyriformis and the ilium.

The Obturator Membrane (membrana obturatoria) (Fig. 215) is a thin layer of interlacing fibres which closes almost completely the obturator foramen. It is attached, externally, to the margin of the foramen; internally, to the posterior surface of the ischio-pubic ramus, below and internal to the margin of the foramen. It presents at its upper and outer part a small canal, obturator canal (canalis obturatorius) for the passage of the obturator vessels and nerve. Both obturator muscles are connected with this membrane.

Dissection.—The next muscle, as well as the origin of the Pyriformis, can only be seen when the pelvis is divided and the viscera removed.

The Obturator Internus (Figs. 346 and 347), like the preceding muscle, is situated partly within the cavity of the pelvis, and partly at the back of the hip-joint. It arises from the inner surface of the anterior and external wall of the pelvis, where it surrounds the greater part of the obturator foramen, being attached to the descending ramus of the os pubis and the ramus of the ischium, and at the side to the inner surface of the innominate bone below and behind the pelvic brim, reaching from the upper part of the great sacro-sciatic foramen above and behind to the obturator foramen below and in front. It also arises from the inner surface of the obturator membrane except at its posterior part, from the tendinous arch which completes the canal for the passage of the obturator vessels and nerve and to a slight extent from the obturator layer of the pelvic fascia, which covers it. The fibres converge rapidly, and are directed backward and downward, and terminate in four or five tendinous bands, which are found on its deep surface; these bands are reflected at a right angle over the inner surface of the tuberosity of the ischium, which is grooved for their reception; the groove is covered with cartilage, and lined by a synovial bursa (bursa m. obturatoris interni). The muscle leaves the pelvis by the lesser sacro-sciatic foramen; and the tendinous bands unite into a single flattened tendon, which passes horizontally outward, and, after receiving the attachment of the Gemelli, is inserted into the forepart of the inner surface of the great trochanter in front of the Obturator externus. A synovial bursa, narrow and elongated in form, is usually found between the tendon of this muscle and the capsular ligament of the hip: it occasionally communicates with the bursa between the tendon and the tuberosity of the ischium, the two forming a single sac.

In order to display the peculiar appearances presented by the tendon of this muscle, it must be divided near its insertion and reflected inward.

Relations.—Within the pelvis this muscle is in relation, by its anterior surface, with the obturator membrane and inner surface of the anterior wall of the pelvis; by its posterior surface, with the pelvic and obturator fasciae, which separate it from the Levator ani; and it is crossed by the internal pudic vessels and nerve. This surface forms the outer boundary of the ischio-rectal fossa (Fig. 337). External to the pelvis it is covered by the Gluteus maximus, is crossed by the great sciatic nerve, and rests on the back part of the hip-joint. As the tendon of the Obturator internus emerges from the lesser sacro-sciatic foramen it is over-
lapped by the two Gemelli, while nearer its insertion the Gemelli pass in front of it and form a groove in which the tendon lies.

The Gemelli (Fig. 346) are two small muscular fasciculi, accessories to the tendon of the Obturator internus, which is received into a groove between them. They are called superior and inferior.

The Gemellus Superior, the smaller of the two, arises from the outer surface of the spine of the ischium, and, passing horizontally outward, becomes blended

with the upper part of the tendon of the Obturator internus, and is inserted with it into the inner surface of the great trochanter. This muscle is sometimes wanting.

Relations.—By its superficial surface, with the Gluteus maximus and the sciatic vessels and nerves; by its deep surface, with the capsule of the hip-joint; by its
upper border, with the lower margin of the Pyriformis; by its lower border, with the tendon of the Obturator internus.

The Gemellus Inferior arises from the upper part of the tuberosity of the ischium, where it forms the lower edge of the groove for the Obturator internus tendon, and, passing horizontally outward, is blended with the lower part of the tendon of the Obturator internus, and is inserted with it into the inner surface of the great trochanter.

Relations.—By its superficial surface, with the Gluteus maximus and the sciatic vessels and nerves; by its deep surface, with the scapular ligament of the hip-joint; by its upper border, with the tendon of the Obturator internus; by its lower border, with the tendon of the Obturator externus and Quadratus femoris.

The Quadratus Femoris (Fig. 346) is a short, flat muscle, quadrilateral in shape (hence its name), situated between the Gemellus inferior and the upper margin of the Adductor magnus. It arises from the upper part of the external lip of the tuberosity of the ischium, and, proceeding horizontally outward, is inserted into the upper part of the linea quadrata; that is, the line which crosses the posterior intertrochanteric line. A synovial bursa is often found between the under surface of this muscle and the lesser trochanter, which it covers.

Relations.—By its posterior surface, with the Gluteus maximus and the sciatic vessels and nerves; by its anterior surface, with the tendon of the Obturator externus and trochanter minor and with the capsule of the hip-joint; by its upper border, with the Gemellus inferior. Its lower border is separated from the Adductor magnus by the terminal branches of the internal circumflex vessels.

Dissection.—In order to expose the next muscle (the Obturator externus) it is necessary to remove the Psoas, Iliacus, Pectineus, and Adductor brevis and longus muscles from the front
and inner side of the thigh, and the Gluteus maximus and Quadratus femoris from the back part. Its dissection should, consequently, be postponed until the muscles of the anterior and internal femoral regions have been explained.

The Obturator Externus (Figs. 347 and 348) is a flat, triangular muscle, which covers the outer surface of the anterior wall of the pelvis. It arises from the margin of bone immediately around the inner side of the obturator foramen—viz., from the body and ramus of the os pubis and the ramus of the ischium; it also arises from the inner two-thirds of the outer surface of the obturator membrane, and from the tendinous arch which completes the canal for the passage of the obturator vessels and nerves. The fibres from the pubic arch extend on to the inner surface of the bone, from which they obtain a narrow origin between the margin of the foramen and the attachment of the membrane. The fibres converging pass backward, outward, and upward, and terminate in a tendon which runs across the back part of the hip-joint, and is inserted into the digital fossa of the femur.

Relations.—By its anterior surface, with the Psoas, Iliacus, Pectineus, Adductor magnus, and Adductor brevis; and more externally, with the neck of the femur and capsule of the hip-joint. The obturator artery and vein lie between this muscle and the obturator membrane; the superficial part of the obturator nerve lies above the muscle, and the deep branch perforates it; by its posterior surface, with the obturator membrane and Quadratus femoris.

Nerves.—The Gluteus maximus is supplied by the fifth lumbar and first and second sacral nerves through the inferior gluteal nerve from the sacral plexus; the Gluteus medius and minimus, by the fourth and fifth lumbar and first sacral nerves through the superior gluteal; the Pyriformis is supplied by the first and second sacral nerves; the Gemellus inferior and Quadratus femoris by the last lumbar and first sacral nerve; the Gemellus superior and Obturator internus by the fifth lumbar and first and second sacral nerves, and the Obturator externus by the second, third, and fourth lumbar nerves through the obturator.

Actions.—The Gluteus maximus, when it takes its fixed point from the pelvis, extends the femur and brings the bent thigh into a line with the body. Taking its fixed point from below, it acts upon the pelvis, supporting it and the whole trunk upon the head of the femur, which is especially obvious in standing on one leg. Its most powerful actions are to hold the head of the femur in close approximation to the acetabulum in walking and to cause the body to regain the erect position after stooping by drawing the pelvis backward, being assisted in this action by the Biceps, Semitendinosus, and Semimembranosus. The Gluteus maximus is a tensor of the fascia lata, and by its connection with the ilio-tibial band it steadies the femur on the articular surface of the tibia during standing, when the Extensor muscles are relaxed. The lower part of the muscle also acts as an adductor and external rotator of the limb. The Gluteus medius and minimus abduct the thigh when the limb is extended, and are principally called into action in supporting the body on one limb, in conjunction with the Tensor fasciae latae. Their anterior fibres, by drawing the great trochanter forward, rotate the thigh inward, in which action they are also assisted by the Tensor fasciae latae. The remaining muscles are powerful rotators of the thigh outward. In the sitting posture, when the thigh is flexed upon the pelvis, their action as rotators cease, and they become abductors, with the exception of the Obturator externus, which still rotates the femur outward. When the femur is fixed, the Pyriformis and Obturator muscles serve to draw the pelvis forward if it has been inclined backward, and assist in steadying it upon the head of the femur.

Surgical Anatomy.—The fascia over the gluteal region is extremely dense and an abscess beneath it may pass far down into the thigh.
4. The Posterior Femoral Region.


(Hamstring muscles.)

Dissection (Fig. 345).—Make a vertical incision along the middle of the back of the thigh, from the lower fold of the buttock to about three inches below the back of the knee-joint, and there connect it with a transverse incision, carried from the inner to the outer side of the leg. Make a third incision transversely at the junction of the middle with the lower third of the thigh. The integument having been removed from the back of the knee, and the boundaries of the popliteal space having been examined, the removal of the integument from the remaining part of the thigh should be continued, when the fascia and muscles of this region will be exposed.

The Biceps or Biceps Flexor Cruris (m. biceps femoris) is a large muscle, of considerable length, situated on the posterior and outer aspect of the thigh (Figs. 346 and 349). It arises by two heads. One, the long head (caput longum), arises from the lower and inner impression on the back part of the tuberosity
THE POSTERIOR FEMORAL REGION

of the ischium, by a tendon common to it and the Semitendinosus, and from the lower part of the great sacro-sciatic ligament. Between this tendon of origin and the Semimembranosus there is often a bursa (bursa m. bicipitis femoris superior). The femoral, or short head (caput breve), arises from the outer lip of the linea aspera, between the Adductor magnus and Vastus externus, extending up almost as high as the insertion of the Gluteus maximus; from the outer prolongation of the linea aspera to within two inches of the outer condyle, and from the external intermuscular septum. The fibres of the long head form a fusiform belly, which, passing obliquely downward and a little outward, terminates in an aponeurosis which covers the posterior surface of the muscle, and receives the fibres of the short head: this aponeurosis becomes gradually contracted into a tendon, which is inserted into the outer side of the head of the femur, and by a small slip into the lateral surface of the external tuberosity of the tibia. At its insertion the tendon divides into two portions, which embrace the long external lateral ligament of the knee-joint. From the posterior border of the tendon a thin expansion is given off to the fascia of the leg. The tendon of this muscle forms the outer hamstring. Sometimes there is a bursa (bursa bicipitogastrocnemialis) between the tendon of insertion of the Biceps and the origin of the Gastrocnemius, and there is a bursa (bursa m. bicipitis femoris inferior) between the tendon of the Biceps and the external lateral ligament.

Relations.—By its superficial surface, with the Gluteus maximus and the small sciatic nerve, the fascia lata, and integument. By its deep surface, with the Semimembranosus, Adductor magnus, and Vastus externus, the great sciatic nerve, and, near its insertion, with the external head of the Gastrocnemius, the Plantaris, the superior external articular artery, and the external popliteal nerve.

The Semitendinosus (Figs. 346 and 349), remarkable for the great length of its tendon, is situated at the posterior and inner aspect of the thigh. It arises from the lower and inner impression on the tuberosity of the ischium by a tendon common to it and the long head of the Biceps; it also arises from an aponeurosis which connects the adjacent surfaces of the two muscles to the extent of about three inches after their origin. There is a bursa (bursa m. bicipitis femoris superior) between the tendons of origin of the Biceps and Semitendinosus on one side and the tendon of origin of the Semimembranosus on the other. The Semitendinosus is a fusiform muscle, which, passing downward and inward, terminates a little below the middle of the thigh in a long round tendon which lies along the inner side of the popliteal space, then curves around the inner tuberosity of the tibia, and is inserted into the upper part of the inner surface of the shaft of that bone nearly as far forward as its anterior border. At its insertion it gives off from its lower border a prolongation to the deep fascia of the leg. This tendon lies behind the tendon of the Sartorius, and below that of the Gracilis, to which it is united. A tendinous intersection is usually observed about the middle of the muscles. The bursa anserina lies between the tendon of the Semitendinosus and the tibia. This bursa was referred to in speaking of the Gracilis, p. 522.

Relations.—By its superficial surface, with the Gluteus maximus and fascia lata; by its deep surface, with the Semimembranosus, Adductor magnus, inner head of the Gastrocnemius, and internal lateral ligament of the knee-joint.

The Semimembranosus (Figs. 346 and 349), so called from its membranous tendon of origin, is situated at the back part and inner side of the thigh. It arises by a thick tendon from the upper and outer impression on the back part of the tuberosity of the ischium, above and to the outer side of the Biceps and Semitendinosus, and is inserted into the groove on the inner and back part of the inner tuberosity of the tibia, beneath the internal lateral ligament. The tendon of the muscle at its origin expands into an aponeurosis which covers the upper part.
of its anterior surface: from this aponeurosis muscular fibres arise, and converge to another aponeurosis, which covers the lower part of its posterior surface and contracts into the tendon of insertion. The tendon of the muscle at its insertion gives off certain fibrous expansions; one of these, of considerable size, passes upward and outward to be inserted into the back part of the outer condyle of the femur, forming part of the posterior ligament of the knee-joint; a second is continued downward to the fascia which covers the Popliteus muscle. The tendon also sends a few fibres to join the internal lateral ligament of the joint.

The tendons of the two preceding muscles, with that of the Gracilis, form the *inner hamstrings*.

**Relations.**—By its superficial surface, with the Gluteus maximus, Semitendinosus, Biceps, and fascia lata; by its deep surface, with the origin of the Quadratus femoris, popliteal vessels, Adductor magnus, and inner head of the Gastrocnemius; by its inner border, with the Gracilis; by its outer border, with the great sciatic nerve, and its internal popliteal branch. There is a *bursa* between the Gastrocnemius and Semimembranosus and another *bursa* between the Semimembranosus and the inner condyle of the tibia. The first bursa usually communicates with the knee-joint. These two *bursae* are in communication and in reality constitute a *double bursa* (*bursa m. semimembranos*).

**Nerves.**—The muscles of this region are supplied by the first, second, and third sacral nerves through the great sciatic nerve.

**Actions.**—The hamstring muscles flex the leg upon the thigh. When the knee is semiflexed, the Biceps, in consequence of its oblique direction downward and outward, rotates the leg slightly outward; and the Semitendinosus, and to a slight extent the Semimembranosus, rotate the leg inward, assisting the Popliteus. Taking their fixed point from below, these muscles, especially the Semimembranosus, serve to support the pelvis upon the head of the femur and to draw the trunk directly backward, as in raising it from the stooping position or in feats of strength, when the body is thrown backward in the form of an arch. When the leg is extended on the thigh, they limit the amount of flexion of the trunk on the lower limbs.

**Surgical Anatomy.**—The hamstring tendons are occasionally ruptured. In disease of the knee-joint the hamstrings may contract, flexing the knee, drawing the tibia backward, and sometimes causing incomplete dislocation. The tendons of these muscles occasionally require *subcutaneous division* in some forms of spurious ankylosis of the knee-joint dependent upon permanent contraction and rigidity of the Flexor muscles, or from stiffening of the ligamentous and other tissues surrounding the joint, the result of disease. Division of a tendon is effected by putting the tendon upon the stretch, and inserting a narrow sharp-pointed knife between it and the skin: the cutting edge being then turned toward the tendon, it should be divided, taking great care that the wound in the skin is not at the same time enlarged. The relation of the external popliteal nerve to the tendon of the Biceps must always be borne in mind in dividing this tendon.

**III. MUSCLES AND FASCIAE OF THE LEG.**

These may be divided into three groups: those on the anterior, those on the posterior, and those on the outer side of the leg.

5. The Anterior Tibio-fibular Region (Fig. 350).

- Tibialis anticus.
- Extensor proprius hallucis.¹
- Peroneus tertius.

¹ There is no such word as "Hallux, -eis." It is the result of some ignorant blunder, copied until it has become established by usage; it has been thought better, therefore, to retain it. According to Lewis and Short, the word is *Allex*, masculine; genitive, *Allicis*, the great toe, and the correct rendering would be Extensor proprius allicis. It is a rare word, and is sometimes spelled, but not so correctly, "Haller." It is used by Plautus, in the "Perkins," V., v. 31, of a little man, as we might say "a hop-o'-my-thumb." "Tune hic amator audes esse, allex viri" (To think of you daring to make up to her, you hop-o'-my-thumb). The word "alex," sometimes spelled "'allex," a fish sauce, is probably a different word altogether. It is used by Horace and Pliny. —Ed. of 15th English edition.
Dissection (Fig. 339).—The knee should be bent, a block placed beneath it, and the foot kept in an extended position; then make an incision through the integument in the middle line of the leg to the ankle, and continue it along the dorsum of the foot to the toes. Make a second incision transversely across the ankle, and a third in the same direction across the bases of the toes; remove the flaps of integument included between these incisions in order to examine the deep fascia of the leg.

The Deep Fascia of the Leg (*fascia cruris*) forms a complete investment to the muscles, but is not continuous over the subcutaneous surfaces of the bones. It is continuous above with the fascia lata, receiving an expansion from the tendon of the Biceps on the outer side, and from the tendons of the Sartorius, Gracilis, and Semitendinosus on the inner side; in front it blends with the periosteum covering the subcutaneous surface of the tibia, and with that covering the head and external malleolus of the fibula; below it is continuous with the annular ligaments of the ankle. It is thick and dense in the upper and anterior part of the leg, and gives attachment, by its deep surface, to the Tibialis anticus and Extensor longus digitorum muscles, but is thinner behind, where it covers the Gastrocnemius and Soleus muscles. Over the popliteal space it is much strengthened by transverse fibres which stretch across from the inner to the outer hamstring muscles, and it is here perforated by the external saphenous vein. Its deep surface gives off, on the outer side of the leg, two strong intermuscular septa which enclose the Peronei muscles, and separate them from the muscles of the anterior and posterior tibial regions. It also gives off several smaller and more slender processes which enclose the individual muscles in each region; at the same time a broad transverse intermuscular septum, called the deep transverse fascia of the leg, intervenes between the superficial and deep muscles in the posterior tibio-fibular region.

Remove the fascia by dividing it in the same direction as the integument, excepting opposite the ankle, where it should be left entire. Commence the removal of the fascia from below, opposite the tendons, and detach it in the line of direction of the muscular fibres.

The Tibialis Anticus (*m. tibialis anterior*) is situated on the outer side of the tibia; it is thick and fleshy at its upper part, tendinous below. It arises from the outer tuberosity and upper two-thirds of the external surface of the shaft of the tibia; from the adjoining part of the interosseous membrane; from the deep surface of the fascia; and from the intermuscular septum between it and the Extensor longus digitorum: the fibres pass vertically downward, and terminate in a tendon which is apparent on the anterior surface of the muscle at the lower third of the leg. After passing through the innermost compartment of the anterior annular ligament, it is inserted into the inner and under surface of the internal cuneiform bone and base of the metatarsal bone of the great toe. There is usually a bursa (*bursa subtendinea m. tibialis anteriors*) between the tendon of the tibialis anticus and the internal cuneiform bone.

Relations.—By its anterior surface, with the fascia and with the annular ligament; by its posterior surface, with the interosseous membrane, tibia, ankle-joint, and inner side of the tarsus; this surface also overlaps the anterior tibial vessels and nerve in the upper part of the leg. By its inner surface, with the tibia; by its outer surface, with the Extensor longus digitorum and Extensor proprius hallucis, and the anterior tibial vessels and nerve.

The Extensor Proprius Hallucis (*m. extensor hallucis longus*) is a thin, elongated, and flattened muscle situated between the Tibialis anticus and Extensor longus digitorum. It arises from the anterior surface of the fibula for about the middle two-fourths of its extent, its origin being internal to that of the Extensor longus digitorum; it also arises from the interosseous membrane to a similar extent. The fibres pass downward, and terminate in a tendon which occupies
the anterior border of the muscle, passes through a distinct compartment in the lower portion of the annular ligament, crosses the anterior tibial vessels near the bend of the ankle, and is inserted into the base of the last phalanx of the great toe. Opposite the metatarso-phalangeal articulation the tendon gives off a thin prolongation on each side, which covers the surface of the joint. It usually sends an expansion from the inner side of the tendon, to be inserted into the base of the first phalanx.

**Relations.**—By its anterior surface, with the fascia and the anterior annular ligament; by its posterior surface, with the interosseous membrane, fibula, tibia, and ankle-joint; by its outer side, with the Extensor longus digitorum above, the dorsalis pedis vessels, anterior tibial nerve, and Extensor brevis digitorum below; by its inner side, with the Tibialis anticus and the anterior tibial vessels above. The muscle is external to the anterior tibial vessels in the upper part of the leg; but in the lower third its tendon crosses over them, so that it lies internal to them on the dorsum of the foot.

The **Extensor Longus Digitorum** (m. extensor digitorum longus) is an elongated, flattened, penniform muscle situated the most externally of all the muscles on the forepart of the leg. It arises from the outer tuberosity of the tibia; from the upper three-fourths of the anterior surface of the shaft of the fibula; from the interosseous membrane; from the deep surface of the fascia; and from the intermuscular septa between it and the Tibialis anticus on the inner and the Peronei on the outer side. The tendon enters a canal in the annular ligament with the Peroneus tertius, and divides into four slips, which run across the dorsum of the foot and are inserted into the second and third phalanges of the four lesser toes. The mode in which the tendons are inserted is the following: Each of the three inner tendons opposite the metatarso-phalangeal articulation is joined, on its outer side, by a tendon from the Extensor brevis digitorum. The outer tendon does not receive such a tendinous slip. They all receive a fibrous expansion from the Interossei and Lumbricales, and then spread out into a broad aponeurosis, which covers the dorsal surface of the first phalanx: this aponeurosis, at the articulation of the first with the second phalanx, divides into three slips—a middle one, which is inserted into the base of the second phalanx, and two lateral slips, which, after uniting on the dorsal surface of the second phalanx, are continued onward, to be inserted into the base of the third.

**Relations.**—By its anterior surface, with the fascia and the annular ligament; by its posterior surface,
with the fibula, interosseous membrane, ankle-joint, and Extensor brevis digitorum; by its inner side, with the Tibialis anticus, Extensor proprius hallucis, and anterior tibial vessels and nerve; by its outer side, with the Peroneus longus and brevis.

The Peroneus Tertius (m. peroneus tertius) is a part of the Extensor longus digitorum, and might be described as its fifth tendon. The fibres belonging to this tendon arise from the lower fourth of the anterior surface of the fibula, from the lower part of the interosseous membrane, and from an intermuscular septum between it and the Peroneus brevis. The tendon, after passing through the same canal in the annular ligament as the Extensor longus digitorum, is inserted into the dorsal surface of the base of the metatarsal bone of the little toe. This muscle is sometimes wanting.

Nerves.—These muscles are supplied by the fourth and fifth lumbar and first sacral nerves through the anterior tibial nerve.

Actions.—The Tibialis anticus and Peroneus tertius are the direct flexors of the foot at the ankle-joint; the former muscle, when acting in conjunction with the Tibialis posticus, raises the inner border of the foot (i.e., inverts the foot); and the latter, acting with the Peroneus brevis and longus, draws the outer border of the foot upward and the sole outward (i.e., everts the foot). The Extensor longus digitorum and Extensor proprius hallucis extend the phalanges of the toes, and, continuing their action, flex the foot upon the leg. Taking their fixed point from below, in the erect posture, all these muscles serve to fix the bones of the leg in the perpendicular position, and give increased strength to the ankle-joint.

6. The Posterior Tibio-fibular Region (Figs. 349, 352).

Dissection (Fig. 345).—Make a vertical incision along the middle line of the back of the leg, from the lower part of the popliteal space to the heel, connecting it below by a transverse incision extending between the two malleoli; the flaps of integument being removed, the fascia and muscles should be examined.

The muscles in this region of the leg are subdivided into two layers—superficial and deep. The superficial layer constitutes a powerful muscular mass, forming the calf of the leg. Their large size is one of the most characteristic features of the muscular apparatus in man, and bears a direct connection with his ordinary attitude and mode of progression.

The Superficial Layer.


The Gastrocnemius is the most superficial muscle, and forms the greater part of the calf. It arises by two heads, which are connected to the condyles of the femur by two strong flat tendons. The inner and larger head (caput mediale) arises from a depression at the upper and back part of the inner condyle and from the adjacent part of the femur. There is a bursa (bursa m. gastrocnemii medialis) between the tendon of origin and the inner condyle. The outer head (caput laterale) arises from an impression on the outer side of the external condyle and from the posterior surface of the femur immediately above the condyle. There is a bursa (bursa m. gastrocnemii lateralis) between the tendon of origin and the outer condyle. Both heads, also, arise by a few tendinous and fleshy fibres from the ridges which are continued upward from the condyles to the linea aspera. Each tendon spreads out into an aponeurosis, which covers the posterior surface of that portion of the muscle to which it belongs; the muscular fibres of the inner head being thicker and extending lower than those of the outer. From the anterior surface of these tendinous expansions muscular fibres are given off.
The fibres in the median line, which correspond to the accessory portions of the muscle derived from the bifurcations of the linea aspera, unite at an angle upon a median tendinous raphe below: the remaining fibres converge to an aponeurosis which covers the anterior surface of the muscle, and this, gradually contracting, unites with the tendon of the Soleus, and forms with it the tendo Achillis.

Relations.—By its superficial surface, with the fascia of the leg, which separates it from the external saphenous vein and nerve; by its deep surface, with the posterior ligament of the knee-joint, the Popliteus, Soleus, Plantaris, popliteal vessels, and internal popliteal nerve. The tendon of the inner head corresponds with the back part of the inner condyle, from which it is separated by a synovial bursa, which, in some cases, communicates with the cavity of the knee-joint. The tendon of the outer head contains a sesamoid fibro-cartilage (rarely osseous) where it plays over the corresponding outer condyle; and one is occasionally found in the tendon of the inner head.

The Gastrocnemius should be divided across, just below its origin, and turned downward, in order to expose the next two muscles.

The Soleus is a broad flat muscle situated immediately beneath the Gastrocnemius. It has received its name from its resemblance in shape to a sole-fish. It arises by tendinous fibres from the back part of the head of the fibula and from the upper third of the posterior surface of its shaft; from the oblique line of the tibia and from the middle third of its internal border; some fibres also arise from a tendinous arch placed between the tibial and fibular origins of the muscle, beneath which the popliteal vessels and internal popliteal nerve pass. The fibres pass backward to an aponeurosis which covers the posterior surface of the muscle, and this, gradually becoming thicker and narrower, joins with the tendon of the Gastrocnemius, and forms with it the tendo Achillis.

The triceps surae is the designation in the new nomenclature of the Gastrocnemius and Soleus.

Relations.—By its superficial surface, with the Gastrocnemius and Plantaris; by its deep surface, with the Flexor longus digitorum, Flexor longus hallucis, Tibialis posticus, and posterior tibial vessels and nerve, from which it is separated by the transverse intermuscular septum or deep transverse fascia of the leg.

The Tendo Achillis (tendo calcaneus), the common tendon of the Gastrocnemius and Soleus,\(^1\) is the thickest and strongest tendon in the body. It is about six inches in length, and commences about the middle of the leg, but receives fleshy fibres on its anterior surface nearly to its lower end. Gradually becoming contracted below, it is inserted into the lower part of the posterior surface of the os calcis, a synovial bursa, the retrocalcaneal bursa (bursa tendinis calcanei [Achillis]) (Fig. 351), being interposed between the tendon and the upper part of this surface. The tendon spreads out somewhat at its lower end, so that its narrowest part is usually about an inch and a half above its insertion. The tendon is covered by the fascia and the integument, a bursa (bursa subcutanea calcanea) (Fig. 351) being often interposed between the tendon and the fascia. The tendon

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\(^1\) These two muscles with a common tendon are by some anatomists classed together as one muscle, the Triceps surae, the two heads of origin of the Gastrocnemius and the Soleus constituting the three heads of the Triceps, and the tendo Achillis the single tendon of insertion.—Ed. of 15th English edition.
is separated from the deep muscles and vessels by a considerable interval filled up with areolar and adipose tissue. Along its outer side, but superficial to it, is the external saphenous vein.

The Plantaris is an extremely diminutive muscle placed between the Gastrocnemius and Soleus, and remarkable for its long and delicate tendon. It arises
from the lower part of the outer prolongation of the linea aspera and from the posterior ligament of the knee-joint. It forms a small fusiform belly, about three or four inches in length, terminating in a long slender tendon which crosses obliquely between the two muscles of the calf, and, running along the inner border of the tendon Achillis, is inserted with it into the posterior part of the os calcis. This muscle is occasionally double, and is sometimes wanting. Occasionally its tendon is lost in the internal annular ligament or in the fascia of the leg.

**Nerves.**—The Gastrocnemius is supplied by the first and second sacral nerves, and the Plantaris by the fourth and fifth lumbar and first sacral nerves through the internal popliteal. The Soleus is supplied by the fifth lumbar and first and second sacral nerves through the internal popliteal and posterior tibial.

**Actions.**—The muscles of the calf are the chief extensors of the foot at the ankle-joint. They possess considerable power, and are constantly called into use in standing, walking, dancing, and leaping; hence the large size they usually present. In walking these muscles draw powerfully upon the os calcis, raising the heel, and with it the entire body, from the ground; the body being thus supported on the raised foot, the opposite limb can be carried forward. In standing, the Soleus, taking its fixed point from below, steadies the leg upon the foot, and prevents the body from falling forward, to which there is a constant tendency from the superincumbent weight. The Gastrocnemius, acting from below, serves to flex the femur upon the tibia, assisted by the Popliteus. The Plantaris is the rudiment of a large muscle which exists in some of the lower animals and is continued over the os calcis to be inserted into the plantar fascia. In man it is an accessory to the Gastrocnemius, extending the ankle if the foot is free, or bending the knee if the foot is fixed. Possibly, acting from below, by its attachment to the posterior ligament of the knee-joint, it may pull that ligament backward during flexion, and so protect it from being compressed between the two articular surfaces.

**The Deep Layer (Fig. 353).**

- **Popliteus.**
- **Flexor longus digitorum.**
- **Flexor longus hallucis.**
- **Tibialis posticus.**

**Dissection.**—Detach the Soleus from its attachment to the fibula and tibia, and turn it downward, when the deep layer of muscles is exposed, covered by the deep transverse fascia of the leg.

**Deep Transverse Fascia.**—The deep transverse fascia of the leg is a transversely placed, intermuscular septum, between the superficial and deep muscles in the posterior tibio-fibular region. On either side it is connected to the margins of the tibia and fibula. Above, where it covers the Popliteus, it is thick and dense, and receives an expansion from the tendon of the Semimembranosus; it is thinner in the middle of the leg, but below, where it covers the tendons passing behind the malleoli, it is thickened and continuous with the internal annular ligament.

This fascia should now be removed, commencing from below opposite the tendons, and detaching it from the muscles in the direction of their fibres.

**The Popliteus (Fig. 349)** is a thin, flat, triangular muscle, which forms part of the floor of the popliteal space. It arises by a strong tendon, about an inch in length, from a deep depression on the outer side of the external condyle of the femur, and from the posterior ligament of the knee-joint. A **bursa (bursa m. poplitei)** is placed between the condyle and the muscle. The muscle is inserted into the inner two-thirds of the triangular surface above the oblique line on the posterior surface of the shaft of the tibia, and into the tendinous expansion covering the surface of the muscle. The tendon of the muscle is covered by that of the Biceps and by the external lateral ligament of the knee-joint; it grooves
the posterior border of the external semilunar fibro-cartilage, and is invested by the synovial membrane of the knee-joint.

**Relations.**—By its superficial surface, with the fascia covering it, which separates it from the Gastrocnemius, Plantaris, popliteal vessels, and internal popliteal nerve; by its deep surface, with the knee-joint and back of the tibia.

The **Flexor Longus Hallucis** (*m. flexor hallucis longus*) is situated on the fibular side of the leg, and is the most superficial and largest of the three next muscles. It arises from the lower two-thirds of the posterior surface of the shaft of the fibula, with the exception of an inch at its lowest part; from the lower part of the interosseous membrane; from an intermuscular septum between it and the Peronei, externally; and from the fascia covering the Tibialis posticus internally. The fibres pass obliquely downward and backward, and terminate in a tendon which occupies nearly the whole length of the posterior surface of the muscle. This tendon occupies a groove on the posterior surface of the lower end of the tibia; it then lies in a second groove on the posterior surface of the astragalus, and finally in a third groove, beneath the sustentaculum tali of the os calcis, and passes into the sole of the foot, where it runs forward between the two heads of the Flexor brevis hallucis, and is inserted into the base of the last phalanx of the great toe (Fig. 355). The grooves in the astragalus and os calcis, which contain the tendon of the muscle, are converted by tendinous fibres into distinct canals lined by synovial membrane; and as the tendon crosses the sole of the foot, it is connected to the common flexor by a tendinous slip.

**Relations.**—By its superficial surface, with the Soleus and tendo Achillis, from which it is separated by the deep transverse fascia; by its deep surface, with the fibula, Tibialis posticus, the peroneal vessels, the lower part of the interosseous membrane, and the ankle-joint; by its outer border, with the Peronei; by its inner border, with the Tibialis posticus and posterior tibial vessels and nerve. In the sole of the foot it lies above the Abductor hallucis and Flexor longus digitorum.

The **Flexor Longus Digitorum** (*m. flexor digitorum longus*) is situated on the tibial side of the leg. At its origin it is thin and pointed, but gradually increases in size as it descends. It arises from the posterior surface of the shaft of the tibia, immediately below the oblique line to within three inches of its extremity, internal to the tibial origin of the Tibialis posticus; some fibres also arise from the fascia covering the Tibialis posticus. The fibres terminate in a tendon which runs nearly the whole length of the posterior surface of the muscle. This tendon passes behind the internal malleolus in a groove, common to it and the Tibialis posticus, but separated from the latter by a fibrous septum, each tendon being contained in a special sheath lined by a separate synovial membrane. It then passes obliquely forward and outward, superficial to the internal lateral ligament, into the sole of the foot (Fig. 355), where, crossing superficially to the tendon of the Flexor longus hallucis, to which it is connected by a strong tendinous slip, it becomes expanded, is joined by the Flexor accessorius, and finally divides into four tendons which are inserted into the bases of the last phalanges of the four lesser toes, each tendon passing through a fissure in the tendon of the Flexor brevis digitorum opposite the base of the first phalanges (Fig. 354).

**Relations.**—In the leg: by its superficial surface, with the posterior tibial vessels and nerve, and the deep transverse fascia, which separates it from the Soleus muscle; by its deep surface, with the Tibia and Tibialis posticus. In the foot it is covered by the Abductor hallucis and Flexor brevis digitorum, and crosses superficial to the Flexor longus hallucis.

The **Tibialis Posticus** (*m. tibialis posterior*) lies between the two preceding muscles, and is the most deeply seated of all the muscles in the leg. It com-

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1 That is, in the order of dissection of the sole of the foot.
mences above by two pointed processes, separated by an angular interval, through which the anterior tibial vessels pass forward to the front of the leg. It arises from the whole of the posterior surface of the interosseous membrane, excepting its lowest part, from the outer portion of the posterior surface of the shaft of the tibia, between the commencement of the oblique line above, and the junction of the middle and lower third of the shaft below; and from the upper two-thirds of the internal surface of the fibula; some fibres also arise from the deep transverse fascia and from the intermuscular septa, separating it from the adjacent muscles on each side. This muscle, in the lower fourth of the leg, passes in front of the Flexor longus digitorum, and terminates in a tendon which passes through a groove behind the inner malleolus with the tendon of that muscle, but enclosed in a separate sheath; it then passes through another sheath, over the internal lateral ligament into the foot, and then beneath the inferior calcaneo-scaphal ligament, and is inserted into the tuberosity of the scaphoid and internal cuneiform bones (Fig. 356). The tendon of this muscle contains a sesamoid fibro-cartilage as it passes over the scaphoid bone, and gives off fibrous expansions, one of which passes backward to the sustentaculum tali of the os calcis, others outward to the middle and external cuneiform and cuboid, and some forward to the base of the second, third, and fourth metatarsal bones (Fig. 355).

**Relations.**—By its superficial surface, with the Soleus, from which it is separated by the deep transverse fascia, the Flexor longus digitorum, the posterior tibial vessels and nerve, and the peroneal vessels; by its deep surface, with the interosseous ligament, the tibia, fibula, and ankle-joint.

**Nerves.**—The Popliteus is supplied by the fourth and fifth lumbar and first sacral nerves, through the internal popliteal; the Flexor longus digitorum and Tibialis posticus by the fifth lumbar and first sacral; and the Flexor longus hallucis by the fifth lumbar and first and second sacral nerves through the posterior tibial.

**Actions.**—The Popliteus assists in flexing the leg upon the thigh; when the leg is flexed, it will rotate the tibia inward. It is especially called into action at the commencement of the act of bending the knee, inasmuch as it produces a slight inward rotation of the tibia, which is essential in the early stage of this movement. The Tibialis posticus is a direct extensor of the foot at the ankle-joint; acting in conjunction with the Tibialis anticus, it turns the sole of the foot inward (i.e., inverts the foot), antagonizing the Peronei, which turn it outward (evert it). In the sole of the foot the tendon of the Tibialis posticus lies directly below the inferior calcaneo-scaphoid ligament, and is therefore an important factor in maintaining the arch of the foot. The Flexor longus digitorum and Flexor longus hallucis are the direct flexors of the phalanges, and, continuing their action, extend the foot upon the leg; they assist the Gastrocnemius and Soleus in extending the foot, as in the act of walking or in standing on tiptoe. In consequence of the oblique direction of the tendon of the long flexor the toes would be drawn inward were it not for the Flexor accessorius muscle, which is inserted into the outer side of its tendon and draws it to the middle line of the foot during its action. Taking their fixed point from the foot, these muscles serve to maintain the upright posture by steadying the tibia and fibula perpendicularly upon the ankle-joint. They also serve to raise these bones from the oblique position they assume in the stooping posture.

7. The Fibular Region (Fig. 353).

**Peroneus longus.**

**Dissection.**—The muscles are readily exposed by removing the fascia covering their surface, from below upward, in the line of direction of their fibres.

The **Peroneus Longus** (*m. peroneus longus*) is situated at the upper part of the outer side of the leg, and is the more superficial of the two muscles. It arises
from the head and upper two-thirds of the outer surface of the shaft of the fibula, from the deep surface of the fascia, and from the intermuscular septa between it and the muscles on the front, and those on the back of the leg, occasionally also by a few fibres from the outer tuberosity of the tibia. Between its attachment to the head and to the shaft of the fibula there is a small interval of bone from which no muscular fibres arise; through this gap the external popliteal nerve passes beneath the muscle. The muscle terminates in a long tendon, which passes behind the outer malleolus, in a groove common to it and the tendon of the Peroneus brevis, behind which it lies, the groove being converted into a canal by a fibrous band, and the tendons being invested by a common synovial membrane; it is then reflected obliquely forward across the outer side of the os calcis, below its peroneal tubercle, being contained in a separate fibrous sheath, lined by a prolongation of the synovial membrane which lines the groove behind the malleolus. Having reached the outer side of the cuboid bone, it runs in a groove on the under surface of that bone, which is converted into a canal by the long calcaneo-cuboid ligament, and is lined by a synovial membrane: the tendon then crosses the sole of the foot obliquely, and is inserted into the outer side of the base of the metatarsal bone of the great toe and the internal cuneiform bone (Figs. 355 and 356). Occasionally it sends a slip to the base of the second metatarsal bone. The tendon changes its direction at two points: first, behind the external malleolus; secondly, on the outer side of the cuboid bone; in both of these situations the tendon is thickened, and in the latter a sesamoid fibro-cartilage, or sometimes a bone, is usually developed in its substance.

Relations.—By its superficial surface, with the fascia and integument; by its deep surface, with the fibula, external popliteal nerve, the Peroneus brevis, os calcis, and cuboid bone; by its anterior border, with an intermuscular septum, which intervenes between it and the Extensor longus digitorum; by its posterior border, with an intermuscular septum, which separates it from the Soleus above and the Flexor longus hallucis below.

The **Peroneus Brevis** (m. peronaeus brevis) lies beneath the Peroneus longus, and is shorter and smaller than it. It arises from the lower two-thirds of the external surface of the shaft of the fibula, internal to the Peroneus longus, and from the intermuscular septa separating it from the adjacent muscles on the front and back part of the leg. The fibres pass vertically downward, and terminate in a tendon which runs in front of that of the preceding muscle through the same groove, behind the external malleolus, being contained in the same fibrous sheath and lubricated by the same synovial membrane. It then passes through a separate sheath on the outer side of the os calcis, above that for the tendon of the Peroneus longus, the two tendons being here separated by the peroneal tubercle, and is finally inserted into the tuberosity at the base of the metatarsal bone of the little toe, on its outer side.

Relations.—By its superficial surface, with the Peroneus longus and the fascia of the leg and foot; by its deep surface, with the fibula and outer side of the os calcis.

**Nerves.**—The Peroneus longus and brevis are supplied by the fourth and fifth lumbar and first sacral nerves through the musculo-cutaneous branch of the external popliteal nerve.

**Actions.**—The Peroneus longus and brevis extend the foot upon the leg, in conjunction with the Tibialis posticus, antagonizing the Tibialis anticus and Peroneus tertius, which are flexors of the foot. The Peroneus longus also everts the sole of the foot; hence the extreme eversion occasionally observed in fracture of the lower end of the fibula, where that bone offers no resistance to the action of this muscle. From the oblique direction of the Peroneus longus tendon across the sole of the foot it is an important agent in the maintenance of the transverse
arch of the foot. Taking their fixed point below, the Peronei serve to steady the leg upon the foot. This is especially the case in standing upon one leg, when the tendency of the superincumbent weight is to throw the leg inward; the Peroneus longus overcomes this tendency by drawing on the outer side of the leg, and thus maintains the perpendicular direction of the limb.

Surgical Anatomy.—The student should now consider the position of the tendons of the various muscles of the leg, their relation with the ankle-joint and surrounding blood-vessels, and especially their action upon the foot, as their rigidity and contraction give rise to one or other of the kinds of deformity known as club-foot. The most simple and common deformity, and one that is rarely, if ever, congenital, is the talipes equinovarus, the heel being raised by rigidity and contraction of the Gastrocnemius muscle, and the patient walking upon the ball of the foot. In the talipes varus the foot is forcibly adducted and the inner side of the sole raised, sometimes to a right angle with the ground, by the action of the Tibialis anticus and posterior. In the talipes valgus the outer edge of the foot is raised by the Peronei muscles, and the patient walks on the inner ankle. In the talipes calcaneus the toes are raised by the Extensor muscles, the heel is depressed, and the patient walks upon it. Other varieties of deformity are met with, as the talipes equino-varus, equino-valgus, and calcaneo-valgus, whose names sufficiently indicate their nature. Of these, the talipes equino-varus is the most common congenital form: the heel is raised by the tendon Achillis, the inner border of the foot drawn upward by the Tibialis anticus, the anterior two-thirds twisted inward by the Tibialis posterior, and the arch increased by the contraction of the plantar fascia, so that the patient walks on the middle of the outer border of the foot. Each of these deformities may sometimes be successfully relieved by division of the opposing tendons and fascia; by this means the foot regains its proper position, and the tendons subsequently heal. The operation is easily performed by putting the contracted tendon upon the stretch, and dividing it by means of a narrow, sharp-pointed knife inserted beneath it. Pes cavus or hollow foot is accentuation of the longitudinal arch. Pes planus or flat-foot has been discussed elsewhere.

Rupture of a few of the fibres of the Gastrocnemius may take place. Rupture of the Plantaris tendon not uncommonly occurs, especially in men somewhat advanced in life, from some sudden exertion, and frequently occurs during the game of lawn tennis, and is hence known as lawntennis leg. The accident is accompanied by a sudden pain, and produces a sensation as if the individual had been struck a violent blow on the part. The tendon Achillis is also sometimes ruptured. It is stated that John Hunter ruptured his tendon Achillis whilst dancing at the age of forty. The retro-calcaneal bursa is interposed between the posterior surface of the os calcis and the tendon Achillis, just above the point of insertion of the tendon. If it inflames it produces disabling pain (achillodyinia, or Albert's disease, retro-calcaneal bursitis). This bursa may become cartilaginous or osteophytes may form on the surface toward the os calcis.

IV. MUSCLES AND FASCIA OF THE FOOT.

The fibrous bands, or thickened portions of the fascia of the leg, which bind down the tendons in front of and behind the ankle in their passage to the foot should now be examined; they are termed the annular ligaments, and are three in number—ante
or internal, and external.

The Anterior Annular Ligament (Fig. 350) consists of a superior or transverse portion (ligamentum transversum cruris) which binds down the Extensor tendons as they descend on the front of the tibia and fibula; and an inferior or Y-shaped portion (ligamentum cruciatum cruris), which retains them in connection with the tarsus, the two portions being connected by a thin intervening layer of fascia. The transverse portion is attached externally to the lower end of the fibula and internally to the tibia; above it is continuous with the fascia of the leg; it contains only one synovial sheath, for the tendon of the Tibialis anticus; the other tendons and the anterior tibial vessels and nerve passing beneath it, but without any distinct synovial sheath. The Y-shaped portion is placed in front of the ankle-joint, the stem of the Y, the fundiform ligament of Retzius, being attached externally to the upper surface of the os calcis, in front of the depression for the interosseous ligament; it is directed inward, as a double layer, one lamina passing in front, and the other behind, the tendons of the Peroneus tertius and Extensor longus digitorum. At the inner border of the latter tendon these two layers join together,
forming a sort of loop or sheath in which the tendons are enclosed, surrounded by a synovial membrane. From the inner extremity of this loop the two limbs of the Y diverge: one passes upward and inward, to be attached to the internal malleolus, passing over the Extensor proprius hallucis and the vessels and nerves, but enclosing the Tibialis anticus and its synovial sheath by a splitting of its fibres. The other limb extends downward and inward to be attached to the inner border of the plantar fascia, and passes over the tendons of the Extensor proprius hallucis and Tibialis anticus and also the vessels and nerves. These two tendons are contained in separate synovial sheaths situated beneath the ligament.

The Internal Annular Ligament (ligamentum laciniatum) is a strong fibrous band which extends from the inner malleolus above to the internal margin of the os calcis below, converting a series of grooves in this situation into canals for the passage of the tendons of the Flexor muscles and vessels into the sole of the foot. It is continuous by its upper border with the deep fascia of the leg, and by its lower border with the plantar fascia and the fibres of origin of the Abductor hallucis muscle. The four canals which the ligament completes transmit, counting from before backward, first, the tendon of the Tibialis posticus; second, the tendon of the Flexor longus digitorum; third, the posterior tibial vessels and nerve, which run through a broad space beneath the ligament; lastly, in a canal formed partly by the astragalus, the tendon of the Flexor longus hallucis. The canals for the tendons are lined by a separate synovial membrane.

The External Annular Ligament is divided into two portions: a superior portion (retinaculum mm. peronaeorum superius), which extends from the extremity of the outer malleolus to the outer surface of the os calcis: it binds down the tendons of the Peroneus longus and brevis muscles in their passage behind the external malleolus. The two tendons are enclosed in one synovial sac. An inferior portion (retinaculum mm. peronaeorum inferius), which bridges the Peronei on the side of the os calcis and is attached to the bone above and below them.

Dissection of the Sole of the Foot.—The foot should be placed on a high block with the sole uppermost, and firmly secured in that position. Carry an incision round the heel and along the inner and outer borders of the foot to the great and little toes. This incision should divide the integument and thick layer of granular fat beneath until the fascia is visible; the skin and fat should then be removed from the fascia in a direction from behind forward, as seen in Fig. 345.

Plantar Fascia (aponeurosis plantaris).—The plantar fascia, the densest of all the fibrous membranes, is of great strength, and consists of pearly-white glistening fibres, disposed, for the most part, longitudinally; it is divided into a central and two lateral portions.

Central Portion.—The central portion, the thickest, is narrow behind and attached to the inner tubercle of the os calcis, posterior to the origin of the Flexor brevis digitorum, and, becoming broader and thinner in front, divides near the heads of the metatarsal bones into five processes, one for each of the toes. Each of these processes divides opposite the metatarso-phalangeal articulation into two strata, superficial and deep. The superficial stratum is inserted into the skin of the transverse sulcus which divides the toes from the sole. The deeper stratum divides into two slips which embrace the sides of the flexor tendons of the toes, and blend with the sheaths of the tendons, and laterally with the transverse metatarsal ligament, thus forming a series of arches through which the tendons of the short and long flexors pass to the toes. The intervals left between the five processes allow the digital vessels and nerves and the tendons of the Lumbricales muscles to become superficial. At the point of division of the fascia into processes and slips numerous transverse fibres are superadded, which serve to increase the strength of the fascia at this part by binding the processes
together and connecting them with the integument. The central portion of the plantar fascia is continuous with the lateral portions at each side, and sends upward into the foot, at their point of junction, two strong vertical intermuscular septa, broader in front than behind, which separate the middle from the external and internal plantar group of muscles; from these, again, thinner transverse septa are derived, which separate the various layers of muscles in this region. The upper surface of this fascia gives attachment behind to the Flexor brevis digitorum muscle.

Lateral Portions.—The lateral portions of the plantar fascia are thinner than the central piece, and cover the sides of the foot. The outer portion covers the under surface of the Abductor minimi digitii; it is thick behind, thin in front, and extends from the os calcis, forward, to the base of the fifth metatarsal bone, into the outer side of which it is attached; it is continuous internally with the middle portion of the plantar fascia, and externally with the dorsal fascia. The inner portion is very thin, and covers the Abductor hallucis muscle; it is attached behind to the internal annular ligament, and is continuous around the side of the foot with the dorsal fascia, and externally with the middle portion of the plantar fascia.

Bursae about the Ankle and Foot.—(1) A subcutaneous bursa on the sole of the foot, beneath the tuberosity of the os calcis. (2) A subcutaneous bursa over the tendo Achillis (bursa subcutanea calcanea). (3) The retrocalcaneal bursa, between the posterior surface of the os calcis and the insertion of the tendo Achillis (bursa tendinitis calcanei [Achillis]). (4) A bursa between the internal cuneiform bone and the tendon of the Tibialis anticus (bursa subtendinea m. tibialis anteriors). (5) Bursae between the heads of the metatarsal bones (bursae intermetatarsophalangeae). (6) A subcutaneous bursa over the internal malleolus (bursa subcutanea malleoli medialis). (7) Bursae between the scaphoid and middle cuneiform bones on the one hand and the tendon of the Tibialis posticus on the other (bursa subtendinea m. tibialis posteriors). (8) Bursae between the Lumbricales and the transverse ligaments (bursaemmm. lumbicalesum pedis). (9) A bursa over the external malleolus (bursa subcutanea malleoli lateralis). (10) A bursa over the head of the first metatarsal bone. Various muscles have tendon-sheaths lined with synovial membrane (vaginal sheaths).

Surgical Anatomy.—The dense plantar fascia aids powerfully in maintaining the arch of the foot. When this fascia stretches or gives way flat-foot forms. In some forms of club-foot the plantar fascia is contracted. This contraction is usually a secondary change.

When inflammation causes tenderness and enlargement of the bursa over the metatarsophalangeal articulation of the great toe, the enlargement is called a bunion. Enlargement of the retro-calcaneal bursa is known as Albert’s disease, or achillodynia.

8. The Dorsal Region (Fig. 350).

Extensor brevis digitorum.

Fascia (fascia dorsalis pedis).—The fascia on the dorsum of the foot is a thin membranous layer continuous above with the anterior margin of the annular ligament; it becomes gradually lost opposite the heads of the metatarsal bones, and on each side blends with the lateral portions of the plantar fascia; it forms a sheath for the tendons placed on the dorsum of the foot. On the removal of this fascia the muscles and tendons of the dorsal region of the foot are exposed.

The Extensor Brevis Digitorum (m. extensor digitorum brevis) (Fig. 350) is a broad thin muscle which arises from the forepart of the upper and outer surfaces of the os calcis, in front of the groove for the Peroneus brevis, from the external calcaneo-astragaloid ligament, and from the common limb of the Y-shaped portion of the anterior annular ligament. It passes obliquely
across the dorsum of the foot, and terminates in four tendons. The innermost, which is the largest, is inserted into the dorsal surface of the base of the first phalanx of the great toe, crossing the dorsalis pedis artery; the other three, into the outer sides of the long extensor tendons of the second, third, and fourth toes.

Relations.—By its superficial surface, with the fascia of the foot, the tendons of the Extensor longus digitorum and Peroneus tertius; by its deep surface, with the tarsal and metatarsal arteries and bones and the Dorsal interossei muscles.

Nerves.—It is supplied by the anterior tibial nerve.

Actions.—The Extensor brevis digitorum is an accessory to the long Extensor, extending the phalanges of the four inner toes, but acting only on the first phalanx of the great toe. The obliquity of its direction counteracts the oblique movement given to the toes by the long Extensor, so that, both muscles acting together, the toes are evenly extended.


The muscles in the plantar region of the foot may be divided into three groups, in a similar manner to those in the hand. Those of the internal plantar region are connected with the great toe, and correspond with those of the thumb; those of the external plantar region are connected with the little toe, and correspond with those of the little finger; and those of the middle plantar region are connected with the tendons intervening between the two former groups. But in order to facilitate the dissection of these muscles it will be found more convenient to divide them into four layers, as they present themselves, in the order in which they are successively exposed.

The First Layer.


Dissection.—Remove the fascia on the inner and outer sides of the foot, commencing in front over the tendons and proceeding backward. The central portion should be divided transversely in the middle of the foot, and the two flaps dissected forward and backward.

The Abductor Hallucis lies along the inner border of the foot. It arises from the inner tubercle on the under surface of the os calcis; from the internal annular ligament; from the plantar fascia; and from the intermuscular septum between it and the Flexor brevis digitorum. The fibres terminate in a tendon which is inserted, together with the innermost tendon of the Flexor brevis hallucis, into the inner side of the base of the first phalanx of the great toe.

Relations.—By its superficial surface, with the plantar fascia; by its deep surface, with the Flexor brevis hallucis, the Flexor accessorius, and the tendons of the Flexor longus digitorum and Flexor longus hallucis, the Tibialis anticus and posticus, the plantar vessels and nerves. Its outer border is in relation to the Flexor brevis digitorum.

The Flexor Brevis Digitorum (m. flexor digitorum brevis) lies in the middle of the sole of the foot, immediately beneath the plantar fascia, with which it is firmly united. It arises by a narrow tendinous process, from the inner tuberele of the os calcis, from the central part of the plantar fascia, and from the intermuscular septa between it and the adjacent muscles. It passes forward, and divides into four tendons, one for each of the four outer toes. Opposite the bases of the first phalanges each tendon divides into two slips, to allow of the passage of the corresponding tendon of the Flexor longus digitorum;
the two portions of the tendon then unite and form a grooved channel for the reception of the accompanying long flexor tendon. Finally, they divide a second time, to be inserted into the sides of the second phalanges about their middle. The mode of division of the tendons of the Flexor brevis digitorum and their insertion into the phalanges is analogous to the division and insertion of the Flexor sublimis digitorum in the hand.

**Relations.**—By its superficial surface, with the plantar fascia; by its deep surface, with the Flexor accessorius, the Lumbricales, the tendons of the Flexor longus digitorum, and the lateral plantar vessels and nerve, from which it is separated by a thin layer of fascia. The outer and inner borders are separated from the adjacent muscles by means of vertical prolongations of the plantar fascia.

Fibrous Sheaths of the Flexor Tendons.—These are not so well marked as in the fingers. The flexor tendons of the toes as they run along the phalanges are retained against the bones by a fibrous sheath, forming osseo-aponeurotic canals. These sheaths are formed by strong fibrous bands which arch across the tendons and are attached on each side to the margins of the phalanges. Opposite the middle of the proximal and second phalanges the sheath is very strong, and the fibres pass transversely, but opposite the joints it is much thinner, and the fibres pass obliquely. Each sheath is lined by a synovial membrane which is reflected on the contained tendon.

The Abductor Minimi Digiti (m. abductor digiti quinti) lies along the outer border of the foot. It arises, by a very broad origin, from the outer tubercle of the os calcis, from the under surface of the os calcis between the two tubercles, from the forepart of the inner tubercle, from the plantar fascia and the intermuscular septum, between it and the Flexor brevis digitorum. Its tendon, after gliding over a smooth facet on the under surface of the base of the fifth metatarsal bone, is inserted with the short Flexor of the little toe into the outer side of the base of the first phalanx of this toe.

**Relations.**—By its superficial surface, with the plantar fascia; by its deep surface, with the Flexor accessorius, the Flexor brevis minimi digiti, the long plantar ligament, and the tendon of the Peroneus longus. On its inner side are the lateral plantar vessels and nerve, and it is separated from the Flexor brevis digitorum by a vertical septum of fascia.

**Dissection.**—The muscles of the superficial layer should be divided at their origin by inserting the knife beneath each, and cutting obliquely backward, so as to detach them from the bone; they should then be drawn forward, in order to expose the second layer, but not cut away at their insertion. The two layers are separated by a thin membrane, the deep plantar fascia,
on the removal of which is seen the tendon of the Flexor longus digitorum, the Flexor accessorius, the tendon of the Flexor longus hallucis, and the Lumbricales. The long flexor tendons diverge from each other at an acute angle; the Flexor longus hallucis runs along the inner side of the foot, on a plane superior to that of the Flexor longus digitorum, the direction of which is obliquely outward.

The Second Layer.

Flexor accessorius. Lumbricales.

The Flexor Accessorius (m. quadratus plantae) arises by two heads, which are separated from each other by the long plantar ligament: the inner or larger head, which is muscular, being attached to the inner concave surface of the os calcis below the groove which lodges the tendon of the Flexor longus digitorum; the outer head, flat and tendinous, to the outer surface of the os calcis, in front of its lesser tuberele, and to the long plantar ligament; the two portions join at an acute angle, and are inserted into the outer margin and upper and under surfaces of the tendon of the Flexor longus digitorum, forming a kind of groove in which the tendon is lodged.\(^1\)

Relations.—By its superficial surface, with the muscles of the superficial layer, from which it is separated by the lateral plantar vessels and nerves; by its deep surface, with the os calcis and long calcaneo-cuboid ligament.

The Lumbricales are four small muscles accessory to the tendons of the Flexor longus digitorum: they arise from the tendons of the long Flexor, as far back as their angle of division, each arising from two tendons, except the internal one. Each muscle terminates in a tendon, which passes forward on the inner side of the four lesser toes and is inserted into the expansion of the long Extensor tendon on the dorsum of the first phalanx of the corresponding toe.

Dissection.—The flexor tendons should be divided at the back part of the foot, and the Flexor accessorius at its origin, and drawn forward, in order to expose the third layer.

The Third Layer.


The Flexor Brevis Hallucis (m. flexor hallucis brevis) arises, by a pointed tendinous process, from the inner part of the under surface of the cuboid bone, from the contiguous portion of the external cuneiform, and from the prolongation of the tendon of the Tibialis posticus, which is attached to that bone. The muscle divides, in front, into two portions, which are inserted into the inner and outer sides of the base of the first phalanx of the great toe, a sesamoid bone being developed in each tendon at its insertion. The inner portion of this muscle is blended with the Abductor hallucis previous to its insertion, the outer portion with the Adductor obliquus hallucis, and the tendon of the Flexor longus hallucis lies in a groove between them.

Relations.—By its superficial surface, with the Abductor hallucis and the tendon of the Flexor longus hallucis; by its deep surface, with the tendon of the Peroneus longus and metatarsal bone of the great toe; by its inner border, with the Abductor hallucis; by its outer border, with the Adductor obliquus hallucis.

The Adductor Obliquus Hallucis is a large, thick, fleshy mass passing obliquely across the foot and occupying the hollow space between the four inner metatarsal bones. It arises from the tarsal extremities of the second, third, and fourth metatarsal bones, and from the shear of the tendon of the Peroneus longus,

\(^1\) According to Turner, the fibres of the Flexor accessorius end in aponeurotic bands, which contribute slips to the second, third, and fourth digits.
and is inserted, together with the outer portion of the Flexor brevis hallucis, into the outer side of the base of the first phalanx of the great toe.

The small muscles of the great toe, the Abductor, Flexor brevis, Adductor obliquus, and Adductor transversus, like the similar muscles of the thumb, give off fibrous expansions, at their insertions, to blend with the long Extensor tendon.

The Flexor Brevis Minimi Digiti (m. flexor digiti quinti brevis) lies on the metatarsal bone of the little toe, and much resembles one of the Interossei. It arises from the base of the metatarsal bone of the little toe, and from the sheath of the Peroneus longus; its tendon is inserted into the base of the first phalanx of the little toe on its outer side. Occasionally some of the deeper fibres of the muscle are inserted into the outer part of the distal half of the fifth metatarsal bone; these are described by some as a distinct muscle, the Opponens minimi digiti.

Relations.—By its superficial surface, with the plantar fascia and tendon of the Abductor minimi digiti; by its deep surface, with the fifth metatarsal bone.
The Adductor Transversus Hallucis (m. transversus pedis) is a narrow, flat, muscular fasciculus, stretched transversely across the heads of the metatarsal bones, between them and the flexor tendons. It arises from the inferior metatarso-phalangeal ligaments of the three outer toes, sometimes only from the third and fourth and from the transverse ligament of the metatarsus; and is inserted into the outer side of the first phalanx of the great toe, its fibres being blended with the tendon of insertion of the Adductor obliquus hallucis.

**Relations.**—By its superficial surface, with the tendons of the long and short Flexors and Lumbricales; by its deep surface, with the Interossei.

### The Fourth Layer.

**The Interossei.**

The Interossei Muscles in the foot are similar to those in the hand, with this exception, that they are grouped around the middle line of the second toe, instead of the middle line of the third finger, as in the hand. They are seven in number, and consist of two groups, Dorsal and Plantar.

![Fig. 357.—The Dorsal Interossei. Left foot.](image1)
![Fig. 358.—The Plantar Interossei. Left foot.](image2)

The **Dorsal Interossei** (m. interossei dorsales), four in number, are situated between the metatarsal bones. They are bipenniform muscles, arising by two heads from the adjacent sides of the metatarsal bones, between which they are placed; their tendons are inserted into the bases of the first phalanges, and into the aponeurosis of the common extensor tendon. In the angular interval left between the heads of each muscle at its posterior extremity the perforating arteries pass to the dorsum of the foot, except in the First interosseous muscle, where the interval allows the passage of the communicating branch of the dorsalis pedis artery. The First dorsal interosseous muscle is inserted into the inner side of the second toe; the other three are inserted into the outer sides of the second, third, and fourth toes.

The **Plantar Interossei** (m. interossei plantares), three in number, lie beneath, rather than between, the metatarsal bones. They are single muscles, and are each connected with but one metatarsal bone. They arise from the base and
inner sides of the shaft of the third, fourth, and fifth metatarsal bones, and are inserted into the inner sides of the bases of the first phalanges of the same toes, and into the aponeurosis of the common extensor tendon.

Nerves.—The Flexor brevis digitorum, the Flexor brevis and Abductor hallucis, and the innermost Lumbrical are supplied by the medial plantar nerve. All the other muscles in the sole of the foot by the lateral plantar. The first dorsal interosseous muscle frequently receives an extra filament from the internal branch of the anterior tibial nerve on the dorsum of the foot, and the second dorsal interosseous a twig from the external branch of the same nerve.

Actions.—All the muscles of the foot act upon the toes, and for purposes of description as regard their action may be grouped as Abductors, Adductors, Flexors, or Extensors. The Abductors are the Dorsal interossei, the Abductor hallucis, and the Abductor minimi digitii. The Dorsal interossei are abductors from an imaginary line passing through the axis of the second toe, so that the first muscle draws the second toe inward, toward the great toe; the second muscle draws the same toe outward; the third draws the third toe, and the fourth draws the fourth toe, in the same direction. Like the interossei in the hand, they also flex the proximal phalanges and extend the two terminal phalanges. The Abductor hallucis abducts the great toe from the others, and also flexes the proximal phalanx of this toe. And in the same way the action of the Abductor minimi digitii is twofold—as an abductor of this toe from the others, and also as a flexor of the proximal phalanx. The Adductors are the Plantar interossei, the Adductor obliquus hallucis, and the Adductor transversus hallucis. The Plantar interosseous muscles adduct the third, fourth, and fifth toes toward the imaginary line passing through the second toe, and by means of their insertion into the aponeurosis of the extensor tendon they, with the dorsal interossei, flex the proximal phalanges and extend the two terminal phalanges. The Adductor obliquus hallucis is chiefly concerned in adducting the great toe toward the second one, but also assists in flexing this toe. The Adductor transversus hallucis approximates all the toes, and thus increases the curve of the transverse arch of the metatarsus. The Flexors are the Flexor brevis digitorum, the Flexor accessorius, the Flexor brevis hallucis, the Flexor brevis minimi digitii, and the Lumbricales. The Flexor brevis digitorum flexes the second phalanges upon the first, and, continuing its action, may flex the first phalanges also and bring the toes together. The Flexor accessorius assists the Long flexor of the toes, and converts the oblique pull of the tendons of that muscle into a direct backward pull upon the toes. The Flexor brevis hallucis flexes and slightly adducts the first phalanx of the great toe. The Flexor brevis minimi digitii flexes the little toe and draws its metatarsal bone downward and inward. The Lumbricales, like the corresponding muscles in the hand, assist in flexing the proximal phalanx, and by their insertion into the long Extensor tendon aid in straightening the two terminal phalanges. The only muscle in the Extensor group is the Extensor brevis digitorum. It extends the first phalanx of the great toe, and assists the long Extensor in extending the next three toes, and at the same time gives to the toes an outward direction when they are extended.

SURFACE FORM OF THE LOWER EXTREMITY.

Of the muscles of the thigh, those of the iliac region have no influence on surface form, while those of the anterior femoral region, being to a great extent superficial, largely contribute to the surface form of this part of the body. The Tensor fasciae femoris pro-

1 Formerly the two inner Lumbricales were described as being supplied by the internal plantar nerve. Brooks (Journal of Anatomy, vol. xxii. p. 375) in ten dissections found that in nine of them only the inner Lumbrical obtained its nerve supply from this source. In the tenth instance the first and second Lumbricales were supplied by both external and internal plantar.
duces a broad elevation immediately below the anterior portion of the crest of the ilium and behind the anterior superior spinous process. From its lower border a longitudinal groove, corresponding to the ilio-tibial band, may be seen running down the outer side of the thigh to the outer side of the knee-joint. The Sartorius muscle, when it is brought into action by flexing the leg on the thigh and the thigh on the pelvis, and rotating the thigh outward, presents a well-marked surface form. At its upper part, where it constitutes the outer boundary of Scarpa's triangle, it forms a prominent oblique ridge, which becomes changed into a flattened plane below, and this gradually merges in a general fulness on the inner side of the knee-joint. When the Sartorius is not in action, a depression exists between the Quadriceps extensor and the Adductor muscles, running obliquely downward and inward from the apex of Scarpa's triangle to the inner side of the knee, which depression corresponds to this muscle. In the depressed angle formed by the divergence of the Sartorius and Tensor fasciae latae muscles, just below the anterior superior spinous process of the ilium, the Rectus femoris muscle appears, and, below this, determines to a great extent the convex form of the front of the thigh. In a well-developed subject the borders of the muscle, when in action, are clearly to be defined. The Vastus externus forms a long flattened plane on the outer side of the thigh, traversed by the longitudinal groove formed by the ilio-tibial band. The Vastus internus, on the inner side of the lower half of the thigh, gives rise to a considerable prominence, which increases toward the knee and terminates somewhat abruptly in this situation with a full, curved outline. The Crureus and Subcrureus are completely hidden, and do not directly influence surface form. The Adductor muscles, constituting the internal femoral group, are not to be individually distinguished from each other, with the exception of the upper tendon of the Adductor magnus and the lower tendon of the Adductor magnus. The upper tendon of the Adductor longus, when the muscle is in action, stands out as a prominent ridge, which runs obliquely downward and outward from the neighborhood of the pubis spine, and forms the inner boundary of a flattened triangular space on the upper part of the front of the thigh, known as Scarpa's triangle. The lower tendon of the Adductor magnus can be distinctly felt as a short ridge extending down to the Adductor tubercle on the internal condyle, between the Sartorius and Vastus internus. The Adductor group of muscles fills in the triangular space at the upper part of the thigh, formed between the oblique femur and the pelvic wall, and to them is due the contour of the inner border of the thigh, the Gracilis largely contributing to the smoothness of the outline. These muscles are not marked off on the surface from those of the posterior femoral region by any intermuscular marking; but on the outer side of the thigh these latter muscles are defined from the Vastus externus by a distinct marking, corresponding to the external intermuscular septum. The Gluteus maximus and a part of the Gluteus medius are the only muscles of the buttock which influence surface form. The other part of the Gluteus medius, the Gluteus minimus, and the External rotators are completely hidden. The Gluteus maximus forms the full rounded outline of the buttoc; it is more prominent behind, compressed in front, and terminates at its tendinous insertion in a depression immediately behind the great trochanter. Its lower border does not correspond to the gluteal fold, but is much more oblique, being marked by a line drawn from the side of the coccyx to the junction of the upper with the lower two-thirds of the thigh on the outer side. From beneath the lower margin of this muscle the hamstring muscles appear, at first narrow and not well marked, but as they descend becoming more prominent and widened out, and eventually dividing into two well-marked ridges, which constitute the upper boundaries of the popliteal space, and are formed by the tendons of the inner and outer hamstring muscles respectively. In the upper part of the thigh these muscles are not to be individually distinguished from each other, but lower down the separation between the Semitendinosus and Semimembranosus is denoted by a slight intermuscular marking. The external hamstring tendon formed by the Biceps is seen as a thick cord running down to the head of the fibula. The inner hamstring tendons comprise the Semitendinosus, the Semimembranosus, and the Gracilis. The Semitendinosus is the most internal of these, and can be felt, in certain positions of the limb, as a sharp cord; the Semimembranosus is thick, and the Gracilis is situated a little farther forward than the other two. All the muscles on the front of the leg appear to a certain extent somewhere on the surface, but the form of this region is mainly dependent upon the Tibialis anticus and the Extensor longus digitorum. The Tibialis anticus is well marked, and presents a fusiform enlargement at the outer side of the tibia, and projects beyond the crest of the shinbone. From the muscular mass its tendons may be traced downward, standing out boldly, when the muscle is in action, on the front of the tibia and ankle-joint, and coursing down to its insertion along the inner border of the foot. A well-marked groove separates this muscle externally from the Extensor longus digitorum, which fills up the rest of the space between the upper part of the shaft of the tibia and fibula. It does not present so bold an outline as the Tibialis anticus, and its tendons below, diverging from the tendon of the Tibialis anticus, forms with the latter a sort of plane, in which may be seen the tendon of the Extensor proprius hallucis. A groove on the outer side of the extensor longus digitorum, seen most plainly when the muscle is in action, separates the tendon from a slight eminence corresponding to the Peroneus tertius. The fleshy fibres of the Peroneus longus are strongly marked at the upper part of the outer
side of the leg, especially when the muscle is in action. It forms a bold swelling, separated by furrows from the Extensor longus digitorum in front and the Soleus behind. Below, the fleshy fibres terminate abruptly in a tendon which overlaps the more flattened form of the Extensor brevis. At the external malleolus the tendon of the Peroneus brevis is more marked than that of the Peroneus-longus. On the dorsum of the foot the tendons of the Extensor muscles, emerging from beneath the anterior annular ligament, spread out and can be distinguished in the following order: The most internal and largest is the Tibialis anticus, then the Extensor proprius hallucis; next comes the Extensor longus digitorum, dividing into four tendons to the four outer toes; and lastly, most externally, is the Peroneus tertius. The flattened form of the dorsum of the foot is relieved by the rounded outline of the fleshy belly of the Extensor brevis digitorum, which forms a soft fulness on the outer side of the tarsus in front of the external malleolus, and by the Dorsal interossei, which bulge between the metatarsal bones. At the back of the knee is the popliteal space, bounded above by the tendons of the hamstring muscle; below, by the two heads of the Gastrocnemius. Below this space is the prominent fleshy mass of the calf of the leg, produced by the Gastrocnemius and Soleus. When these muscles are in action, as in standing on tiptoe, the borders of the Gastrocnemius are well defined, presenting two curved lines, which converge to the tendon of insertion. Of these borders, the inner is more prominent than the outer. The fleshy mass of the calf terminates somewhat abruptly below in the tendon Achilles, which stands out prominently on the lower part of the back of the leg. It presents a somewhat tapering form in the upper three-fourths of its extent, but widens out slightly below. When the muscles of the calf are in action, the lateral portions of the Soleus may be seen, forming curved eminences, of which the outer is the longer, on either side of the Gastrocnemius. Behind the inner border of the lower part of the shaft of the tibia a well-marked ridge, produced by the tendon of the Tibialis posticus, is visible when this muscle is in a state of contraction. On the sole of the foot the superficial layer of muscles influences surface form; the Abductor minimi digitii most markedly. This muscle forms a narrow rounded elevation along the outer border of the foot, while the Abductor hallucis does the same, though to a less extent, on the inner side. The Flexor brevis digitorum, bound down by the plantar fascia, is not very apparent; it produces a flattened form, covered by the thickened skin of the sole, which is here thrown into numerous wrinkles.

**Surgical Anatomy of the Lower Extremity.**

The student should now consider the effects produced by the action of the various muscles in fractures of the bones of the lower extremity. The more common forms of fractures are selected for illustration and description.

![Fig. 359. Fracture of the neck of the femur within the capsular ligament.](image)

In fracture of the neck of the femur internal to the capsular ligament (Fig. 359) the characteristic marks are slight shortening of the limb and eversion of the foot, neither of which symp-
toms occurs, however, in some cases until some time after the injury. The eversion is caused by the weight of the limb rotating it outward. The shortening is produced by the action of the Glutei, and by the Rectus femoris in front and the Bieeps, Semitendinosus, and Semimembranosus behind. The treatment is extension by means of adhesive plaster and weights and counter-extension by raising the foot of the bed, eversion being corrected by sand-bags. In some cases Thomas's splint is used.

In fracture of the femur just below the trochanters (Fig. 360) the upper fragment, the portion chiefly displaced, is tilted forward almost at right angles with the pelvis by the combined action of the Psoas and Iliacus, and, at the same time, everted and drawn outward by the External rotator and Glutei muscles, causing a marked prominence at the upper and outer side of the thigh, and much pain from the bruising and laceration of the muscles. The limb is shortened, in consequence of the lower fragment being drawn upward by the rectus in front, and the Bieeps, Semimembranosus, and Semitendinosus behind, and is at the same time everted. This fracture may be reduced by direct relaxation of all the opposing muscles, to effect which the limb should be put up in such a manner that the thigh is flexed on the pelvis and the leg on the thigh, the extremity being placed upon a double inclined plane and extension being made in the axis of the partly flexed thigh by means of adhesive plaster and weights. In some cases it is necessary to incise and wire the fragments together.

Oblique fracture of the femur immediately above the condyles (Fig. 361) is a formidable injury, and attended with considerable displacement. On examination of the limb the lower fragment may be felt deep in the popliteal space, being drawn backward by the Gastrocnemius and Plantaris muscles, and upward by the Hamstring and Rectus muscles. The pointed end of the upper fragment is drawn inward by the Pectineus and Adductor muscles, and tilted forward by the Psoas and Iliacus, piercing the Rectus muscle and occasionally the integument. Relaxation of these muscles and direct approximation of the broken fragments are effected by placing the limb on a double inclined plane. The greatest care is requisite in keeping the pointed extremity of the upper fragment in proper position; otherwise, after union of the fracture, the power of extension of the limb is partially destroyed from the Rectus muscle being held down by the fractured end of the bone, and from the patella, when elevated, being drawn upward against the projecting fragment.

In fracture of the patella (Fig. 362) the fragments are separated by the effusion which takes place into the joint, and by the action of the Quadriceps extensor; the extent of separation of the two fragments depending upon the degree of laceration of the ligamentous structures around the bone. Some cases may be treated by a posterior straight splint, the fragments being pulled together by strips of adhesive plaster. In many cases it is advisable to incise, remove intervening pieces of fibrous tissue and wire the fragments together.
The *tibia* is fractured most commonly by indirect force at the junction of the middle third with the lower third of the shaft. Compound fractures are more common in the leg than in any other region of the body because the tibia is such a superficial bone and is so much exposed to injury. Most fractures from indirect force are oblique.

In *oblique fracture of the shaft of the tibia* (Fig. 363), if the fracture has taken place obliquely from above, downward and forward, the fragments ride over one another, the lower fragments being drawn backward and upward by the powerful action of the muscles of the calf; the pointed extremity of the upper fragment projects forward immediately beneath the integument, often protruding through it and rendering the fracture a compound one. If the direction of the fracture is the reverse of that shown in the figure, the pointed extremity of the lower fragment projects forward, riding upon the lower end of the upper one. By bending the knee, which relaxes the opposing muscles, and making extension from the ankle and counter-extension at the knee, the fragments may be brought into apposition. It is often necessary, however, in a compound fracture, to remove a portion of the projecting bone with the saw before complete adaptation can be effected.

*Fracture of the fibula with dislocation of the foot outward* (Fig. 364), commonly known as *Pott’s fracture*, is one of the most frequent injuries of the ankle-joint. The fibula is fractured about three inches above the ankle; in addition to this the internal malleolus is broken off, or the deltoid ligament torn through, and the end of the tibia displaced from the corresponding surface of the astragalus. The foot is markedly everted, and the sharp edge of the upper end of the fractured malleolus presses strongly against the skin; at the same time, the heel is drawn up by the muscles of the calf. This injury can generally be reduced by flexing the leg at right angles with the thigh, which relaxes all the opposing muscles, and by making extension from the ankle and counter-extension at the knee.
THE BLOOD-VASCULAR SYSTEM.

ANGIOLOGY is the branch of anatomy which treats of the blood-vessels. The blood-vascular system comprises the heart and blood-vessels with their contained fluid, the blood.

The Heart is the central organ of the entire system, and is a hollow muscle; by its contraction the blood is pumped to all parts of the body through a complicated series of tubes, termed arteries. The arteries undergo almost infinite ramification in their course throughout the body, and end in very minute vessels, called arterioles, which in their turn open into a close-meshed network of microscopic vessels, termed capillaries. After the blood has passed through the capillaries it enters into minute vessels called venules and from them it is collected into a series of larger vessels, called veins, by which it is returned to the heart. The passage of the blood through the heart and blood-vessels constitutes what is termed the circulation of the blood, of which the following is an outline.

The human heart is divided by a septum into two halves, right and left, each half being further constricted into two cavities, the upper of the two being termed the auricle and the lower the ventricle. The heart therefore consists of four chambers or cavities, two forming the right half, the right auricle and right ventricle; and two the left half, the left auricle and left ventricle. The right half of the heart contains venous or impure blood; the left, arterial or pure blood. From the cavity of the left ventricle the pure blood is carried into a large artery, the aorta, through the numerous branches of which it is distributed to all parts of the body, with the exception of the lungs. In its passage through the capillaries of the body the blood gives up to the tissues the materials necessary for their growth and nourishment, and at the same time receives from the tissues the waste products resulting from their metabolism, and in doing so becomes changed from arterial or pure blood into venous or impure blood, which is collected by the veins and through them returned to the right auricle of the heart. From this cavity the impure blood passes into the right ventricle, from which it is conveyed through the pulmonary arteries to the lungs. In the capillaries of the lungs it again becomes arterialized, and is then carried to the left auricle by the pulmonary veins. From this cavity it passes into that of the left ventricle, from which the cycle once more begins.

The course of the blood from the left ventricle through the body generally to the right side of the heart constitutes the greater or systemic circulation, while its passage from the right ventricle through the lungs to the left side of the heart is termed the lesser or pulmonary circulation.

It is necessary, however, to state that the blood which circulates through the spleen, pancreas, stomach, small intestine, and the greater part of the large intestine is not returned directly from these organs to the heart, but is collected into a large vein, termed the portal vein, by which it is carried to the liver. In the liver this vein divides, after the manner of an artery, and ultimately ends in capillary vessels, from which the rootlets of a series of veins, called the hepatic veins, arise; these carry the blood into the postcava (inferior vena cava), which conveys it to the right auricle.
From this it will be seen that the blood contained in the portal vein passes through two sets of capillary vessels: (1) those in the spleen, pancreas, stomach, etc., and (2) those in the liver.

Speaking generally, the arteries may be said to contain pure, and the veins impure, blood. This is true of the systemic, but not of the pulmonary, vessels, since it has been seen that the impure blood is conveyed from the heart to the lungs by the pulmonary arteries, and the pure blood returned from the lungs to the heart by the pulmonary veins. Arteries, therefore, must be defined as vessels which convey blood from the heart, and veins as vessels which return blood to the heart.

The heart and lungs are contained within the cavity of the thorax, the walls of which afford them protection (Fig. 366). The heart lies between the two lungs, and is there enclosed within a sero-membranous bag, the pericardium, while each lung is invested by a serous membrane, the pleura. The skeleton of the thorax was described on page 156.

The Cavity of the Thorax (cavum thoracis).—The capacity of the cavity of the thorax does not correspond with its apparent size externally, because (1) the space enclosed by the lower ribs is occupied by some of the abdominal viscera; and (2) the cavity extends above the first rib into the neck.

The size of the cavity of the thorax is constantly varying during life, with the movements of the ribs and diaphragm, and with the degree of distention of the abdominal viscera. From the collapsed state of the lungs, as seen when the thorax is opened, in the dead body, it would appear as if the viscera only partly filled the cavity of the thorax, but during life there is no vacant space, that which is seen after death being filled up during life by the expanded lungs.

The Upper Opening of the Thorax (apertura thoracis superior).—The parts which pass through the upper opening of the thorax are, from before backward in or near the middle line, the Sterno-hyoid and Sterno-thyroid muscles, the remains of the thymus gland, the trachea, esophagus, thoracic duct, the inferior thyroid veins, and the Longus colli muscle of each side; at the sides, the innominate artery, the left common carotid, and left subclavian arteries, the internal mammary and superior intercostal arteries, the right and left innominate veins, the vagus, cardiac, phrenic, and sympathetic nerves, the anterior branch of the first thoracic nerve, and the recurrent laryngeal nerve of the left side. The apex of each lung, covered by the pleura, also projects through this aperture, a little above the margin of the first rib.

The Lower Opening of the Thorax (apertura thoracis inferior) is wider transversely than from before backward. It slopes obliquely downward and backward, so that the cavity of the thorax is much deeper behind than in front. The
Diaphragm (see page 429) closes in the opening, forming the floor of the thorax. The floor is flatter at the centre than at the sides, and is higher on the right side than on the left, corresponding in the dead body to the upper border of the fifth costal cartilage on the former, and to the corresponding part of the sixth costal cartilage on the latter. From the highest point on each side the floor slopes suddenly downward to the attachment of the Diaphragm to the ribs; this is more marked behind than in front, so that only a narrow space is left between it and the wall of the thorax.

**THE PERICARDIUM.**

The pericardium (Figs. 367, 368, 369, 370, 371, and 372) is a conical seromembranous sac, placed in the middle mediastinum. In this sac the heart and the commencement of the great vessels are contained. It is placed behind the sternum and the cartilages of the third, fourth, fifth, sixth, and seventh ribs of the left side, in the interval between the pleure.

Its apex is directed upward, and surrounds the great vessels about two inches above their origin from the base of the heart. Its base is attached to the central tendon and to the left part of the adjoining muscular structure of the Diaphragm. In front it is separated from the sternum by the remains of the thymus gland.
above and a little loose areolar tissue below, and is covered by the margins of the lungs, especially the left. **Behind**, it rests upon the bronchi, the oesophagus, and the descending aorta. **Laterally**, it is covered by the pleura, and is in relation to the inner surface of the lungs; the phrenic nerve with its accompanying vessels descends between the pericardium and pleura on either side (Fig. 371).

**Structure of the Pericardium.**—The pericardium is a fibro-serous membrane, and consists, therefore, of two layers, an external fibrous and an internal serous.

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**Fig. 367.**—Pericardium from in front. The sac has been distended with plaster. (From a preparation in the Museum of the Royal College of Surgeons of England.)

The **Fibrous Layer** is a strong, dense, connective-tissue membrane. Above, it surrounds the great vessels arising from the base of the heart, on which it is continued in the form of tubular prolongations which are gradually lost upon their external coat, the strongest being that which encloses the aorta. The pericardium may be traced over these vessels, to become continuous with the deep layer of the cervical fascia. The prolongations to the cervical fascia constitute the **vertebro-pericardial ligaments** (Fig. 370). In front the pericardium is connected to the posterior surface of the sternum by two fibrous bands, the **superior** and **inferior sterno-pericardiac ligaments** or ligaments of Luschka (ligamenta sternopericardiaca) (Fig. 370). The superior sterno-pericardial ligament, called also the **sternocosto-**
pericardial ligament (Fig. 370), passes to the manubrium. The inferior sternopericardial ligament, called also the xipho-pericardial ligament (Fig. 370), passes to the ensiform cartilage. On each side of the ascending aorta the pericardium sends upward a diverticulum: the one on the left side, somewhat conical in shape, passes upward and outward, between the arch of the aorta and the pulmonary artery, as far as the ductus arteriosus, where it terminates in a cecal extremity, which is attached by loose connective tissue to the obliterated duct (Fig. 367). The one on the right side passes upward and to the right, between the ascending aorta and precava (vena cava superior), and also terminates in a cecal extremity. Below, the fibrous layer is attached to the central tendon of the Diaphragm, and on the left side to its muscular fibres. The pericardium is fixed to the Diaphragm by the anterior phreno-pericardial ligament and by the lateral phreno-pericardial ligaments (Fig. 370).

The vessels receiving fibrous prolongations from this membrane are the aorta, the precava, the right and left pulmonary arteries, and the four pulmonary veins. The postcava (inferior vena cava) enters the pericardium through the central tendon of the Diaphragm, and consequently it receives no covering from the fibrous layer (Fig. 371).
The **Serous Pericardium** invests the heart, and is then reflected on the inner surface of the fibrous pericardium. It consists, therefore, of a **visceral layer** (*epicardium*) and a **parietal layer**. The former invests the surface of the heart, and the commencement of the great vessels, to the extent of an inch and a half from their origin; from these it is reflected upon the inner surface of the fibrous layer. The serous membrane encloses the aorta and pulmonary artery in a single tube, so that a passage, termed the **great transverse sinus of the pericardium** (*sinus transversus pericardii*), exists between these vessels in front and the auricle behind. This sinus is closed above and below but often to the right and left. The mem-

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**Fig. 369.**—The line of reflection of the serous pericardium. (Modified from Poirier and Charpy.)

brane only partially covers the precava (superior vena cava) and the four pulmonary veins, and scarcely covers the postcava (inferior vena cava), as this vessel enters the heart almost directly after it has passed through the Diaphragm. A deep blind recess formed by the serous pericardium is found behind the heart when that organ is raised up. This recess runs backward between the left auricle and the posterior portion of the fibrous pericardium, and forms a diverticulum between the heart and the oesophagus. This recess is called the **oblique sinus**. It passes upward between the postcava and the lower left pulmonary vein and terminates between the right and left pulmonary veins. The inner surface of the pericardium is covered with endothelium, which rests upon a mixture of fibrous and elastic tissue, which is smooth and glistening, and secretes a serous fluid (*liquor pericardii*), which serves
to facilitate the movements of the heart. In the serous layer of the pericardium are many blood-vessels, lymph vessels, and nerves.

**Arteries of the Pericardium.**—These are derived from the internal mammary and its musculo-phrenic branch, and from the descending thoracic aorta.

**Nerves of the Pericardium.**—These are branches from the vagus, the phrenic, and the sympathetic.

**The Vestigial Fold of the Pericardium.**—Between the left pulmonary artery and subjacent pulmonary vein and behind the left extremity of the transverse sinus is a triangular fold of the serous pericardium; it is known as the *vestigial fold of Marshall* (ligamentum *v. cavae sinistri*). It is formed by the duplicature of the serous layer over the remnant of the lower part of the left *precava* (*superior vena cava, v. cava sinistra*), or the *duct of Cuvier*, which, after birth, becomes obliterated, and remains as a fibrous band stretching from the left superior intercostal vein to the left auricle, where it is continuous with a small vein, the *oblique vein of Marshall* (*v. obliqua atri sinistri [Marshalli]*), which opens into the coronary sinus and is a remnant of the foetal left precava.

**Surgical Anatomy.**—*Aspiration* of the pericardium (*paracentesis* of the pericardium) is occasionally though seldom performed. It is only to be thought of when pericardial effusion endangers life. The operation is very dangerous, because the effusion lifts the heart and pushes it forward.
and the needle is apt to wound the heart or even enter one of the cavities. There is also danger of wounding the internal mammary artery. The operation is never to be thought of in purulent pericarditis. The safest way to aspirate is to introduce the needle in the fifth interspace two inches to the left of the sternum and push it straight backward.

A better operation, even in a case of serous effusion, and one invariably selected in purulent pericarditis, is incision (pericardotomy). A portion of the cartilage of the fifth rib of the left side is excised. The pericardium is exposed and is punctured, to learn the nature of the contained fluid, and is then incised. By this method the surgeon avoids opening the pleural cavity, and can obtain free drainage if pus is found.

Porter maintains that by "reason of the uncertain and varying relations of the pleura, and also of the anterior position of the heart, whenever the pericardial sac is distended with fluid, aspiration of the pericardium is a much more dangerous procedure than open incision when done by skilled hands."

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**Fig. 371.**—Posterior wall of the pericardial sac, showing the lines of reflection of the serous pericardium on the great vessels.

**THE HEART (COR).**

The heart is a hollow muscular organ of a conical form, placed between the lungs, and enclosed in the cavity of the pericardium.

**Position** (Fig. 372).—The heart is placed obliquely in the chest: the broad attached end, or base (basis cordis), is directed upward, backward, and to the right, and corresponds with the thoracic vertebrae, from the fifth to the eighth inclusive; the apex (apex cordis) is directed downward, forward, and to the left, and corresponds to the space between the cartilages of the fifth and sixth ribs, three-quarters
of an inch to the inner side, and an inch and a half below the left nipple, or about three and a half inches from the middle line of the sternum. The heart is placed behind the sternum, and projects farther into the left than into the right half of the cavity of the chest, extending from the median line about three inches in the former direction, and only one and a half in the latter; about one-third of the heart lies to the right and two-thirds to the left of the mesial plane. The **antero-superior surface** (*facies sternocostalis*) is round and convex, directed upward and forward, is formed chiefly by the right auricle and ventricle, together with a small part of the left ventricle. It lies behind the middle portion of the sternum and the costal cartilages of the third, fourth, fifth, and sixth ribs on both sides. On account of

Fig. 372.—Position of the heart. The pericardium laid open. Adult male. (Poirier and Charpy.)

the heart's inclination to the left side, only a small part of it lies behind the cartilages of the right ribs. Lying in front of the heart, between it and the anterior chest-wall, is the thin anterior margin of the lungs, covered by the pleura. On the left side, however, owing to the notch in the anterior margin of the left lung (*incisura cardiaca*), there is a portion of the pericardium lying in contact with the Triangularis sterni muscle. This area is called the **area of greatest** or of **absolute cardiac dulness** or the **area of superficial cardiac dulness**. The **postero-inferior surface** of the heart (*facies diaphragmatica*), which looks downward rather
than backward, is flattened and rests upon the Diaphragm, and is formed chiefly by the left ventricle. The right or lower border is long, thin, and sharp; the left or upper border short, but thick and round.

**Size and Weight.**—The heart, in the adult, measures five inches in length, three inches and a half in breadth in the broadest part, and two inches and a half in thickness. The prevalent weight, in the male, varies from ten to twelve ounces; in the female, from eight to ten: its proportions to the body being as 1 to 169 in males; 1 to 149 in females. The heart continues increasing in weight, and also in length, breadth, and thickness, up to an advanced period of life: this increase is more marked in men than in women.

**Capacity of the Cavities of the Heart.**—This matter is in dispute. Professor Cunningham believes that during life the capacity of the ventricles is nearly identical, each holding about four ounces of blood. Each auricle holds a little less than four ounces. Stewart maintains that at each heart beat each ventricle throws out only eighty-seven grams of blood. Morrant Baker says that, "taking the mean of various estimates, it may be inferred that each ventricle is able to contain four to six ounces of blood."

**Fat upon the Heart.**—Normally there is a certain amount of fat upon the surface of the heart. This begins to appear in the early weeks of life and increases in amount as age advances. It is found upon the surface of the muscles and along the course of the vessels. Poirier is of the opinion that the cardiac fat on the anterior surface of the heart is arranged in three movable

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1. Kirkes' Physiology, 10th ed., p. 156.
pads, which act as valves and fill vacant spaces about the heart created during the cardiac contractions.1

Component Parts.—The heart is subdivided by a muscular septum into two lateral halves, which are named respectively the right or pulmonary heart and the left or systemic heart; and a transverse constriction subdivides each half of the organ into two cavities, the upper cavity on each side being called the auricle, the lower the ventricle. The course of the blood through the heart cavities and blood-vessels has already been described (page 557).

The division of the heart into four cavities is indicated by grooves upon its surface. The groove separating the auricles from the ventricles is called the auriculoventricular groove (sulcus coronarius). It is deficient, in front, where it is crossed by the root of the pulmonary artery. It contains the trunks of the nutrient vessels of the heart. The auricular portion occupies the base of the heart, and is subdivided into two cavities by a median septum. The two venticles are also separated into a right and left by two furrows, the interventricular grooves (sulci longitudinales), which are situated one on the anterior (sulcus longitudinalis anterior), the other on the posterior (sulcus longitudinalis posterior) surface; these extend from the base of the ventricular portion to near the apex of the organ; the former being situated nearer to the left border of the heart, and the latter to the right. It follows, therefore, that the right ventricle forms the greater portion of the anterior surface of the heart, and the left ventricle more of its posterior surface.

The internal surface of the heart is lined with endocardium.

The auricular portion occupies the base of the heart and is subdivided into two cavities, fore-chambers or auricles (atria), by a septum. As before stated, this portion of the heart corresponds to the middle segment of the thoracic spine. Its form is quadrilateral in shape, and has two processes extending upward from its two upper angles, called the auricular appendices (appendices auriculares), between which are found the aorta and the pulmonary artery. The greater part of the base of the heart is formed by the left auricle. Its boundaries are, above, the pulmonary artery; below, the coronary sinus; on the left it is bounded by the left superior and inferior pulmonary veins, while on the right side it is limited by the sulcus terminalis. The latter corresponds to a ridge in the interior of the auricle, called the crista terminalis. Running vertically on this surface, just to the left of the openings of the two vena cave, is the interauricular furrow, which exactly indicates the proportion of the base of the heart formed by each auricle.

Each of the cavities should now be separately examined.

The Right Fore-chamber or Auricle2 (atrium dextrum) is a little larger than the left, its walls somewhat thinner, measuring about one line. It consists of two parts: a principal cavity, the sinus venosus, situated posteriorly, and an anterior, smaller portion, the auricular appendix. The right auricle is separated from the left auricle by the interauricular septum (septum atriorum). Part of this septum is muscular; part is composed of connective tissue.

The sinus venosus (sinus venarum) is the large quadrangular cavity, placed between the two vena cave; its walls are extremely thin; it is connected below with the right ventricle, and internally with the left auricle, being free in the rest of its extent. It is derived from a portion of the sinus reuniens of the facial heart.

The right auricular appendix (auricula dextra), so-called from its fancied resemblance to a dog’s ear, is a small conical muscular pouch, the margins of which present a dentated edge. It projects from the sinus forward and to the left side, overlapping the root of the aorta.

1 L’appareil sero-graisseux. La Presse Médicale, December 7, 1904.
2 In the new nomenclature the auricle is called the atrium, and auricular appendix is called the auricle.
To examine the interior of the right auricle, an incision should be made along its right border, from the entrance of the precava to that of the postcava. A second cut is to be made from the centre of the first incision to the tip of the auricular appendix, and the flaps raised.

The internal surface of the right auricle is smooth, except in the appendix and adjacent part of the anterior wall of the sinus venosus, where the muscular wall is thrown into parallel ridges resembling the teeth of a comb and hence named the musculi pectinati. These end behind on a vertical smooth ridge, the crista terminalis of His, the position of which is indicated on the surface of the distended auricle by a furrow, the sulcus terminalis of His. The sulcus terminalis passes from in front of the precava to the left of the postcava. It represents the line of fusion of the sinus venosus of the embryo with the primitive auricle proper.

The right auricle presents the following parts for examination:

Openings

- Precava, or Superior vena cava.
- Postcava, or Inferior vena cava.
- Coronary sinus.
- Foramini Thebesii.

Auriculo-ventricular

- Fossa ovalis.
- Annulus ovalis.
- Tuberculum Loweri.
- Musculi pectinati.

Valves

- Eustachian.
- Coronary.

The precava (superior vena cava) returns the blood from the upper half of the body, and opens into the upper and back part of the auricle, the direction of its orifice being downward and forward. The precava does not possess valves.

The postcava (inferior vena cava), larger than the precava, returns the blood from the lower half of the body, and opens into the lowest part of the auricle near the
septum, the direction of its orifice being upward and inward. The direction of a current of blood through the precava would consequently be toward the auriculo-ventricular orifice, whilst the direction of the blood through the postcava would be toward the auricular septum. This is the normal direction of the two currents in foetal life. The postcava does not possess valves until its termination at the right auricle.

The **coronary sinus** (**sinus coronarius**) opens into the auricle, between the postcava and the auriculo-ventricular opening. It returns the blood from the substance of the heart, and is protected by a semicircular fold of the lining membrane of the auricle, the **coronary valve** or **valve of Thebesius**. The sinus, before entering the auricle, is considerably dilated—nearly to the size of the end of the little finger. Its wall is partly muscular, and at its junction with the great coronary vein it is somewhat constricted and is furnished with a valve consisting of two unequal segments.

The **foramini Thebesii** (**foramina venarum minima**) are numerous minute fosse or apertures on various parts of the inner surface of the auricle. Many of these foramina have at their points the minute openings of small veins (**venae minima cordis**). They return the blood directly from the muscular substance of the heart. Some of these foramina are minute depressions in the walls of the heart, presenting a closed extremity.

The **right auriculo-ventricular opening** or the **tricuspid orifice** (**ostium venosum dextrum**) is the large oval aperture of communication between the right auricle and the ventricle, to be presently described.

The **Eustachian valve** (**valvula venae cavae inferioris** [**Eustachii**]) is situated between the anterior margin of the postcava and the auriculo-ventricular orifice. It is semilunar in form, its convex margin being attached to the wall of the vein; its concave margin, which is free, terminating in two cornua, of which the left is attached to the anterior edge of the annulus ovalis, the right being lost on the wall of the auricle. The valve is formed by a duplicature of the lining membrane of the auricle and contains a few muscular fibres.

In the **fetus** this valve is of large size, and serves to direct the blood from the postcava, through the foramen ovale, into the left auricle.

In the **adult** it is occasionally large, and may assist in preventing the reflux of blood into the postcava; more commonly it is small, and its free margin presents a cribriform or filamentous appearance; occasionally it is altogether wanting.

The **coronary valve** or **valve of Thebesius** (**valvulae sinus coronarii** [**Thebesii**]) is a semicircular fold of the lining membrane of the auricle, protecting the orifice of the coronary sinus. It prevents the regurgitation of blood into the sinus during the contraction of the auricle. This valve is occasionally double.

The **fossa ovalis** is an oval depression corresponding to the situation of the **foramen ovale** in the fetus. It is situated at the lower part of the **septum atriorum**, above and to the left of the orifice of the postcava. In foetal life an opening, the **foramen ovale**, exists at this point between the two auricles; almost immediately after birth the valve-like edge is pressed down by the increased pressure in the left auricle, and by the tenth day it passes to the annulus and closes the opening.

The **annulus ovalis** (**limbus fossae ovalis** [**Vieusseni**]) is a prominent oval margin which surrounds anteriorly and superiorly the fossa ovalis. It is most distinct above and at the sides; below, it is deficient. A small slit-like valvular opening is occasionally found, at the upper margin of the fossa ovalis, which leads upward beneath the annulus into the left auricle, and is the remains of the aperture between the two auricles in the foetus.
The tubercle of Lower (tuberculum intervenosum [Loweri]) is a small projection on the interauricular septum between the fossa ovalis and the opening of the precava. It is most distinct in the hearts of quadrupeds; in man it is scarcely visible. It was supposed by Lower to direct the blood from the precava toward the auriculo-ventricular opening.

The **Left Fore-chamber or Auricle** (atrium sinistrum) is rather smaller than the right; its walls are thicker, measuring about one line and a half; and it consists, like the right, of two parts, a principal cavity, or sinus, and an auricular appendix.

The **sinus** is cuboidal in form, and concealed in front by the pulmonary artery and aorta; internally, it is separated from the right auricle by the **auricular septum** (septum atriorum); behind, it receives on each side two pulmonary veins, being free in the rest of its extent.

The **left auricular appendix** (auricula sinistra) is somewhat constricted at its junction with the auricle; it is longer, narrower, and more curved than that of the right side, and its margins are more deeply indented, presenting a kind of foliated appearance. Its direction is forward and toward the right side, overlapping the root of the pulmonary artery.

Within the auricle the following parts present themselves for examination:

1. The openings of the four pulmonary veins.
2. Auriculo-ventricular opening.
4. Foramina Thebesii.

The **pulmonary veins**, four in number, open, two into the right and two into the left side of the auricle. The two left veins frequently terminate by a common opening. They are not provided with valves.

The **auriculo-ventricular opening** or **mitral orifice** (ostium venosum ventriculi sinistri) is the large oval aperture of communication between the left auricle and the left ventricle. It is rather smaller than the corresponding opening on the opposite side (see note, page 571).

The **musculi pectinati** are fewer in number and smaller than on the right side; they are confined to the inner surface of the auricular appendix.

On the inner surface of the auricular septum may be seen a lunated impression bounded below by a crescentic ridge the concavity of which is turned upward. The depression is just above the fossa ovalis in the right auricle. The inner surface of the auricle shows **foramini Thebesii** and **venae minimis cordis**.

To examine the interior of the left ventricle, make an incision a little to the left of the anterior interventricular groove from the base to the apex of the heart, and carry it up from thence, a little to the left of the posterior interventricular groove, nearly as far as the auriculo-ventricular groove.

The **ventricular portion of the heart** is conical in shape with its base extending backward and upward and fitting against the atrii of the auricles. Its apex constitutes the **apex of the heart** (apex cordis) and extends to the fifth intercostal space three and a quarter inches to the left of the middle line. The ventricles are thick and muscular and have an **antero-superior surface** (facies sternalis) and a **postero-inferior surface** (facies diaphragmatica) and two borders, a right and a left border. The antero-superior surface is composed mainly of the right ventricle; coursing on this surface, nearer the left border than the right from the auriculo-ventricular groove to the apex, is the **anterior interventricular groove** (sulcus longitudinalis anterior). The inferior surface rests on the diaphragm and is chiefly made by the left ventricle; it is also traversed by a groove called the **inferior or posterior interventricular groove** (sulcus longitudinalis posterior). The two grooves meet in a groove (**incisura apicis cordis**) at the right side of the
apex of the heart. Of the two borders of the ventricular portion the right is sharp and thin (margo acutus) and is a continuation of the sulcus terminalis of the base of the heart. It extends from right to left. The left border is thick and rounded (margo obtusus). The base of the ventricles is perforated by four large openings, namely, the aorta, the pulmonary artery, the right and left auriculo-ventricular openings.

The Right Ventricle (ventriculus dexter) is triangular in form, and extends from the right auricle to near the apex of the heart. Its antero-superior surface is rounded and convex, and forms the larger part of the front of the heart. Its inferior surface is flattened, rests upon the Diaphragm, and forms only a small part of the back of the heart. Its posterior wall is formed by the partition between the two ventricles, the interventricular septum (septum ventriculorum), so that a transverse section of the cavity presents a semilunar outline. The surface of the septum is convex and bulges into the cavity of the right ventricle. The upper and inner angle of the ventricle is prolonged into a conical pouch, the infundibulum (conus arteriosus), from which the pulmonary artery arises. The balance of the ventricle, the body, is the portion into which the auriculo-ventricular orifice opens. The conus arteriosus is marked off from the body of the ventricle by a muscular projection (crista supraventricularis). The walls of the right ventricle are thinner than those of the left, the proportion between them being as 1 to 3. The wall is thickest at the base, and gradually becomes thinner toward the apex.

To examine the interior of the right ventricle, its anterior wall should be turned downward and to the right in the form of a triangular flap. This is accomplished by making two incisions: (1) from the pulmonary artery to the apex of the ventricle parallel to, but a little to the right of, the anterior interventricular furrow; (2) another, starting from the upper extremity of the first and carried outward parallel to, but a little below, the auriculo-ventricular furrow, care being taken not to injure the auriculo-ventricular valve.

The following parts present themselves for examination:

Openings
- Auriculo-ventricular.
- Opening of the pulmonary artery.

Valves
- Tricuspid.
- Semilunar.

And a muscular and tendinous apparatus connected with the tricuspid valve:

Columnae carneae.

Chordae tendineae.

The right auriculo-ventricular opening or the tricuspid orifice (ostium venosum ventriculi dextri) is the large oval aperture of communication between the auricle and ventricle. It is situated at the base of the ventricle, near the right border of the heart. It is about an inch and a half in diameter, oval from side to side, surrounded by a fibrous ring and covered by the lining membrane of the heart; it is considerably larger than the corresponding aperture on the left side, being sufficient to admit the ends of four fingers. It is guarded by the tricuspid valve.

The opening of the pulmonary artery (ostium arteriosum) is circular in form, and is situated at the summit of the conus arteriosus, close to the ventricular septum. It is placed above and on the left side of the auriculo-ventricular

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1 In the Pathological Transactions, vol. vi, p. 119, Dr. Peacock has given some careful researches upon the weight and dimensions of the heart in health and disease. He states, as a result of his investigations, that in the healthy adult heart the right auriculo-ventricular aperture has a mean circumference of 54.4 lines, or 4\(\frac{3}{4}\) inches; the left auriculo-ventricular aperture a mean circumference of 44.3 lines, or 3\(\frac{3}{4}\) inches; the pulmonic orifice of 40 lines, or 3\(\frac{3}{4}\) inches; and the aortic orifice of 35.5 lines, or 2\(\frac{3}{4}\) inches; but the dimensions of the orifices varied greatly in different cases, the right auriculo-ventricular aperture having a range of from 40 to 50 lines, and the others in the same proportion. — Ed. of 15th English edition.
opening, upon the anterior aspect of the heart. Its orifice is guarded by the pulmonary semilunar valves.

The tricuspid valve (valvula tricuspidalis) consists of three segments or cusps (cuspidés) of a triangular or trapezoidal shape, each formed by a duplication of the lining membrane of the heart, strengthened by a layer of fibrous tissue, which contains, according to Kürschner and Senac, muscular fibres. These segments are connected by their bases to the oval fibrous ring surrounding the auriculo-ventricular orifice (annulus fibrosus dexter), and by their sides with one another, so as to form a continuous annular membrane, which is attached round the margin of the auriculo-ventricular opening, their free margins and ventricular surfaces affording attachment to a number of delicate tendinous cords, the chordae tendineae. The largest and most movable segment is placed toward the left side of the auriculo-ventricular opening, and is interposed between that opening and the infundibulum; hence it is called the left or infundibular cusp (cuspis medialis). Another segment corresponds to the right part of the front of the ventricle, the right or marginal cusp (cuspis anterior), and a third to its posterior wall, the posterior or septal cusp (cuspis posterior). The central part of each segment is thick and strong: the lateral margins are thin and translucent. The chordae tendineae are connected with the adjacent margins of the principal segments of the valve, and are further attached to each segment in the following manner: 1. Three or four reach the attached margin of each segment, where they are continuous with the auriculo-ventricular tendinous ring. 2. Others, four to six in number, are attached to the central thickened part of each segment. 3. The most numerous and finest are connected with the marginal portion of each segment.

The columnae carneæ (trabeculae carneae) are the rounded muscular columns which project from nearly the whole of the inner surface of the ventricle, excepting near the opening of the pulmonary artery, where the wall is smooth. They may be classified, according to their mode of connection with the ventricle, into three sets. The first set merely forms prominent ridges on the inner surface of the ventricle, being attached by their entire length on one side, as well as by their extremities. The second set are attached by their two extremities, but are free in the rest of their extent; while the third set (musculi papillares) are attached by one extremity to the wall of the heart, the opposite extremity giving attachment to the chordæ tendineae. There are two papillary muscles, the anterior and the posterior; of these, the anterior is the larger; its chordæ tendineae are connected with the right and left segments of the tricuspid valve. The posterior is not always single, but sometimes consists of two or three muscular columns; its chordæ tendineae are connected with the posterior and the right segments of the tricuspid valve. In addition to these, some few chordæ may be seen springing directly from the ventricular septum, or from small eminences on it, and passing to the left and posterior segments. A fleshy band, well marked in the ox and some other animals, is frequently seen passing from the base of the anterior papillary muscle to the interventricular septum. From its attachments it may assist in preventing overdistention of the auricle, and so has been named the moderator band.

The right auriculo-ventricular orifice allows the blood to pass freely from the right auricle into the right ventricle, and it will be noted that the surface of the tricuspid valve next the blood-current is quite smooth. When the right ventricle contracts to force the blood into the pulmonary artery, the segments of the tricuspid valve come together and close the auriculo-ventricular opening, and so prevent the blood from passing back into the auricle. The papillary muscles and chordæ tendineae moor the segments of the valve and prevent their being forced through into the auricle by the weight of blood behind them.
The semilunar valves (valvulae semilunares a. pulmonalis), three in number, guard the orifice of the pulmonary artery. They consist of three semicircular folds: two of which are anterior and one of which is posterior. They are formed by duplicatures of the lining membrane of the ventricle, strengthened by fibrous tissue. They are attached, by their convex margins, to the wall of the artery, at its junction with the ventricle, the straight border being free, and directed upward in the lumen of the vessel. The free margin of each is somewhat thicker than the rest of the valve, is strengthened by a bundle of tendinous fibres, and presents, at its middle, a small projecting thickened nodule, consisting of bundles of interlacing connective-tissue fibres with branched connective-tissue cells and some few elastic fibres. Such a nodule is called the corpus Arantii or body of Arangi (noduli valvularum semilunarium [Arantii]). From this nodule tendinous fibres radiate through the valve to its attached margin, and these fibres form a constituent part of its substance throughout its whole extent, excepting two narrow lunated portions, the lunulae (lunulae valvularum semilunarium), placed one on each side of the nodule immediately adjoining the free margin; here the valve is thin, and formed merely by the lining membrane. During the passage of the blood along the pulmonary artery these valves are opened, and the course of the blood along the tube is uninterrupted; but during the ventricular diastole, when the current of blood along the pulmonary artery is checked and partly thrown back by its elastic walls, these valves become immediately expanded, and effectually close the entrance of the tube. When the valves are closed, the lunated portions of each are brought into contact with one another by their opposed surfaces, the three corpora Arantii filling up the small triangular space that would be otherwise left by the approximation of the three semilunar valves.

Between the semilunar valves and the commencement of the pulmonary artery are three pouches or dilatations, one behind each valve. These are the pulmonary sinuses of Valsalva. Similar sinuses exist between the semilunar valves and the commencement of the aorta; they are larger than the pulmonary sinuses. The blood, in its regurgitation toward the heart, finds its way into these sinuses, and so shuts down the valve-flaps.

In order to examine the interior of the left auricle, make an incision on the posterior surface of the auricle from the pulmonary veins on one side to those on the other, the incision being carried a little way into the vessels. Make another incision from the middle of the horizontal one to the appendix.

The Left Ventricle (ventriculus sinister) is longer and more conical in shape than the right ventricle, and on transverse section its cavity presents an oval or nearly circular outline. It forms a small part of the anterior surface of the heart and a considerable part of its posterior surface. It also forms the apex of the heart by its projection beyond the right ventricle. Its walls are much thicker than those of the right side, the proportion being as 3 to 1. They are thickest opposite the widest part of the ventricle, becoming gradually thinner toward the base, and also toward the apex, which is the thinnest part.

The following parts present themselves for examination:

- Openings
  - Aortico-ventricular.
  - Chordae tendineae.

- Valves
  - Mitral.
  - Semilunar.
  - Columnæ carnea.

The left aortico-ventricular opening or the mitral orifice (ostium venosum ventriculi sinistri) is placed below and to the left of the aortic orifice. It is a little

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1 The pulmonary semilunar valves have been found to be two in number instead of three (Dr. Hand, of St. Paul, Minn., in North Western Med. and Surg. Journ., July, 1873), and the same variety is more frequently noticed in the aortic semilunar valves.—Ed. of 15th English edition.
smaller than the corresponding aperture of the opposite side, admitting only two fingers; but, like it, is broader in the transverse than in the antero-posterior diameter. Its right, posterior, and left sides are surrounded by a dense horseshoe-shaped fibrous ring (annulus fibrosus sinister). The orifice is guarded by the mitral valves, which are covered with endocardium.

The aortic opening (ostium arteriosum) is a circular aperture, in front and to the right side of the auriculo-ventricular opening, from which it is separated by one of the segments of the mitral valve. Its orifice is guarded by the semilunar valves. The portion of the ventricle immediately below the aortic orifice is often termed the aortic vestibule of Sibson. It possesses fibrous instead of muscular walls, and so does not collapse during the ventricular diastole; it thus gives space for the segments of the aortic valve during its closure.

![Diagram of the heart](image)

**Fig. 375.**—The left auricle and ventricle laid open, the posterior walls of both being removed.

The mitral or bicuspid valve (valvula bicuspidalis) is attached to the circumference of the auriculo-ventricular orifice in the same way that the tricuspid valve is on the opposite side. It is formed by a duplicature of the lining membrane, strengthened by fibrous tissue, and contains a few muscular fibres. It is larger in size, thicker, and altogether stronger than the tricuspid, and consists of two segments of unequal size. The larger segment, the anterior or aortic cusp (cuspis anterior), is placed in front and to the right between the auriculo-ventricular and aortic orifices, the smaller, the posterior or marginal cusp (cuspis posterior), is placed to the left and behind the opening, close to the wall of the ventricle. Two smaller segments are usually found at the angles of junction of the larger. The mitral valve-flaps are furnished with chordae tendineae, the mode of attachment of which is precisely similar to those on the right side; but they are thicker, stronger, and less numerous.

The aortic semilunar valves (valvulae semilunares aortae) surround the orifice of the aorta; one is posterior (valvula semilunaris posterior); one right (valvula
semilunaris dextra), and one left (valvula semilunaris sinistra): they are similar in structure and in their mode of attachment to those of the pulmonary artery. They are, however, larger, thicker, and stronger than those of the right side; the lunulae are more distinct and the corpora Arantii larger and more prominent. Opposite each segment the wall of the aorta presents a slight dilatation or bulging, the sinus of Valsalva.

The columnae carneae admit of a subdivision into three sets, like those upon the right side; but they are smaller, more numerous, and present a dense interlacement, especially at the apex, and upon the posterior wall. Those attached by one extremity only, the musculi papillares, are two in number, being connected

one to the anterior, the other to the posterior wall; they are of large size, and terminate by free rounded extremities, from which the chordae tendineae arise.

The septum between the two ventricles (septum ventriculorum) is thick and muscular, especially below (Fig. 376). At its upper part it suddenly tapers off, becomes destitute of muscular fibres, and consists only of fibrous tissue, covered by two layers of endocardium; and on the right side also covered, during diastole, by one of the flaps of the tricuspid valve. This upper portion is termed the undefended or membranous part of the septum (septum membranaceum ventriculorum), and is continued upward and forms the septum between the aortic vestibule and the right auricle. It is derived from the lower part of the aortic septum of the foetus, and an abnormal communication may exist at this part, owing to defective development of this septum.
Structure of the Heart.—The heart is a hollow muscular organ, and its walls are divisible into three layers: the endocardium, myocardium, and epicardium or visceral layer of the pericardium (page 562).

The **Endocardium** is the lining membrane of the cavities of the heart. It is decidedly thinner than the epicardium. It is composed of endothelial cells resting upon a connective-tissue membrane which contains unstriated muscle cells and elastic tissue. This connective-tissue membrane of the endocardium is attached to the myocardium by loose elastic tissue which contains blood-vessels and nerves. The endothelial layer of the endocardium is continuous with the endothelial coat of the blood-vessels which pass to and emerge from the heart. The endocardium is more opaque on the left than on the right side of the heart, thicker in the auricles than in the ventricles, and thickest in the left auricle. It is thin on the musculi pectinati and on the columnae carneae, but thicker on the smooth parts of the auricular and ventricular walls and on the tips of the musculi papillares.

The **Fibrous Rings** (annuli fibrosi) surround the auriculo-ventricular and arterial orifices; they are stronger upon the left than on the right side of the heart. The auriculo-ventricular rings serve for the attachment of the muscular fibres of the auricles and ventricles, and also for the mitral and tricuspid valves; the ring on the left side is closely connected by its right margin with the aortic arterial ring. Between these and the right auriculo-ventricular ring is a mass of fibrous tissue, and in some of the larger animals, as the ox and elephant, a nodule of bone, the *os cordis*.

The fibrous rings surrounding the arterial orifices serve for the attachment of the great vessels and semilunar valves. Each ring receives, by its ventricular margin, the attachment of the muscular fibres of the ventricles; its opposite margin presents three deep semicircular notches, within which the middle coat of the artery (which presents three convex semicircular segments) is firmly fixed, the attachment of the artery to its fibrous ring being strengthened by the thin cellular coat and serous membrane externally and by the endocardium within. It is opposite the margins of these semicircular notches, in the arterial rings, that the endocardium by its reduplication forms the semilunar valves, the fibrous structure of the ring being continued into each of the segments of the valve at this part. The middle coat of the artery in this situation is thin, and the sides of the vessel are dilated to form the sinuses of Valsalva.

The **Myocardium** is composed of muscle fibres. The muscle fibres, though striated, are involuntary and constitute a special type called **cardiac fibres**. Cardiac fibres
are shorter than ordinary striated muscle fibres, many of the cells are oblong and the nuclei are centrally placed. During the first year of life, and occasionally even in adult life, certain peculiar fibres are found beneath the elastic tissue which attaches the endocardium to the myocardium. These peculiar fibres are called the fibres of Purkinje. The striation in these cells is peripheral only. Between individual fibres and between bundles of fibres of cardiac muscle is connective tissue carrying capillaries.

The Muscular Structure of the heart consists of bands and layers of fibres which present an exceedingly intricate interlacement. They are of a deep red color and marked with transverse striae. The arrangement of the fasciculi varies in different parts of the heart. It requires elaborate care to demonstrate the layers, and it is more than probable that some of those described are really artificially produced. The fasciculi of the heart admit of a subdivision into two groups, those of the auricles and those of the ventricles. It was long thought that auricular fasciculi were entirely separate from the ventricular fasciculi. It is now known that there is a direct connection by means of the auriculo-ventricular fasciculus of His (see below).

![Fig. 378.—The arrangement of the muscles of the auricles. (Poirier and Charpy.)](image)

Fibres of the Auricles (Fig. 378).—These are disposed in two layers—a superficial layer common to both cavities, and a deep layer proper to each. The superficial fibres are more distinct on the anterior surface of the auricles, across the bases of which they run in a transverse direction, forming a thin but incomplete layer. Some of these fibres pass into the septum atriorum. The internal or deep fibres proper to each auricle consist of two sets, looped and annular fibres. The looped fibres pass upward over each auricle, being attached by two extremities to the corresponding auriculo-ventricular rings in front and behind. The annular fibres surround the whole extent of the auricular appendices, and are continued upon the walls of the venae cavae and coronary sinus on the right side, and upon the pulmonary veins on the left side, at their connection with the heart. In the appendices they interlace with the longitudinal fibres.

Fibres of the Ventricles.—These are arranged in an exceedingly complex manner, and the accounts given by various anatomists differ considerably. This is probably due partly to the fact that the various layers of muscular fibres of which the heart is said to be composed are not independent, but their fibres are interlaced to a considerable extent, and therefore any separation into layers must be to a great extent artificial; and also partly to the fact, pointed out by Henle, that there are varieties in the arrangement due to individual differences. If the epicardium and the subjacent fat are removed from a heart which has been sub-
jected to prolonged boiling, so as to dissolve the connective tissues, the superficial fibres of the ventricles will be exposed. They will be seen to commence at the base of the heart, where they are attached to the tendinous rings around the orifices, and to pass obliquely downward toward the apex, with a direction from right to left. At the apex the fibres turn suddenly inward into the interior of the ventricle, forming what is called the vortex (Fig. 379). On the back of the heart it will be seen that the fibres pass continuously from one ventricle to the other over the interventricular groove; and the same thing will be noticed on the front of the heart at the upper and lower end of the anterior interventricular groove, but in the middle portion of this groove the fibres passing from one ventricle to the other are interrupted by fibres emerging from the septum along the groove; many of the superficial fibres pass in also at this groove to the septum. The vortex is produced, as stated above, by the sudden turning inward of the superficial fibres in a peculiar spiral manner into the deepest portion of the wall of the ventricle. Those fibres which descended on the posterior surface of the heart enter the left ventricle at the vortex, and, ascending, form the posterior part of the inner layer of muscular fibres lining this cavity and the right (posterior) musculus papillaris; those fibres which descend on the front of the heart to reach the apex also pass, at the vortex, into the interior of the ventricle, where they form the remainder of the innermost layer of the ventricle and the left (anterior) musculus papillaris. The fibres forming the inner layer of the wall of the ventricle ascend to be attached to the fibrous rings around the orifices.

By dissection these superficial fibres may be removed as a thin stratum, and it will then be found that the ventricles are made up of oblique fibres (Fig. 380), superimposed in layers one on the top of another, and assuming gradually a less oblique direction as they pass to the middle of the thickness of the ventricular wall, so that in the centre of the wall the fibres are transverse. Internal to this central transverse layer the fibres become oblique again, but in the opposite direction to the external ones. This division into distinct layers is, however, to a great extent artificial, as the fibres pass across from one layer to another, and have therefore to be divided in the dissection, and the change in the direction of the fibres is very gradual. These oblique fibres commence above at the fibrous rings at the base of the heart, and, descending toward the apex, they enter the septum near its lower end. In the septum the fibres which form the left ventricle may be traced in three directions: 1. Some pass upward to be attached to the central mass of fibrous tissue. 2. Others pass through the septum to become continuous with the fibres of the right ventricle. 3. The remainder pass through the septum to encircle the ventricle as annular fibres. Of the fibres of the right ventricle, some on entering the septum pass upward to be attached to the central mass of fibrous tissue; some, entering the septum from behind, pass forward to become continuous with the fibres on the anterior surface of the left ventricle; and others, entering in front, pass backward to join the fibres on the posterior wall of the left ventricle. The septum therefore consists of three varieties of fibres—viz., annular fibres, special to the left ventricle; ascending fibres, derived from both ventricles and ascending through the septum to the central fibro-cartilage; and decussating fibres, derived from the
anterior wall of one ventricle and passing to the posterior wall of the other ventricle, or from the posterior wall of the right ventricle and passing to the anterior wall of the left. In addition to these fibres there are a considerable number which appear to encircle both ventricles and which pass across the septum without turning into it.

**THE HEART**

**Fig. 380.**—The muscular arrangement of the ventricle. (Poirier and Charpy.)

**THE AURICULO-VENTRICULAR FASCICULUS, OR THE BUNDLE OF HIS.**—The only direct connection between the muscle of the auricles and the muscle of the ventricles is the muscular bundle described by His and known as the **auriculo-ventricular fasciculus**. It takes origin from the posterior wall of the right auricle close to the auricular septum. This bundle descends from its point of origin and reaches the upper margin of the ventricular septum. At a portion of this margin which is distinctly muscular it takes a turn forward, crosses the septum between the membranous and muscular areas, and disappears in the ventricular muscle. A wave of contraction starts in the auricles and is transmitted to the ventricles by the bundle of His. If this bundle is cut or clamped, heart block occurs, because the stimulus is no longer transmitted from the auricle to the ventricle.

Erlanger showed that all degrees of heart block can be induced by compression of the bundle. Erlanger says that, "as a rule, the ventricles take on a constant slow rate at the moment complete heart block is established." The auricles beat normally or more rapidly than normally.

Stokes-Adams disease is a condition of heart block produced by a lesion of the auriculo-ventricular bundle. This was demonstrated by Erlanger.

In Stokes-Adams disease there are attacks of vertigo or syncope, perhaps with epileptiform convulsions, and in these attacks the ventricles beat at less than the normal rate, and the auricles normally or more frequently than normally.
Vessels and Nerves.—The arteries supplying the heart are the right and left coronary from the aorta. Branches from the coronary vessels supply the muscular structure, the subendocardial, and the subepicardial tissue. There are no vessels in the endocardium. The valves contain no vessels unless they contain muscle, in which case minute vessels enter them. There are numerous capillary networks about the muscular fibres.

The veins accompany the arteries. They are: the anterior or great, the posterior, the left, and the anterior cardiac veins, the right or small, and the left or great, coronary sinuses. The coronary sinus receives most of the veins of the heart and empties into the right auricle. Some few small veins open directly into the right and left auricles and into the ventricles. They are the venae minima cordis. The oblique vein of the left auricle is known as the oblique vein of Marshall.

The lymphatics are arranged in two networks: one in the muscle beneath the endocardium, another in the muscle beneath the epicardium. The deep empty into the superficial network, the anterior collecting trunks from the subepicardial network pass to the tracheo-bronchial glands. The posterior collecting trunk terminates in the same group of glands.¹

The nerves are derived from the superficial and deep cardiac plexuses, and from these plexuses obtain fibres of the vagus, accessory, and sympathetic. The superficial cardiac plexus lies under the arch of the aorta. The deep cardiac plexus is in front of the tracheal bifurcation. The nerves from the plexuses are freely distributed both on the surface and in the substance of the heart, the separate filaments being furnished with small ganglia.

Surface Form.—In order to show the extent of the heart in relation to the front of the chest, draw a line from the lower border of the second left costal cartilage, one inch from the sternum, to the upper border of the third right costal cartilage, half an inch from the sternum. This represents the base-line or upper limit of the organ. Take a point an inch and a half below and three-quarters of an inch internal to the left nipple—that is, about three and a half inches to the left of the median line of the body. This represents the apex of the heart. Draw a line from this apex-point, with a slight convexity downward, to the junction of the seventh right costal cartilage to the sternum. This represents the lower limit of the heart. Join the right extremity of the first line—that is, the base-line—with the right extremity of this line—that is, to the seventh right chondro-ternal joint—with a slight curve outward, so that it projects about an inch and a half from the middle line of the sternum. Lastly, join the left extremity of the base-line and the apex-point by a line curved slightly to the left.

The position of the various orifices is as follows—viz., the pulmonary orifice is situated in the upper angle formed by the articulation of the third left costal cartilage with the sternum; the aortic orifice is a little below and internal to this, behind the left border of the sternum, close to the articulation of the third left costal cartilage to this bone. The left auriculo-ventricular opening is behind the sternum, rather to the left of the median line, and opposite the fourth costal cartilages. The right auriculo-ventricular opening is a little lower, opposite the fourth interspace and in the middle line of the body (Fig. 306).

A portion of the area of the heart thus mapped out is uncovered by lung, and therefore gives a dull note on percussion; the remainder, being overlapped by the lung, gives a more or less resonant note. The former is known as the area of superficial cardiac dulness; the latter as the area of deep cardiac dulness. The area of superficial cardiac dulness is included between a line drawn from the centre of the sternum, on a level with the fourth costal cartilages, to the apex of the heart and a line drawn from the same point down the lower third of the middle line of the sternum. Below, this area merges into the dulness which corresponds to the liver. Dr. McClellan states that the area of superficial cardiac dulness may be mapped out “by drawing a line from the middle of the sternum opposite the fourth left costal cartilage to the point of junction of the fifth rib and its cartilage, and from this point horizontally back to the middle line.”

Surgical Anatomy.—Wounds of the heart are often immediately fatal, but not necessarily so. They may be non-penetrating, when death may occur from hemorrhage, if one of the coronary vessels has been wounded, or subsequently from pericarditis; or, on the other hand, the patient may recover. Even a penetrating wound is not necessarily fatal, if the wound is a small one. An attempt should be made to save the patient by means of a surgical operation. A

¹ The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
trap-door flap comprising the whole thickness of the thoracic wall should be made. The hinges of the trap-door are the rib cartilages. The pericardium is exposed and opened freely, clots are removed, the wound in the heart is sought for, and when discovered is sutured. In a penetrating wound the sutures include the whole thickness of the heart, except the endocardium. Interrupted sutures should be used, and each one had better be tied during diastole. A number of successful operations of this character have been performed.

**Peculiarities in the Vascular System of the Fetus (Fig. 382).**

The chief peculiarities in the heart of the foetus are the direct communication between the two auricles through the foramen ovale, and the large size of the Eustachian valve. There are also several minor peculiarities. Thus, the position of the heart is vertical until the fourth month, when it commences to assume an oblique direction. Its size is also very considerable as compared with the body, the proportion at the second month being 1 to 50; at birth it is as 1 to 120; whilst in the adult the average is about 1 to 160. At an early period of foetal life the auricular portion of the heart is larger than the ventricular, the right auricle being more capacious than the left; but toward birth the ventricular portion becomes the larger. The thickness of both ventricles is at first about equal, but toward birth the left becomes much the thicker of the two.

![Diagram of the heart](attachment:image)

**Fig. 381.—The right auricle of a foetal heart (eighth month). Enlarged. (Spalteholz.)**

The **foramen ovale** (Fig. 381) is situated at the lower and back part of the auricular septum, forming a communication between the auricles. It remains as a free oval opening until the middle period of foetal life. About this period a fold grows up from the posterior wall of the auricle to the left of the foramen ovale, and advances over the opening so as to form a sort of valve, which allows the blood to pass only from the right to the left auricle, and not in the opposite direction.

The **Eustachian valve** (Fig. 381) is directed upward on the left side of the opening of the postcava (inferior vena cava), and serves to direct the blood from this vessel through the foramen ovale into the left auricle.

The peculiarities in the arterial system of the foetus are the communication between the pulmonary artery and the descending aorta by means of the **ductus arteriosus**, and the communication between the internal iliac arteries and the placenta by means of the **umbilical arteries**.
The Ductus Arteriosus (Fig. 382).—The ductus arteriosus is a short tube, about half an inch in length at birth, and of the diameter of a goose-quill. In the early condition it forras the continuation of the pulmonary artery, and opens into the descending aorta just below the origin of the left subclavian artery, and so conducts the chief part of the blood from the right ventricle into this vessel. When the branches of the pulmonary artery have become larger relatively to the ductus arteriosus, the latter is chiefly connected to the left pulmonary artery; and the fibrous cord (ligamentum arteriosum), which is all that remains of the ductus arteriosus in later life, will be found to be attached to the root of that vessel.
The Umbilical Arteries.—The umbilical or hypogastric arteries arise from the internal iliacs, in addition to the branches given off from those vessels in the adult. Ascending along the sides of the bladder to its apex, they pass out of the abdomen at the umbilicus and are continued along theumbilical cord to the placenta, coiling round the umbilical veins. They carry to the placenta the blood which has circulated in the system of the foetus.

The peculiarity in the venous system of the foetus is the communication established between the placenta and the liver and portal vein through the umbilical vein, and the postcava through the ductus venosus.

Fœtal Circulation.—The blood destined for the nutrition of the foetus is returned from the placenta to the foetus by the umbilical vein. This vein enters the abdomen at the umbilicus, and passes upward along the free margin of the suspensory ligament of the liver to the under surface of that organ, where it gives off two or three branches to the left lobe, one of which is of large size, and others to the lobus quadratus and lobulus Spigelii. At the transverse fissure it divides into two branches: of these, the larger is joined by the portal vein and enters the right lobe; the smaller branch continues outward, under the name of the ductus venosus, and joins the left hepatic vein at the point of junction of that vessel with the postcava. The blood, therefore, which traverses the umbilical vein reaches the postcava in three different ways: the greater quantity circulates through the liver with the portal venous blood before entering the postcava by the hepatic veins; some enters the liver directly, and is also returned to the postcava by the hepatic veins; the smaller quantity passes directly into the postcava by the junction of the ductus venosus with the left hepatic vein.

In the postcava (inferior vena cava) the blood carried by the ductus venosus and hepatic veins becomes mixed with that returning from the lower extremities and wall of the abdomen. It enters the right auricle, and, guided by the Eustachian valve, passes through the foramen ovale into the left auricle, where it becomes mixed with a small quantity of blood returned from the lungs by the pulmonary veins. From the left auricle it passes into the left ventricle, and from the left ventricle into the aorta, by means of which it is distributed almost entirely to the head and upper extremities, a small quantity being probably carried into the descending aorta. From the head and upper extremities the blood is returned by the tributaries of the precava (superior vena cava) to the right auricle, where it becomes mixed with a small portion of the blood from the postcava (inferior vena cava). From the right auricle it descends over the Eustachian valve into the right ventricle, and from the right ventricle passes into the pulmonary artery. The lungs of the foetus being inactive, only a small quantity of the blood of the pulmonary artery is distributed to them by the right and left pulmonary arteries, and is returned by the pulmonary veins to the left auricle; the greater part passes through the ductus arteriosus into the commencement of the descending aorta, where it becomes mixed with a small quantity of blood transmitted by the left ventricle into the aorta. Through this vessel it descends to supply the lower extremities and viscera of the abdomen and pelvis, the chief portion being, however, conveyed by the umbilical arteries to the placenta.

From the preceding account of the circulation of the blood in the foetus it will be seen—

1. That the placenta serves the purposes of nutrition and excretion, receiving the impure blood from the foetus, and returning it charged with additional nutritive material.

2. That nearly the whole of the blood of the umbilical vein traverses the liver before entering the postcava; hence the large size of this organ, especially at an early period of fœtal life.

3. That the right auricle is the point of meeting of a double current, the blood
in the postcava being guided by the Eustachian valve into the left auricle, whilst
that in the precava descends into the right ventricle. At an early period of the
fœtal life it is highly probable that the two streams are quite distinct, for the
postcava opens almost directly into the left auricle, and the Eustachian valve
would exclude the current along the vein from entering the right ventricle. At a
later period, as the separation between the two auricles becomes more distinct,
it seems probable that some mixture of the two streams must take place.

4. The pure blood carried from the placenta to the fœtus by the umbilical vein,
mixed with the blood from the portal vein and the postcava, passes almost directly
to the arch of the aorta, and is distributed by the branches of that vessel to the
head and upper extremities; hence the large size and perfect development of
those parts at birth.

5. The blood contained in the descending aorta, chiefly derived from that
which has already circulated through the head and upper limbs, together with a
small quantity from the left ventricle, is distributed to the lower extremities;
therefore the small size and imperfect development of these parts at birth.

Changes in the Vascular System at Birth.

At birth, when respiration is established, an increased amount of blood from
the pulmonary artery passes through the lungs, which now perform their office
as respiratory organs, and at the same time the placental circulation is cut off.
Almost immediately after birth the foramen ovale is closed by the valvular edge
being pressed against the annulus ovalis, the pressure being due to respiration,
which increases the pressure in the left auricle. The structures fuse, and closure
is complete by about the tenth day after birth. The valvular fold above men-
tioned becomes adherent to the margins of the foramen for the greater part of its
circumference, but above a slit-like opening is left between the two auricles which
sometimes remains persistent.

The ductus arteriosus begins to contract immediately after respiration is estab-
lished, becomes completely closed from the fourth to the tenth day, and ultimately
degenerates into an impervious cord which serves to connect the left pulmonary
artery to the descending aorta. When respiration begins, the caval opening of
the diaphragm being fixed and the balance of the muscle rising and falling, the
ductus arteriosus is compressed by the muscular structures which pass from the
diaphragm to the pericardium, is narrowed, and is finally obliterated (Forbes).

Of the umbilical or hypogastric arteries, the portion continued on to the bladder
from the trunk of the corresponding internal iliac remains pervious as the superior
vesical artery, and the part extending from the side of the bladder to the umbilicus
becomes obliterated between the second and fifth days after birth, and projects
as a fibrous cord toward the abdominal cavity, carrying on it a fold of peritoneum
and separating two of the fossae of the peritoneum spoken of in the section on the
surgical anatomy of direct inguinal hernia.

The umbilical vein and the ductus venosus become completely obliterated
between the second and fifth days after birth, and ultimately dwindle to fibrous
cords, the former becoming the round ligament of the liver, the latter the fibrous
cord, which in the adult may be traced along the fissure of the ductus venosus.
THE ARTERIES.

The Arteries are cylindrical tubular vessels which serve to convey blood from both ventricles of the heart to every part of the body. These vessels were named arteries (ἄρτηρ, air; τροφή, to contain) from the belief entertained by the ancients that they contained air. To Galen is due the honor of refuting this opinion; he showed that these vessels, though for the most part empty after death, contain blood in the living body.

The distribution of the systemic arteries is like a highly ramified tree, the common trunk of which, formed by the aorta, commences at the left ventricle of the heart, the smallest ramifications corresponding to the circumference of the body and the contained organs. The arteries are found in nearly every part of the body, with the exception of the hairs, epidermis, cartilages, and cornea; and the larger trunks usually occupy the most protected situations, running, in a limb, along the flexor side, where they are less exposed to injury.

There is considerable variation in the mode of division of the arteries: occasionally a short trunk subdivides into several branches at the same point, as we observe in the coeliac and thyroid axes; or the vessel may give off several branches in succession, and still continue as the main trunk, as is seen in the arteries of the limbs; but the usual division is dichotomous; as, for instance, the aorta dividing into the two common iliacs, and the common carotid into the external and internal carotids.

The branches of arteries arise at very variable angles: some, as the superior intercostal arteries from the aorta, arise at an obtuse angle; others, as the lumbar arteries, at a right angle; or, as the spermatic, at an acute angle. An artery from below the point at which a branch is given off is smaller in size than before. It retains a uniform diameter until a second branch is derived from it. A branch of an artery is smaller than the trunk from which it arises; but if an artery divides into two branches, the combined area of the two vessels is, in nearly every instance, somewhat greater than that of the trunk; and the combined area of all the arterial branches greatly exceeds the area of the aorta; so that the arteries collectively may be regarded as a cone, the apex of which corresponds to the aorta, the base to the capillary system.

The arteries, in their distribution, communicate with one another, forming what is called an anastomosis (ἀνάστωμος, between; στόμα, mouth) or inosculation (Fig. 383); and this communication is very free between the larger as well as between the

![Diagram showing the anastomosis of arteries. (Poirier and Charpy.)](image-url)
smaller branches. An anastomosis between trunks of equal size is found where
great activity of the circulation is requisite, as at the base of the brain; here the
two vertebral arteries unite to form the basilar, and the two internal carotid
arteries are connected by a short communicating trunk; it is also found in the
abdomen, the intestinal arteries having very ample anastomoses between their
larger branches. In the limbs the anastomoses are most numerous and of
largest size around the joints, the branches of an artery above inosculating
with branches from the vessels below; these anastomoses are of considerable
interest to the surgeon, as it is by their enlargement that a collateral circula-
tion is established after the application of a ligature to an artery for the cure
of aneurism. The smaller branches of arteries anastomose more frequently
than the larger, and between the smallest twigs these inosculations become so
numerous as to constitute a close network
that pervades nearly every tissue of the body.
A terminal artery is one which forms no
anastomoses. Such vessels are found in the
brain, spleen, kidneys, lungs, and mesen-
tery.
Throughout the body generally the larger
arterial branches pursue a perfectly straight
course, but in certain situations they are tor-
tuous; thus the facial arteries in their course
over the face, and the arteries of the lips,
are extremely tortuous in their course, to
accommodate themselves to the movements
of the parts. The uterine arteries are also
tortuous, to accommodate themselves to the
increase of size which the organ undergoes
during pregnancy. Again, the internal
carotid and vertebral arteries, previous to
their entering the cavity of the skull, de-
scribe a series of curves, which are evidently
intended to diminish the velocity of the cur-
rent of blood by increasing the extent of
surface over which it moves and adding to
the resistance which is produced by friction.
The arteries are dense in structure, of
considerable strength, highly elastic, and,
when divided, they preserve, although empty,
their cylindrical form.

Histology of the Capillaries and Ar-
teries. The Capillaries (Fig. 386).—The
capillaries are very small endothelial tubes
which connect the venous system with the
arterial system. In diameter they vary from \( \frac{1}{3} \) to \( \frac{1}{10} \) of an inch, in length
from \( \frac{1}{20} \) to \( \frac{1}{30} \) of an inch. The nucleated endothelial cells which constitute the
wall of a capillary are flat, irregular in outline, and are united by a cement
material. Small openings (stomata) are frequently noted between these cells,
but they are probably artifacts and do not exist during life.
The capillaries anastomose and form vast networks. When an artery is about
to become a capillary the muscular coat disappears. The endothelial coat which
constitutes the capillaries extends as a system of endothelial tubes throughout the
entire blood-vascular system. The heart is a great muscular thickening around
a portion of the system of endothelial tubes. An artery consists of an endothelial
tube covered by certain accessory coats. The wall of an artery diminishes greatly in thickness (Fig. 387) and is found to be composed of endothelial cells and scattered unstriated muscle-fibres, covered merely by thin connective tissue or elastic-tissue sheath (adventitia capillaris). Such a structure is known as an arteriole or a precapillary artery. By the loss of its thin sheath of connective or elastic tissue it becomes a capillary. A capillary takes on a thin sheath and becomes a venule or precapillary vein. Nerves do not terminate in capillaries, but networks of nerve-filaments often encompass these small vessels.

An artery consists of an internal coat or tunica intima, a middle coat or tunica media, and an external coat or tunica adventitia (Figs. 384 and 385).

The Inner Coat (tunica intima) consists of endothelial cells and yellow elastic tissue. In some cases the elastic fibres are arranged longitudinally, but, as a rule, they form a distinct fenestrated membrane known as the fenestrated membrane of Henle, or the internal elastic coat. In medium-sized vessels the elastic layer of the intima is separated from the endothelial layer by a layer of connective tissue. In the large arteries the interposed layer of connective tissue is thicker and contains elastic fibres.

The Middle Coat (tunica media) consists of muscle, elastic tissue, and white fibrous tissue, and it is often called the elastomuscular coat. The arterioles contain scattered unstriated muscle fibres. In the small arteries they constitute a thin but definite coat. In larger arteries the muscular coat is much thicker. The muscle is unstriated and the fibres are arranged circularly, and in the larger vessels form layers which are separated by elastic fibres. Here and there longitudinally-disposed muscle-fibres exist. The larger the artery the greater is the amount of elastic tissue existing in the middle coat. In the aorta and in some of the very large arteries the amount of elastic tissue exceeds the amount of

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**Fig. 385.**—Section of a medium-sized artery. (After Grünstein.)
muscular tissue. "In the first part of the aorta, in the pulmonary artery and in the arteries of the retina, the muscular fibres are entirely replaced by elastic tissue." The arteries within the skull have no elastic tissue in the media, although they have some in the adventitia.

The External Coat (tunica adventitia) is called the fibrous coat. It contains fibrous connective tissue, elastic tissues, and in some arteries fibres of unstriated muscle arranged longitudinally. The circular elastic membrane which separates the outer coat from the middle coat is known as the external elastic membrane.

Blood-vessels of the Blood-vessel Wall.—Many small blood-vessels course in the external and middle coats of arteries of large and of moderate size. They are mostly in the adventitia. They may arise from the vessel to which they are distributed or take origin from an adjacent vessel. These small arteries are called the vasa vasorum. The blood is returned from the walls of the vessels by small veins.

Lymphatics.—Distinct lymphatic vessels may exist in the adventitia, but are not found in either of the other coats. Lymph-capillaries often surround small blood-vessels or a small blood-vessel may lie in a perivascular lymph-space.

Nerves.—Arteries are supplied with nerves, myelinic and amyelinic. A network of nerve-fibres may surround a vessel and usually capillaries are so surrounded. In the arteries a network of nerves exists in the media. These nerves supply the muscle-fibres and are called vasomotor nerves.

The Arterial Sheath (vagina vasis) surrounds the artery. It is composed of connective tissue, and is attached to the vessel at numerous points by fibrous tissue.

\[1\] D. J. Cunningham. Text-book of Anatomy.
PULMONARY ARTERY (A. PULMONALIS) (Fig. 389, 393).

In the description of the arteries we shall first consider the efferent trunk of the pulmonary circulation, the pulmonary artery, and then the efferent trunk of the systemic circulation, the aorta and its branches.

The pulmonary artery conveys the venous blood from the right side of the heart to the lungs. It is a short, wide vessel, about 2 inches in length and 1½ inches (30 mm.) in diameter, arising from the left side of the base (conus arteriosus) of the right ventricle, in front of the aorta. It extends obliquely upward and backward, passing at first in front of and then to the left of the ascending aorta, as far as the under surface of the arch, where it divides, about on a level with the intervertebral substance between the fifth and sixth thoracic vertebrae, into two branches of nearly equal size, the right and left pulmonary arteries.

The Right Pulmonary Artery (ramus dexter a. pulmonalis), longer and larger than the left, runs horizontally outward to the root of the right lung, where it divides into two branches, of which the lower and larger supplies the middle and lower lobes; the upper and smaller is distributed to the upper lobe. It has in front of it the ascending aorta, the pericard, and the right phrenic nerve. It has behind it the right bronchus. Above it is the transverse portion of the arch of the aorta. Below it is the right auricle.

The Left Pulmonary Artery (ramus sinister a. pulmonalis), shorter and somewhat smaller than the right, passes horizontally to the root of the left lung, where it divides into two branches for the two lobes. In front of it and below it are the pulmonary veins of the left side. Behind are the descending aorta and the left bronchus. Above it are the arch of the aorta, the left recurrent laryngeal nerve, and the ductus arteriosus. The left bronchus in a portion of its course lies below as well as behind.

Relations.—The whole of the vessel is contained, together with the ascending aorta, in the pericardium. It is enclosed with the aorta in a single tube of the serous pericardium, which is continued upward upon them from the base of the heart and connects them together. The fibrous layer of the pericardium becomes gradually lost upon the external coats of its two branches. In front, the pulmonary artery is separated from the anterior extremity of the second left intercostal space by the pleura and left lung, in addition to the pericardium; it rests at first upon the ascending aorta, and higher up lies in front of the left auricle on a plane posterior to the ascending aorta. On each side of its origin is the appendix of the corresponding auricle and a coronary artery, the left coronary artery passing, in the first part of its course, behind the vessel.

The root of the left pulmonary artery is connected to the under surface of the arch of the aorta by a short fibrous cord, the ligamentum arteriosum; this is the remains of a vessel peculiar to foetal life, the ductus arteriosus.

The terminal branches of the pulmonary artery will be described with the anatomy of the lung.

THE AORTA (Figs. 388, 389, 390, 393).

The aorta or arteria magna (ἀορτή) is the main trunk of a series of vessels which convey the oxygenated blood to the tissues of the body for their nutrition. This vessel commences at the upper part of the left ventricle, where it is about one and one-eighth inches in diameter, and, after ascending for a short distance, arches backward and to the left side, over the root of the left lung, then descends within the thorax on the left side of the vertebral column, passes through the aortic opening in the Diaphragm, and, entering the abdominal cavity, terminates, consider-
ably diminished in size (about seven-tenths of an inch in diameter), opposite the lower border of the fourth lumbar vertebra, where it divides into the right and left common iliac arteries. Hence it is divided into the ascending aorta, the arch of the aorta, and the descending aorta, which last is again divided into the thoracic aorta and the abdominal aorta, from the position of these parts.

THE ASCENDING AORTA (AORTA ASCENDENS).

The ascending aorta is about two inches in length. It commences at the upper part of the left ventricle, on a level with the lower border of the third costal cartilage, behind the left half of the sternum; it passes obliquely upward, forward, and to the right, in the direction of the heart's axis, as high as the upper border of the second right costal cartilage, describing a slight curve in its course, and being situated, when distended, about a quarter of an inch behind the posterior surface of the sternum. A little above its commencement it is somewhat enlarged (bulbus aortae), and presents three small dilatations, one of which is anterior, two of which are posterior, which are called the sinuses of Valsalva (sinus aortae). Opposite to the sinuses are attached the three semilunar valves (Fig. 376),
which serve the purpose of preventing any regurgitation of blood into the cavity of the ventricle. These valves are placed one in front and two behind. At the union of the ascending with the transverse part of the aorta the calibre of the vessel is increased, owing to a bulging outward of its right wall. This dilatation is termed the **great sinus of the aorta**. A section of the aorta opposite this part has a somewhat oval figure; but below the attachment of the valves it is circular. This portion of the aorta is contained in the cavity of the pericardium, and, together with the pulmonary artery, is invested in a tube of serous membrane, continued on to them from the surface of the heart.

**Relations.**—The ascending aorta is covered at its commencement by the trunk of the pulmonary artery and the right auricular appendix, and, higher up, is separated from the sternum by the pericardium, the right pleura, and anterior margin of the right lung, some loose areolar tissue, and the remains of the thymus gland; behind, it rests upon the right pulmonary artery, left auricle, and the right bronchus. On the **right side** it is in relation with the precava and right auricle; on the **left side**, with the pulmonary artery.
Plan of the Relations of the Ascending Aorta.

In front.
Pulmonary artery.
Right auricular appendix.
Pericardium.
Right pleura and lung.
Remains of the thymus gland.

Right side.
Precava.
Right auricle.

Left side.
Pulmonary artery.

Behind.
Right pulmonary artery.
Left auricle.
Right bronchus.

Branches—The only branches of the ascending aorta are the coronary arteries. They supply the heart, and are two in number, right and left, arising near the commencement of the aorta, immediately above the free margin of the semilunar valves.

The Coronary Arteries (Fig. 389).

The Right Coronary Artery (a. coronaria [cordis] dextra), about the size of a crow’s quill, arises from the anterior sinus of Valsalva. It passes forward between the pulmonary artery and the right auricular appendix, then runs obliquely to the right side, in the groove between the right auricle and ventricle, and, curving around the right border of the heart, runs to the left along its posterior surface as far as the posterior interventricular groove, where it divides into two branches, one of which, the transverse, continues onward in the groove between the left auricle and ventricle, and anastomoses with the left coronary; the other, the descending (ramus descendens posterior a. coronariae [cordis] dextrae), courses along the posterior interventricular furrow, supplying branches to both ventricles and to the septum, and anastomosing at the apex of the heart with the descending branches of the left coronary. This vessel sends a large branch, the marginal, along the thin margin of the right ventricle to the apex, which in its course gives off numerous small branches to the anterior and posterior surfaces of the ventricle. It also gives off
The Arch of the Aorta (Aarcus Aortae).

The arch, or transverse aorta, commences at the upper border of the second chondro-sternal articulation of the right side, and passes at first upward and backward and from right to left, and then from before backward, to the left side of the lower border of the fourth thoracic vertebra behind. Its upper border is usually about an inch below the upper margin of the sternum.

Between the origin of the left subclavian artery and the attachment of the ductus arteriosus the lumen of the foetal aorta is considerably narrowed, forming what is termed the aortic isthmus (isthmus aortae), while immediately beyond the ductus arteriosus the vessel presents a fusiform dilatation which His has named the aortic spindle (aortenspindel)—the point of junction of the two parts being marked in the concavity of the arch by an indentation or angle. These conditions persist, to some extent, in the adult, where His found that the average diameter of the spindle exceeded that of the isthmus by 3 mm. (about one-eighth of an inch).

1 According to Dr. Samuel West, there is a very free and complete anastomosis between the two coronary arteries (Lancet, June 2, 1883, p. 945). This, however, is not the view generally held by anatomists, for, with the exception of the anastomosis mentioned above in the auriculo-ventricular and interventricular grooves, it is believed that the two arteries only communicate by very small vessels in the substance of the heart.—Ed. of 15th English edition.
Relations.—Its anterior surface is covered by the pleurae and lungs (much more by the left lung than by the right) and the remains of the thymus gland, and crossed toward the left side by the left vagus and phrenic nerves and superficial cardiac branches of the left sympathetic and vagus, and by the left superior intercostal vein. Its posterior surface lies on the trachea, just above its bifurcation, on the great, or deep, cardiac plexus, the cesophagus, thoracic duct, and left recurrent laryngeal nerve. Its upper border is in relation with the left innominate vein, and from its upper part are given off the innominate, left common carotid and left subclavian arteries. Its lower border is in relation with the bifurcation of the pulmonary artery, the remains of the ductus arteriosus, which is connected with the left division of that vessel, and the superficial cardiac plexus; the left recurrent laryngeal nerve winds round it from before backward, whilst the left bronchus passes below it.

Plan of the Relations of the Arch of the Aorta.

Above.
Left innominate vein.
Innominate artery.
Left carotid.
Left subclavian.

In Front.
Pleure and lungs.
Remains of thymus gland.
Left vagus nerve.
Left phrenic nerve.
Superficial cardiac nerves.
Left superior intercostal vein.

Below.
Bifurcation of pulmonary artery.
Remains of ductus arteriosus.
Superficial cardiac plexus.
Left recurrent nerve.
Left bronchus.

Behind.
Trachea.
Deep cardiac plexus.
Cesophagus.
Thoracic duct.
Left recurrent nerve.

Peculiarities.—The height to which the aorta rises in the chest is usually about an inch below the upper border of the sternum; but it may ascend nearly to the top of that bone. Occasionally it is found an inch and a half, more rarely two or even three inches below this point.

In Direction.—Sometimes in man, as is normal in birds, the aorta arches over the root of the right instead of the left lung, and passes down on the right side of the spine. In such cases all of the viscera of the thoracic and abdominal cavities are transposed. Less frequently, the aorta, after arching over the root of the right lung, is directed to its usual position on the left side of the spine, this peculiarity not being accompanied by any transposition of the viscera.

In Conformation.—The aorta occasionally divides, as in some quadrupeds, into an ascending and descending trunk, the former of which is directed vertically upward, and subdivides into three branches, to supply the head and upper extremities. Sometimes the aorta subdivides soon after its origin into two branches, which soon reunite. In one of these cases the cesophagus and trachea were found to pass through the interval left by the division of the aorta; this is the normal condition of the vessel in the reptilia.

Surgical Anatomy.—Of all the vessels of the arterial system, the aorta, and more especially its arch, is most frequently the seat of disease; hence it is important to consider some of the consequences that may ensue from aneurism of this part.

It will be remembered that the ascending aorta is continued in the pericardium, just behind the sternum, being crossed at its commencement by the pulmonary artery and right auricular appendix, and having the right pulmonary artery behind, the vena cava on the right side, and the pulmonary artery and left auricle on the left side.

Aneurism of the ascending aorta, in the situation of the sinuses of Valsalva, in the great majority of cases, affects the anterior sinus; this is mainly owing to the fact that the regurgitation of blood upon the sinuses takes place chiefly on the anterior aspect of the vessel. As the aneurismal sac enlarges it may compress any or all of the structures in immediate proximity to it, but chiefly projects toward the right anterior side, and, consequently, interferes mainly with those structures that have a corresponding relation with the vessel. In the majority of cases it
bursts into the cavity of the pericardium, the patient suddenly drops dead, and, upon a post-mortem examination, the pericardial sac is found full of blood; or it may compress the right auricle, or the pulmonary artery and adjoining part of the right ventricle, and open into one or the other of these parts, or may press upon the precava.

Aneurism of the ascending aorta, originating above the sinuses, most frequently implicates the right anterior wall of the vessel, where, as has been explained, there exists a normal dilatation, the great sinus of the aorta; this is probably mainly owing to the blood being impelled against this part. The direction of the aneurism is also chiefly toward the right of the median line. It attains a large size and projects forward, it may absorb the sternum and the cartilages of the ribs, usually on the right side, and appear as a pulsating tumor on the front of the chest, just below the manubrium; or it may burst into the pericardium, or may compress or open into the right lung, the trachea, bronchi, or esophagus.

Regarding the transverse aorta, the student is reminded that the vessel lies on the trachea, the esophagus, and thoracic duct; that the recurrent laryngeal nerve winds around it; and that from its upper part are given off three large trunks, which supply the head, neck, and upper extremities. An aneurismal tumor, taking origin from the posterior part of the vessel, its most usual site, may press upon the trachea, impede the breathing, or produce cough, hemoptysis, or stridulous breathing, or it may ultimately burst into that tube, producing fatal hemorrhage. Again, its pressure on the laryngeal nerves may give rise to symptoms which so accurately resemble those of laryngitis that the operation of tracheotomy has in some cases been resorted to, from the supposition that disease existed in the larynx; or it may press upon the thoracic duct and destroy life by intination; or it may involve the esophagus, producing dysphagia; or may burst into the esophagus, when fatal hemorrhage will occur. Again, the innominate artery, or the subclavian, or left carotid, may be so obstructed by clots as to produce a weakness, or even a disappearance, of the pulse in one or the other wrist or in the left temporal artery; or the tumor may present itself at or above the manubrium, generally either in the median line or to the right of the sternum, and may simulate an aneurism of one of the arteries of the neck.

Branches (Figs. 389 and 390).—The branches given off from the arch of the aorta are three in number: the innominate, the left common carotid, and the left subclavian arteries.

Peculiarities. Position of the Branches.—The branches, instead of arising from the highest part of the arch (their usual position), may be moved more to the right, arising from the commencement of the transverse or upper part of the ascending portion; or the distance from one another at their origin may be increased or diminished, the most frequent change in this respect being the approximation of the left carotid toward the innominate artery.
The Number of the primary branches may be reduced to a single vessel, or more commonly two: the left carotid arising from the innominate artery, or (more rarely) the carotid and subclavian arteries of the left side arising from the innominate artery. But the number may be increased to four, from the right carotid and subclavian arteries arising directly from the aorta, the innominate being absent. In most of these latter cases the right subclavian has been found to arise from the left end of the arch; in other cases it was the second or third branch given off instead of the first. Another common form in which there are four primary branches is that in which the left vertebral artery arises from the arch of the aorta between the left carotid and subclavian arteries. Lastly, the number of trunks from the arch may be increased to five or six; in these instances, the external and internal carotids arise separately from the arch, the common carotid being absent on one or both sides. In some cases, where six branches have been found, it has been due to a separate origin of the vertebral on both sides.

Number as Usual. Arrangement Different.—When the aorta arches over to the right side, the three branches have an arrangement the reverse of what is usual, the innominate supplying the left side, and the carotid and subclavian (which arise separately) the right side. In other cases, where the aorta takes its usual course, the two carotids may be joined in a common trunk, and the subclavians arise separately from the arch, the right subclavian generally arising from the left end of the arch.1

In some instances other arteries are found to arise from the arch of the aorta. Of these the most common are the bronchial, one or both, and the thyroidea ima; but the internal mammary and the inferior thyroid have been seen to arise from this vessel.

The Innominate Artery (A. Anonyma) (Figs. 389 and 390).

The innominate or brachio-cephalic artery is the largest branch given off from the arch of the aorta. It arises, on a level with the upper border of the second right costal cartilage, from the commencement of the arch of the aorta in front of the left carotid, and, ascending obliquely to the upper border of the right sterno-clavicular articulation, divides into the right common carotid and right subclavian arteries. This vessel varies from an inch and a half to two inches in length.

Relations.—In front, it is separated from the first piece of the sternum by the Sterno-hyoid and Sterno-thyroid muscles, the remains of the thymus gland, the left innominate and right inferior thyroid veins which cross its root, and sometimes the inferior cervical cardiac branch of the right vagus. Behind, it lies upon the trachea, which it crosses obliquely, and continuing upward it lies in the right pleura. On the right side is the right innominate vein, right vagus nerve, and the pleura; and on the left side, the remains of the thymus gland, the origin of the left carotid artery, the left inferior thyroid vein, and the trachea.

Branches.—The innominate usually gives off no branches, but occasionally a small branch, the thyroidea ima, is given off from this vessel. It also sometimes gives off a thymic or bronchial branch.

The Thyroidea Ima (a. thyroidea ima), which is occasionally present, ascends in front of the trachea to the lower part of the thyroid body, which it supplies. It varies greatly in size, and appears to compensate for the deficiency or absence of one of the other thyroid vessels. It occasionally is found to arise from the right common carotid or from the aorta, the subclavian, or internal mammary vessels.

Plan of the Relations of the Innominate Artery.

In front.

Sternum.
Sterno-hyoid and Sterno-thyroid muscles.
Remains of the thymus gland.
Left innominate and right inferior thyroid veins.
Inferior cervical cardiac branch from right vagus nerve.

1 The anomalies of the aorta and its branches are minutely described by Krause in Henle's Anatomy (Brunswick, 1868), vol. iii. p. 203 et seq.—Ed. of 15th English edition.
**Peculiarities in Point of Division.**—When the bifurcation of the innominate artery varies from the point above mentioned it sometimes ascends a considerable distance above the sternal end of the clavicle; less frequently it divides below it. In the former class of cases its length may exceed two inches, and in the latter be reduced to an inch or less. These are points of considerable interest for the surgeon to remember in connection with the operation of tying this vessel.

**Position.**—When the aorta arches over to the right side, the innominate is directed to the left side of the neck instead of the right.

**Collateral Circulation.**—Allan Burns demonstrated, on the dead subject, the possibility of the establishment of the collateral circulation after ligation of the innominate artery, by tying and dividing that artery, after which, he says, "Even coarse injection, impelled into the aorta, passing freely by the anastomosing branches into the arteries of the right arm, filling them and all the vessels of the head completely." The branches by which this circulation would be carried on are very numerous; thus, all the communications across the middle line between the branches of the carotid arteries of opposite sides would be available for the supply of blood to the right side of the head and neck; while the anastomosis between the superior intercostal of the subclavian and the first aortic intercostal (see *infra* on the collateral circulation after obliteration of the thoracic aorta) would bring the blood, by a free and direct course, into the right subclavian: the numerous connections, also, between the intercostal arteries and the branches of the axillary and internal mammary arteries would, doubtless, assist in the supply of blood to the right arm, while the deep epigastric, from the external iliac, would, by means of its anastomosis with the internal mammary, compensate for any deficiency in the vascularity of the wall of the chest.

**Surgical Anatomy.**—The innominate artery has been tied at least thirty times and in six instances, according to Mr. Jacobson, the patient survived. Mott’s patient, however, on whom the operation was first performed, lived nearly four weeks, and Graefe’s more than two months. In 1895 Burrell, of Boston, resected the right sterno-clavicular articulation with the upper end of the sternum and tied the innominate. The patient lived 104 days. The ligation was first successfully performed by A. W. Smyth, of New Orleans, in 1864, for subclavian aneurism. The patient died ten years later of the original aneurism, which was reformed by the collaterals. The chief danger of the operation appears to be the frequency of secondary hemorrhage; but in the present day, with the practice of aseptic surgery and our greater knowledge of the use of the ligature, more favorable results may be anticipated. Other causes of death after operation are pleurisy, pericarditis, and supplicative cellulitis. The main obstacles to the operation are, as the student will perceive from his dissection of this vessel, the deep situation of the artery behind and beneath the sternum, and the number of important structures which surround it in every part.

In order to apply a ligature to this vessel, the patient is to be placed upon his back, with the thorax slightly raised, the head bent a little backward, and the shoulder on the side of the aneurism strongly depressed, so as to draw out the artery from behind the sternum into the neck. An incision three or more inches long is then made along the anterior border of the Sterno-mastoïd muscle, terminating at the sternal end of the clavicle. From this point a second incision is carried about the same length along the upper border of the clavicle. The skin is then dissected back, and the Platysma divided on a director: the sternal end of the Sterno-mastoïd is now brought into view, and, a director being passed beneath it and close to its under surface, so as to avoid any small vessels, it is to be divided; in like manner the clavicular origin is to be divided throughout the whole or greater part of its attachment. By pressing aside any loose cellular tissue or vessels that may now appear the Sterno-hyoid and Sterno-thyroid muscles will be exposed, and must be divided, a director being previously passed beneath them. The inferior thyroid veins may come into view, and must be carefully drawn, either upward or downward, by means of a blunt hook, or tied with double ligatures and divided. After tearing through a strong fibro-cellular lamina, the right carotid is brought into view, and, being traced downward, the *ARTERY* innominate is arrived at. The left innominate vein should now be depressed; the
right innominate vein, the internal jugular vein, and the vagus nerve drawn to the right side; and a curved aneurism needle may then be passed around the vessel, close to its surface, and in a direction from below upward and inward, care being taken to avoid the right pleural sac, the trachea, and cardiac nerves. The ligature should be applied to the artery as high as possible, in order to allow room between it and the aorta for the formation of the coagulum. The importance of avoiding the thyroid plexus of veins during the primary steps of the operation, and the pleural sac whilst including the vessel in the ligature, should be most carefully borne in mind. After the artery has been secured, the common carotid should be tied about half an inch above its origin, and also the thyroidea ima if the vessel is of any size. The several muscles are united by buried sutures. An easier and safer plan than the above is that employed by Burrell—viz., resection of the right sterno-clavicular articulation and of the upper end of the sternum.

ARTERIES OF THE HEAD AND NECK.

The chief artery which supplies the head and neck is the common carotid: it ascends in the neck and divides into two branches: the External Carotid, supplying the superficial parts of the head and face and the greater part of the neck; and the Internal Carotid, supplying to a great extent the parts within the cranial cavity.

THE COMMON CAROTID ARTERY (A. CAROTIS COMMUNIS) (Figs. 388, 389, 390, 394).

The common carotid arteries, although occupying a nearly similar position in the neck, differ in position, and, consequently, in their relation at their origin. The right common carotid (a. carotis communis dextra) arises from the innominate artery, behind the right sterno-clavicular articulation. The left common carotid (a. carotis communis sinistra) arises from the highest part of the arch of the aorta, and is, consequently, longer, and at its origin is contained within the thorax. The course and relations of that portion of the left carotid which intervenes between the arch of the aorta and the left sterno-clavicular articulation will first be described. (See Figs. 388, 389, and 390.)

The left carotid within the thorax ascends obliquely outward from the arch of the aorta to the root of the neck. In front, it is separated from the first piece of the sternum by the Sterno-hyoid and Sterno-thyroid muscles, the left innominate vein, and the remains of the thymus gland; behind, it lies on the trachea, oesophagus, thoracic duct, and the left recurrent laryngeal nerve. Internally, it is in relation with the innominate artery, inferior thyroid veins, and remains of the thymus gland; externally, with the left vagus nerve, left pleura, and left lung. The left subclavian artery is posterior and slightly external to it.

PLAN OF THE RELATIONS OF THE LEFT COMMON CAROTID.

THORACIC PORTION.

In front.

Sternum.
Sterno-hyoid and Sterno-thyroid muscles.
Left innominate vein.
Remains of the thymus gland.

Internally.

Innominate artery.
Inferior thyroid veins.
Remains of the thymus gland.

Externally.

Left vagus nerve.
Left pleura and lung.
Left subclavian artery.

Behind.

Trachea.
Oesophagus.
Thoracic duct.
Left recurrent laryngeal nerve.
In the neck the two common carotids resemble each other so closely that one description will apply to both. Each vessel passes obliquely upward from behind the sterno-clavicular articulation to a level with the upper border of the thyroid cartilage, opposite the fourth cervical vertebra, where it divides into the external and internal carotid; these names being derived from the distribution of the arteries to the external parts of the head and face and to the internal parts of the cranium and orbit respectively.

At the lower part of the neck the two common carotid arteries are separated from each other by a small interval, which contains the trachea; but at the upper part, the thyroid body, the larynx and pharynx project forward between the two vessels, and give the appearance of their being placed farther back in this situation. The common carotid artery is contained in a sheath derived from the
deep cervical fascia, which also encloses the internal jugular vein and vagus nerve, the vein lying on the outer side of the artery, and the nerve between the artery and vein, on a plane posterior to both. On opening the sheath these three structures are seen to be separated from one another, each being enclosed in a separate fibrous investment.

Relations.—At the lower part of the neck the common carotid artery is very deeply seated, being covered by the integument, superficial fascia, Platysma, and deep cervical fascia, the Sterno-mastoid, Sterno-hyoid, and Sterno-thyroid muscles, and by the Omo-hyoid, opposite the cricoid cartilage; but in the upper part of its course, near its termination, it is more superficial, being covered merely by the integument, the superficial fascia, Platysma, deep cervical fascia, and inner margin of the Sterno-mastoid, and, when the latter is drawn backward, it is seen to be contained in a triangular space, bounded behind by the Sterno-mastoid, above by the posterior belly of the Digastric, and below by the anterior belly of the Omo-hyoid. This part of the artery is crossed obliquely, from within outward, by the Sterno-mastoid artery; it is crossed also by the superior and middle thyroid veins, which terminate in the internal jugular; and, descending on its sheath in front, is seen the descendens hypoglossi nerve, this filament being joined by one or two branches from the cervical nerves, which cross the vessel from without inward. Sometimes the descendens hypoglossi is contained within the sheath. The middle thyroid vein crosses the artery about its middle, and the anterior jugular vein below; the latter, however, is separated from the artery by the Sterno-hyoid and Sterno-thyroid muscles. Behind, the artery is separated from the transverse processes of the vertebrae by the Longus colli and Rectus capitis anticus major muscles, the sympathetic nerve being interposed between it and the muscles. The recurrent laryngeal nerve and inferior thyroid artery cross behind the vessel at its lower part. Internally, it is in relation with the trachea and thyroid gland, the latter overlapping it, the inferior thyroid artery and recurrent laryngeal nerve being interposed: higher up, with the larynx and pharynx. On its outer side are placed the internal jugular vein and vagus nerve. At the lower part of the neck the internal jugular vein on the right side diverges from the artery, but on the left side it approaches it, and often overlaps its lower part. This is an important fact to bear in mind during the performance of any operation on the lower part of the left common carotid artery. In this region the relation which the right and left recurrent laryngeal nerves bear to the arteries is not identical. The left recurrent laryngeal nerve lies behind the thoracic portion of the left common carotid artery and internal to the cervical portion of the vessel. The right nerve passes obliquely upward and inward behind the right common carotid to reach its inner side.

Plan of the Relations of the Common Carotid Artery.

In front.

Integument and superficial fascia.
Deep cervical fascia.
Platysma.
Sterno-mastoid.
Sterno-hyoid.
Sterno-thyroid.

Externally.
Internal jugular vein.
Vagus nerve.

-Omo-hyoid.
Descendens and Communicans hypoglossi nerves.
Sterno-mastoid artery.
Superior and middle thyroid veins.
Anterior jugular vein.

Internally.
Trachea.
Thyroid gland.
Recurrent laryngeal nerve.
 Inferior thyroid artery.
Larynx.
Pharynx.
THE COMMON CAROTID ARTERY

Behind.

Longus colli. Sympathetic nerve.
Rectus capitis anticus major. Inferior thyroid artery.
Recurrent laryngeal nerve.

Peculiarities as to Origin.—The right common carotid may arise above or below the upper border of the sterno-clavicular articulation. This variation occurs in one out of about eight cases and a half, and the origin is more frequently below than above; or the artery may arise as a separate branch from the arch of the aorta or in conjunction with the left carotid. The left common carotid varies more frequently in its origin than the right. In the majority of abnormal cases it arises with the innominate artery, or, if the innominate artery is absent, the two carotids arise usually by a single trunk. It rarely joins with the left subclavian, except in cases of transposition of the arch.

Peculiarities as to Point of Division.—The most important peculiarities of this vessel, in a surgical point of view, relate to its place of division in the neck. In the majority of abnormal cases this occurs higher than usual, the artery dividing into two branches opposite the hyoid bone, or even higher; more rarely it occurs below, opposite the middle of the larynx or the lower border of the cricoid cartilage; and one case is related by Morgagni where the common carotid, only an inch and a half in length, divided at the root of the neck. Very rarely the common carotid ascends in the neck without any subdivision, the internal carotid being wanting; and in a few cases the common carotid has been found to be absent, the external and internal carotids arising directly from the arch of the aorta. This peculiarity existed on both sides in some instances, on one side in others.

Occasional Branches.—The common carotid usually gives off no branch previous to its bifurcation; but it occasionally gives origin to the superior thyroid or its laryngeal branch, the ascending pharyngeal, the inferior thyroid, or, more rarely, the vertebral artery.

Surface Marking.—The carotid arteries are covered throughout their entire extent by the Sterno-mastoid muscle, but their course does not correspond to the anterior border of the muscle, which passes in a somewhat curved direction from the mastoid process to the sterno-clavicular joint. The course of the artery is indicated more exactly by a line drawn from the sternal end of the clavicle below, to a point midway between the angle of the jaw and the mastoid process above. That portion of the line below the level of the upper border of the thyroid cartilage would represent the course of the vessel.

Surgical Anatomy.—The operation of tying the common carotid artery may be necessary in a case of wound of that vessel or its branches, in aneurism, or in a case of pulsating tumor of the orbit or skull. If the wound involves the trunk of the common carotid, it will be necessary to tie the artery through the wound above and below the wounded part. If the wound is too small to admit of safe and rapid work it must be enlarged. In cases of aneurism, or where one of the branches of the common carotid is wounded in an inaccessible situation, it may be judged necessary to tie the trunk. In such cases the whole of the artery is accessible, and any part may be tied except close to either end. When the case is such as to allow of a choice being made, the lower part of the carotid should never be selected as the spot upon which to place a ligature, for not only is the artery in this situation placed very deeply in the neck, but it is covered by three layers of muscles, and, on the left side, in the great majority of cases, the internal jugular vein passes obliquely in front of it. Neither should the upper end be selected, for here the superior thyroid vein and its tributaries would give rise to very considerable difficulty in the application of a ligature. The point most favorable for the operation is that part of the vessel which is at the level of the cricoid cartilage. It occasionally happens that the carotid artery bifurcates below its usual position; if the artery be exposed at its point of bifurcation, both divisions of the vessel should be tied near their origin, in preference to tying the trunk of the artery near its termination; and if, in consequence of the entire absence of the common carotid or from its early division, two arteries, the external and internal carotids, are met with, the ligature should be placed on that vessel which is found on compression to be connected with the disease.

Ligation of the Carotid at the Level of the Cricoid Cartilage (Ligation in the Triangle of Election).—The triangle of election is bounded posteriorly by the anterior edge of the sternoclavido-mastoid; is bounded above by the posterior belly of the digastric; is bounded below by the anterior belly of the omohyoid. In this operation the direction of the vessel and the inner margin of the Sterno-mastoid are the chief guides to its performance. The patient should be placed on his back with the head thrown back and turned slightly to the opposite side: an incision is to be made, three inches long, in the direction of the anterior border of the Sterno-mastoid, so that the centre corresponds to the level of the cricoid cartilage; after dividing the integument, superficial fascia, and Platysma, the deep fascia must be cut through on a director, so as to avoid wounding numerous small veins that are usually found beneath. The head may now be brought forward so as to relax the parts somewhat, and the margins of the wound are held asunder by retractors. The descendens hypoglossi nerve may now be exposed, and must be avoided, and, the sheath of the vessel having been raised by forceps, is to be opened to a small
extent over the artery at its inner side. The internal jugular vein may present itself alternately distended and relaxed; this should be compressed both above and below, and drawn outward, in order to facilitate the operation. The aneurism needle is passed from the outside, care being taken to keep the needle in close contact with the artery, and thus avoid the risk of injuring the internal jugular vein or including the vagus nerve. Before the ligature is tied it should be ascertained that nothing but the artery is included in it.

Ligation of the Common Carotid at the Lower Part of the Neck (Ligation in the Triangle of Necessity).—The triangle of necessity is bounded above by the anterior belly of the omohyoid; is bounded behind by the anterior margin of the sterno-cleido-mastoid; is bounded in front by the mid-line of the neck. This operation is sometimes required in cases of aneurism of the upper part of the carotid, especially if the sac is of large size. It is best performed by dividing the sternal origin of the Sterno-mastoid muscle, but may be done in some cases, if the aneurism is not of very large size, by an incision along the anterior border of the Sterno-mastoid, extending down to the sterno-clavicular articulation, and by then retracting the muscle. The easiest and best plan, however, is to make an incision two or three inches long down the lower part of the anterior border of the Sterno-mastoid muscle to the sterno-clavicular joint, and a second incision, starting from the termination of the first, along the upper border of the clavicle for about two inches. This incision is made through the superficial and deep fascia, and the sternal origin of the muscle is exposed. This is to be divided on a director, and turned up, with the superficial structures, as a triangular flap. Some loose connective tissue is to be divided or torn through, and the outer border of the Sterno-hyoid muscle exposed. In doing this care must be taken not to wound the anterior jugular vein, which crosses the muscle to reach the external jugular or subclavian vein. The Sterno-hyoid, and with it the Sterno-thyroid, are to be drawn inward by means of a retractor, and the sheath of the vessel is exposed. This must be opened with great care on its inner or tracheal side, so as to avoid the internal jugular vein. This is especially necessary on the left side, where the artery is commonly overlapped by the vein. On the right side there is usually an interval between the artery and the vein, and not the same risk of wounding the latter.

The common carotid artery, being a long vessel without any branches, is particularly suitable for the performance of Braasor's operation for the cure of an aneurism of the lower part of the vessel. Braasor's procedure consists in ligaturing the artery on the distal side of the aneurism, and in the case of the common carotid there are no branches given off from the vessel between the aneurism and the site of the ligature; hence the flow of blood through the sac of the aneurism is diminished and cure takes place in the usual way, by the deposit of laminated fibrin.

Collateral Circulation.—After ligature of the common carotid the collateral circulation can be perfectly established, by the free communication which exists between the carotid arteries of opposite sides, both without and within the cranium, and by enlargement of the branches of the subclavian artery on the side corresponding to that on which the vessel has been tied—the chief communication outside the skull taking place between the superior thyroid from the external carotid and the inferior thyroid from the subclavian, the profunda cervicis from the subclavian and the superior intercostal with the arteria princeps cervicis of the occipital; the vertebral taking the place of the internal carotid within the cranium.

Sir A. Cooper had an opportunity of dissecting, thirteen years after the operation, the case in which he first successfully tied the common carotid (the second case in which he performed the operation). The injection, however, does not seem to have been a successful one. It showed merely that the arteries at the base of the brain (circle of Willis) were much enlarged on the side of the tied artery, and that the anastomosis between the branches of the external carotid on the affected side and those of the same artery on the sound side was free, so that the external carotid was pervious throughout.

The Intercarotid Body (carotid gland, retrocarotid corpuscle) (see the Ductless Glands).

The External Carotid Artery (A. Carotis Externa) (Figs. 392, 393, 394).

The external carotid artery commences opposite the upper border of the thyroid cartilage, and, taking a slightly curved course, passes upward and forward, and then inclines backward to the space between the neck of the condyle of the lower jaw and the external meatus, where it divides into the superficial temporal and internal maxillary arteries. It rapidly diminishes in size in its course up the neck, owing to the number and large size of the branches given off from it. In the child it is somewhat smaller than the internal carotid, but in the adult the

1 Guy's Hospital Reports, i., 56.
two vessels are of nearly equal size. At its commencement this artery is more superficial, and placed nearer the middle line than the internal carotid, and is contained in the triangular space bounded by the Sterno-mastoid behind, the anterior belly of the Omohyoid below, and the posterior belly of the Digastric and the Stylo-hyoid above.

**Relations.**—It is covered by the skin, superficial fascia, Platysma, deep fascia and anterior margin of the Sterno-mastoid, and is crossed by the hypoglossal nerve, and by the lingual and facial veins; it is afterward crossed by the Digastric and Stylo-hyoid muscles, and higher up passes deeply into the substance of the parotid gland, where it lies beneath the facial nerve and the junction of the temporal and internal maxillary veins. *Internally* is the hyoid bone, wall of the pharynx, the superior laryngeal nerve, and the ramus of the jaw, from which it is separated by a portion of the parotid gland. *Externally*, in the lower part of its course, is the internal carotid artery. *Behind* it, near its origin, is the superior laryngeal nerve; and higher up, it is separated from the internal carotid by the Stylo-glossus and Stylo-pharyngeus muscles, the glosso-pharyngeal nerve, and part of the parotid gland.

**Plan of the Relations of the External Carotid.**

*In front.*

Skin, superficial fascia.
Platysma and deep fascia.
Anterior border of Sterno-mastoid.
Hypoglossal nerve.
Lingual and facial veins.
Digastric and Stylo-hyoid muscles.
Parotid gland with facial nerve and temporo-maxillary vein in its substance.

*Internally.*

Hyoid bone.
Pharynx.
Superior laryngeal nerve.
Parotid gland.
Ramus of jaw.

*Externally.*

Internal carotid artery.

*Behind.*

Superior laryngeal nerve.
Stylo-glossus.
Stylo-pharyngeus.
Glosso-pharyngeal nerve.
Parotid gland.

**Surface Marking.**—The position of the external carotid artery may be marked out with sufficient accuracy by a line drawn from the front of the meatus of the external ear to the side of the cricoid cartilage, slightly arching the line forward.

**Surgical Anatomy.**—The application of a ligature to the external carotid may be required in case of wounds of this vessel, or of its branches when these cannot be tied, and in some cases of pulsating tumor of the scalp or face. The operation has not received the attention which it deserves, owing to the fear which surgeons have entertained of secondary hemorrhage, on account of the number of branches given off from the vessel. This fear, however, has been shown by Mr. Cripps not to be well founded.1 Ligature is often very useful as a means of preventing excessive hemorrhage in operations about the face, jaws, and mouth. It is sometimes employed with the hope of lessening the growth of tumors by cutting off the blood supply, but ligation is useless for this purpose. Ligation of one external carotid artery arrests the circulation for only a brief period, and within a very few days the circulation is practically freely re-established. This result is seen to be inevitable when we recall the numerous branches of the external carotid, their free anastomoses, and the fact that a very great number of extremely minute vessels in the middle line join the external carotid system of one side to that of the other side. Robert H. M. Dawbarn points out that ligation of both external carotids produces only temporary anemia, for "inside of a week or ten days thereafter the pulse can again be felt in the temporals and facials upon both sides."2 Dawbarn points out that even after excision of the external carotids, with separate ligation of each of the eight branches, blood can still reach the nose, tongue, etc.,

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2 The Treatment of Certain Malignant Growths.
from outside systems by twenty-nine distinct routes. Whereas ligation of even both carotids will not prevent the growth of a malignant tumor, excision of each external carotid, with separate control of its eight branches, will sometimes prove of great value in retarding the progress of a growth. It "starves" the growth and may cause it to shrink (Dawbarn's operation). To tie the external carotid near its origin, below the point where it is crossed by the Digastric, an incision about three inches in length should be made along the margin of the Sterno-mastoid, from the angle of the jaw to the upper border of the thyroid cartilage. The ligature should be applied between the lingual and superior thyroid branches. To tie the vessel above the Digastric, between it and the parotid gland, an incision should be made, from the lobe of the ear to the great cornu of the os hyoideus, dividing successfully the skin, Platysma, and fascia. By drawing the Sterno-mastoid outward, the posterior belly of the Digastric and Stylo-hyoid muscles downward, and separating them from the parotid gland, the vessel will be exposed, and a ligature may be applied to it. The circulation is at once re-established by the free communication between most of the large branches of the artery (facial, lingual, superior thyroid, occipital) and the corresponding arteries of the opposite side and by the anastomosis of its branches with those of the internal carotid, and of the occipital with the branches of the subclavian, etc.

**Branches.**—The external carotid artery gives off eight branches, which, for convenience of description, may be divided into four sets. (See Fig. 395, Plan of the Branches.)

<table>
<thead>
<tr>
<th>Anterior</th>
<th>Posterior</th>
<th>Ascending</th>
<th>Terminal</th>
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<tbody>
<tr>
<td>Superior Thyroid</td>
<td>Occipital</td>
<td>Ascending Pharyngeal</td>
<td>Superficial Temporal</td>
</tr>
<tr>
<td>Lingual</td>
<td>Posterior Auricular</td>
<td></td>
<td>Internal Maxillary</td>
</tr>
<tr>
<td>Facial</td>
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The student is here reminded that many variations are met with in the number, origin, and course of these branches in different subjects; but the above arrangement is that which is found in the great majority of cases.

The **Superior Thyroid Artery** ("a. thyreoidea superior") (Figs. 394, 395, and 308) is the first branch given off from the external carotid, being derived from that vessel just below the great cornu of the hyoid bone. At its commencement it is quite superficial, being covered by the integument, fascia, and Platysma, and is contained in the triangular space bounded by the Sterno-mastoid, Digastric, and Omo-hyoid muscles. After running upward and inward for a short distance, it curves downward and forward, in an arched and tortuous manner, to the upper part of the thyroid gland, passing beneath the Omo-hyoid, Sterno-hyoid, and Sterno-thyroid muscles, and supplying them. It distributes numerous branches to the upper part of the gland, anastomosing with its fellow of the opposite side and with the inferior thyroid arteries. The terminal branches supplying the gland are generally two in number: one, the largest, the anterior branch ("ramus anterior"), descends at the anterior border of the lateral lobe of the gland, reaches the upper border of the isthmus, and then passes in the substance of the isthmus to the middle line of the neck, where it anastomoses with the corresponding artery of the opposite side: the posterior branch ("ramus posterior") descends along the posterior border of the lateral lobe of the gland, the anterior and posterior branches anastomose with each other and with branches of the inferior thyroid, and both of them send branches to the thyroid gland ("rami glandulares"). Besides the arteries distributed to the muscles by which it is covered and to the substance of the gland, the branches of the superior thyroid are the following:

- Hyoid.
- Superficial Descending Branch (Sterno-mastoid).
- Superior Laryngeal.
- Crico-thyroid.

The **Hyoid** or **Infra-hyoid** ("ramus hyoideus") is a small branch which runs along the lower border of the os hyoideus beneath the Thryo-hyoid muscle; after supplying the muscles connected to that bone, it forms an arch, by anastomosing with the vessel of the opposite side.
The **Superficial Descending** or Sterno-mastoid Branch (*ramus sternoeleidomastoideus*) runs downward and outward across the sheath of the common carotid artery, and supplies the Sterno-mastoid and neighboring muscles and integument. There is frequently a separate branch from the external carotid distributed to the Sterno-mastoid muscle.

The **Superior Laryngeal** (*a. laryngea superior*), larger than either of the preceding, accompanies the internal laryngeal nerve, beneath the Thyro-hyoid muscle; it pierces the thyro-hyoid membrane, and supplies the muscles, mucous membrane, and glands of the larynx, anastomosing with the branch from the opposite side.

The **Crico-thyroid** (*ramus cricothyreoideus*) is a small branch which runs transversely across the crico-thyroid membrane, communicating with the artery of the opposite side.

**Arteries of the Thyroid Gland.**—The thyroid gland is supplied by the two superior thyroids from the external carotid; the two inferior thyroids from the subclavian, and sometimes also by the thyreoidea ima from the innominate.

The superior thyroid joins the gland at the summit of the upper horn, passes down the posterior surface of the gland toward the inner surface of the upper horn, comes forward to the anterior margin of the inner surface, descends to the isthmus, and on the superior border of the isthmus anastomoses with the artery from the other side. The superior thyroid artery sends numerous branches across the anterior surface of the gland.

The inferior thyroid artery is larger than the superior artery. It passes to the posterior surface of the gland and divides into branches. Some of the branches enter the hilus; others track across the posterior surface of the gland. The inferior thyroid artery is close to the recurrent laryngeal nerve. The artery, as a rule, passes behind the nerve before it divides into branches. It may divide first and then one or two branches may be in front of the nerve. In unusual cases the artery before division is in front of the nerve, or all the branches are in front.

The thyreoidea ima passes to the lower portion of the gland. Berry points out that the thyroid arteries communicate very freely with each other; only the small branches pass into the interior of the gland; the larger branches "ramify on the surface of the gland, just beneath the capsule."

**Surgical Anatomy.**—The superior thyroid, or one of its branches, is often divided in cases of cut throat, giving rise to considerable hemorrhage. In such cases the artery should be secured, the wound being enlarged for that purpose, if necessary. The operation may be easily performed, the position of the artery being very superficial, and the only structures of importance covering it being a few small veins. The operation of tying the superior thyroid artery to lessen the size of a bronchocoele has been performed in numerous instances with partial or temporary success. When, however, the collateral circulation between this vessel and the artery of the opposite side, and the inferior thyroid, is completely re-established, the tumor usually regains its former size, and hence the operation has been given up, especially as better results are obtained by other means. Both thyroid arteries on the same side, and indeed all the four thyroid arteries, have been tied in enlarged thyroid. The superior and inferior thyroid arteries of the involved side are ligated before extirpating a goitrous lobe of the thyroid.

The position of the superficial descending branch is of importance in connection with the operation of ligation of the common carotid artery. It crosses and lies on the sheath of this vessel, and may chance to be wounded in opening the sheath. The position of the crico-thyroid branch should be remembered, as it may prove the source of troublesome hemorrhage during the operation of laryngotomy. In performing the operation of quick laryngotomy the crico-thyroid membrane should be incised transversely in order to avoid this vessel.

The **Lingual Artery** (*a. lingualis*) (Figs. 394 and 395) arises from the external carotid between the superior thyroid and facial; it first runs obliquely upward and inward to the great cornu of the hyoid bone; it then curves downward and forward, forming a loop which is crossed by the hypoglossal nerve, and, passing

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1 Berry. Diseases of the Thyroid Gland.

2 Ibid.
beneath the Digastric and Stylo-hyoid muscles, it runs horizontally forward, beneath the Hyo-glossus, and finally, ascending almost perpendicularly to the tongue, turns forward on its under surface as far as the tip, under the name of the ranine artery.

Relations.—Its first, or oblique, portion is superficial, being contained in the same triangular space as the superior thyroid artery, resting upon the middle constrictor of the pharynx, and covered by the Platysma and fascia of the neck. Its second, or curved, portion also lies upon the middle constrictor, being covered at first by the tendon of the Digastric and the Stylo-hyoid muscle, and afterward by the Hyo-glossus, the latter muscle separating it from the hypoglossal nerve. Its third, or horizontal, portion lies between the Hyo-glossus and Genio-hyoglossus muscles. The fourth, or terminal, part, under the name of the ranine, runs along the under surface of the tongue to its tip: it is very superficial, being covered only by the mucous membrane, and rests on the Lingualis on the outer side of the Genio-hyoglossus. The hypoglossal nerve crosses the lingual artery, and then becomes separated from it, in the second part of its course, by the Hyo-glossus muscle.

Branches.—The branches of the lingual artery are—the

Hyoid. Sublingual.
Dorsalis Linguae. Ranine.

The Hyoid or Supra-hyoid Branch (ramus hyoideus) runs along the upper border of the hyoid bone, supplying the muscles attached to it and anastomosing with its fellow of the opposite side.

The Dorsalis Linguae (ramus dorsalis linguae) (Fig. 445) arises from the lingual artery beneath the Hyo-glossus muscle (which, in the figure, has been partly cut away, to show the vessel); it ascends to the dorsum of the tongue, and supplies the mucous membrane, the tonsil, soft palate, and epiglottis, anastomosing with its fellow from the opposite side. This artery is frequently represented by two or three small branches.

The Sublingual (a. sublingualis), which may be described as a branch of bifurcation of the lingual artery, arises at the anterior margin of the Hyo-glossus muscle, and runs forward between the Genio-hyoglossus and the sublingual gland. It supplies the substance of the gland, giving branches to the Mylo-hyoid and neighboring muscles, the mucous membrane of the mouth and gums. One branch runs behind the alveolar process of the lower jaw in the substance of the gum to anastomose with a similar artery from the other side.

The Ranine or Deep Lingual (a. profunda linguae) may be regarded as the other branch of bifurcation. It is usually described as the continuation of the lingual artery; it runs along the under surface of the tongue, resting on the Inferior lingualis, and covered by the mucous membrane of the mouth; it lies on the outer side of the Genio-hyoglossus, accompanied by the lingual nerve. On arriving at the tip of the tongue it is said to anastomose with the artery of the opposite side, but this is denied by Hyrtl. These vessels in the mouth are placed one on each side of the frenum.

Surgical Anatomy.—The lingual artery may be divided near its origin in cases of cut throat, a complication that not unfrequently happens in this class of wounds; or severe hemorrhage which cannot be restrained by ordinary means may ensue from a wound or deep ulcer of the tongue. In the former case the primary wound may be enlarged if necessary, and the bleeding vessels secured. In the latter case it has been suggested that the lingual artery should be tied near its origin. Ligature of the lingual artery is also occasionally practised, as a palliative measure, in cases of cancer of the tongue, in order to check the progress of the disease by starving the growth, and it is sometimes tied as a preliminary measure to removal of the tongue. The operation is a somewhat difficult one, on account of the depth of the artery, the number of important structures by which it is surrounded, the loose and yielding nature of the parts upon which it is supported, and its occasional irregularity of origin. An incision is to be made in a curved direc-
tion from a point one finger's breadth external to the symphysis of the jaw downward to the cornu of the hyoid bone, and then upward to near the angle of the jaw. Care must be taken not to carry this incision too far backward, for fear of endangering the facial vein. In the first incision the skin, superficial fascia, and Platysma will be divided, and the deep fascia exposed. The deep fascia is then to be incised and the submaxillary gland exposed and pulled upward by retractor. A triangular space is now exposed, Lesser's triangle, bounded internally by the posterior border of the Mylo-hyoid muscle: below and externally, by the tendon of the Digastric; and above, by the hypoglossal nerve. The floor of the space is formed by the Hyo-glossus muscle, beneath which the artery lies. The fibres of this muscle are now to be cut through horizontally and the vessel exposed, care being taken, while near the vessel, not to open the pharynx.

Troublesome hemorrhage may occur in the division of the frenum in children if the canine arteries, which lie on each side of it, are wounded. The student should remember that the operation is always to be performed with a pair of blunt-pointed scissors, and the mucous membrane only is to be divided by a very superficial cut, which cannot endanger any vessel. The scissors also, should be directed away from the tongue. Any further liberation of the tongue which may be necessary can be effected by tearing.

The Facial or External Maxillary Artery (a. maxillaris externa) (Figs. 394, 395, 396, and 397) arises a little above the lingual, and passes obliquely upward, beneath the Digastric and Stylo-hyoid muscles, and frequently beneath the hypoglossal nerve; it now runs forward under cover of the body of the lower jaw, lodged in a groove on the posterior surface of the submaxillary gland; this may be called the cervicale part of the artery. It then curves upward over the body of the jaw at the anterior inferior angle of the Masseter muscle; passes forward and upward across the cheek to the angle of the mouth, then upward along the side of the nose.

![Fig. 396.—The arteries of the face and scalp.](image)

1 The muscular tissue of the lips must be supposed to have been cut away, in order to show the course of the coronary arteries.
and terminates at the inner canthus of the eye, under the name of the **angular artery**. The facial artery, both in the neck and on the face, is remarkably tortuous: in the former situation its tortuosity enables it to accommodate itself to the movements of the pharynx in deglutition, and in the latter to the movements of the jaw and the lips and cheeks.

**Relations.**—*In the neck* its origin is superficial, being covered by the integument, Platysma, and fascia; it then passes beneath the Digastric and Stylo-hyoid muscles and part of the submaxillary gland. It lies upon the middle constrictor of the pharynx, and is separated from the Stylo-glossus and Hyo-glossus muscles by a portion of the submaxillary gland. *On the face*, where it passes over the body of the lower jaw, it is comparatively superficial, lying immediately beneath the Platysma. In this situation its pulsation may be distinctly felt, and compression of the vessel against the bone can be effectually made. In its course over the face it is covered by the integument, the fat of the cheek, and, near the angle of the mouth, by the Platysma, Risorius, and Zygomatic muscles. It rests on the Buccinator, the Levator anguli oris, and the Levator labii superioris (sometimes piercing or else passing under this last muscle). The facial vein lies to the outer side of the artery, and takes a more direct course across the face, where it is separated from the artery by a considerable interval. In the neck it lies superficial to the artery. The branches of the facial nerve cross the artery, and branches of the infraorbital nerve lie beneath it.

**Branches.**—The branches of this vessel may be divided into two sets: those given off below the jaw (cervical), and those on the face (facial).

<table>
<thead>
<tr>
<th>Cervical Branches</th>
<th>Facial Branches</th>
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<tr>
<td>Inferior or Ascending Palatine</td>
<td>Muscular</td>
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<tr>
<td>Tonsillar</td>
<td>Inferior Labial</td>
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<tr>
<td>Submaxillary</td>
<td>Inferior Coronary</td>
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<tr>
<td>Submental</td>
<td>Superior Coronary</td>
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<tr>
<td>Muscular</td>
<td>Lateral Nasal</td>
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<td>Angular</td>
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The **Inferior or Ascending Palatine** (*a. palatine ascendens*) passes up between the Stylo-glossus and Stylo-pharyngeus to the outer side of the pharynx, along which it is continued between the Superior constrictor and the Internal pterygoid to near the base of the skull. It supplies the neighboring muscles, the tonsil, and Eustachian tube, and divides, near the Levator palati, into two branches: one follows the course of the Levator palati, and, winding over the upper border of the Superior constrictor, supplies the soft palate and the palatine glands, anastomosing with its fellow of the opposite side and with the posterior palatine branch of the internal maxillary artery; the other pierces the Superior constrictor and supplies the tonsil, anastomosing with the tonsillar and ascending pharyngeal arteries.

The **Tonsillar** (*ramus tonsillaris*) passes up between the Internal pterygoid and Stylo-glossus, and then ascends along the side of the pharynx, perforating the Superior constrictor, to ramify in the substance of the tonsil and root of the tongue.

The **Submaxillary or Glandular Branches** (*rami glandulares*) consist of three or four large vessels, which supply the submaxillary gland, some being prolonged to the neighboring muscles, lymphatic glands, and integument.

The **Submental** (*a. submentalis*) (Fig. 394), the largest of the cervical branches, is given off from the facial artery just as that vessel quits the submaxillary gland: it runs forward upon the Mylo-hyoid muscle, just below the body of the jaw and beneath the Digastric; after supplying the surrounding muscles, and anastomosing
with the sublingual artery by branches which perforate the mylo-hyoid muscle, it arrives at the symphysis of the chin, where it turns over the border of the jaw and divides into a superficial and a deep branch; the former passes between the integument and Depressor labii inferioris, supplies both, and anastomoses with the inferior labial. The deep branch passes between the latter muscle and the bone, supplies the lip, and anastomoses with the inferior labial and mental arteries.

The **Muscular Branches** are distributed to the Internal pterygoid and Stylo-hyoid in the neck, and to the Masseter and Buccinator on the face.

The **Inferior Labial** (a. labialis inferior) (Fig. 396) passes beneath the Depressor anguli oris, to supply the muscles and integument of the chin and lower lip, anastomosing with the inferior coronary and submental branches of the facial, and with the mental branch of the inferior dental artery.

The **Inferior Coronary** (Figs. 396 and 397) is derived from the facial artery, near the angle of the mouth: it passes upward and inward beneath the depressor anguli oris, and, penetrating the Orbicularis oris muscle, runs in a tortuous course along the edge of the lower lip between this muscle and the mucous membrane, inosculating with the artery of the opposite side. This artery supplies the labial glands, the mucous membrane, and muscles of the lower lip, and anastomoses with the inferior labial from the facial and the mental branch of the inferior dental artery.

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**Fig. 397.**—The coronary arteries, the glands of the lips, and the nerves of the right side seen from the posterior surface after removal of the mucous membrane. (Poirier and Charpy.)

The **Superior Coronary** (a. labialis superior) (Figs. 396 and 397) is larger and more tortuous in its course than the preceding. It follows the same course along the edge of the upper lip, lying between the mucous membrane and the Orbicularis oris, and anastomoses with the artery of the opposite side. It supplies the textures of the upper lip, and gives off in its course two or three vessels which ascend to the nose. One, named the **inferior artery of the septum**, ramifies on the septum of the nostrils as far as the point of the nose, and there anastomoses with the nasopalatine artery; another, the **artery of the ala**, supplies the ala of the nose.

The **Lateralis Nasi** is derived from the facial, as that vessel is ascending along the side of the nose; it supplies the ala and dorsum of the nose, anastomosing with its fellow, the nasal branch of the ophthalmic, the inferior artery of the septum, the artery of the ala, and the infraorbital.

The **Angular Artery** (a. angularis) is the termination of the trunk of the facial; it ascends to the inner angle of the orbit, embedded in the fibres of the Levator labii superioris alaeque nasi, and accompanied by a large vein, the angular vein; it distributes some branches on the cheek which anastomose with the infraorbital. After supplying the lachrymal sac and Orbicularis palpebrarum muscle, the angular artery terminates by anastomosing with the nasal branch of the ophthalmic artery.

The anastomoses of the facial artery are very numerous, not only with the
vessel of the opposite side, but, in the neck, with the sublingual branch of the lingual; with the ascending pharyngeal; and with the posterior palatine, a branch of the internal maxillary, by its inferior or ascending palatine and tonsillar branches; on the face, with the mental branch of the inferior dental as it emerges from the mental foramen, with the transverse facial, a branch of the temporal; with the infraorbital, a branch of the internal maxillary, and with the nasal branch of the ophthalmic.

**Peculiarities.**—The facial artery not unfrequently arises by a common trunk with the lingual. This vessel is also subject to some variations in its size and in the extent to which it supplies the face. It occasionally terminates as the submental, and not unfrequently supplies the face only as high as the angle of the mouth or nose. The deficiency is then supplied by enlargement of one of the neighboring arteries.

**Surgical Anatomy.**—The passage of the facial artery over the body of the jaw would appear to afford a favorable position for the application of pressure in case of hemorrhage from the lips, the result either of an accidental wound or during an operation; but its application is useless, except for a very short time, on account of the free communication of this vessel with its fellow and with numerous branches from different sources. In a **wound involving the lip** it is better to seize the part between the fingers, and exert it, when the bleeding vessel may be at once secured with pressure-forceps. In order to prevent hemorrhage in cases of removal of diseased growths from the part, the lip should be compressed on each side between the fingers and thumb or by a pair of specially devised clamp-forceps, whilst the surgeon excises the diseased part. In order to stop hemorrhage where the lip has been divided in an operation, it is necessary, in uniting the edges of the wound, to pass the sutures through the cut edges from the skin almost as deep as the mucous surface; by these means not only are the cut surfaces more neatly and securely adapted to each other, but the possibility of hemorrhage is prevented by including in the suture the divided artery. If the suture is, on the contrary, passed through merely the cutaneous portion of the wound, hemorrhage occurs into the cavity of the mouth. The student should, lastly, observe the relation of the angular artery to the lachrymal sac, and it will be seen that, as the vessel passes up along the inner margin of the orbit, it ascends on its nasal side. In operating for **fistula lacrimalis** the sac should always be opened on its outer side, in order that this vessel may be avoided.

The **Occipital Artery** (a. occipitalis) (Figs. 394, 395, 396, and 398) arises from the posterior part of the external carotid, opposite the facial, near the lower margin of the Digastric muscle. At its origin it is covered by the posterior belly of the Digastric muscle and the Stylo-hyoid muscle, and the hypoglossal nerve winds around it from behind forward; higher up, it passes across the internal carotid artery, the internal jugular vein, and the vagus and accessory nerves; it then ascends to the interval between the transverse process of the atlas and the mastoid process of the temporal bone, and passes horizontally backward, grooving the surface of the latter bone, being covered by the Serno-mastoid, Splenius, Trachelo-mastoid, and Digastric muscles, and resting upon the Rectus lateralis, the Superior oblique, and Complexus muscles; it then changes its course and passes vertically upward, pierces the fascia which connects the cranial attachment of the Trapezius with the Serno-mastoid, and ascends in a tortuous course over the occiput, as high as the vertex, where it divides into numerous branches. It is accompanied in the latter part of its course by the great occipital nerve, and occasionally by a cutaneous filament from the suboccipital nerve.
Branches.—The branches given off from this vessel are—

Muscular.  Dural or Meningeal.
Sterno-mastoid.  Mastoid.
Auricular.  Arteria Princeps Cervicis.

The Muscular Branches (rami musculares) supply the Digastric, Stylo-hyoid, Splenius, and Tracheo-mastoid muscles.

The Sterno-mastoid (a. sternocleidomastoidea) is a large and constant branch, generally arising from the artery close to its commencement, but sometimes springing directly from the external carotid. It first passes downward and backward over the hypoglossal nerve, and enters the substance of the muscle in company with the accessory nerve.

The Auricular Branch (ramus auricularis) supplies the back part of the concha. It frequently gives off a branch, which enters the skull through the mastoid foramen and supplies the dura, the diploe, and the mastoid cells.

The Dural or Meningeal Branch (ramus meningeus) ascends with the internal jugular vein, and enters the skull through the foramen lacerum posterius, or through the anterior condylloid foramen, to supply the dura in the posterior fossa.

The Mastoid Branch (ramus mastoideus) is a small vessel, by no means constant. It passes into the skull through the mastoid foramen and is distributed upon the dura of the posterior fossa.

The Arteria Princeps Cervicis (ramus descendens), the largest branch of the occipital, descends along the back part of the neck and divides into a superficial and a deep portion. The former runs beneath the Splenius, giving off branches which perforate that muscle to supply the Trapezius, which anastomose with the superficial cervical artery; a branch of the Transversalis colli: the latter passes beneath the Complexus between it and the Semispinalis colli, and anastomoses with branches from the vertebral and with the deep cervical artery, a branch of either the superior intercostal or the subclavian. The anastomosis between these vessels serves mainly to establish the collateral circulation after ligation of the carotid or subclavian artery.

The cranial branches (rami occipitales) of the occipital artery are distributed upon the occiput; they are very tortuous, and lie between the integument and Occipito-frontalis, anastomosing with the artery of the opposite side, the posterior auricular and temporal arteries. They supply the back part of the Occipito-frontalis muscle, the integument, and pericranium.

The Posterior Auricular Artery (a. auricularis posterior) (Figs. 394, 395, and 396) is a small vessel which arises from the external carotid, above the Digastric and Stylo-hyoid muscles, opposite the apex of the styloid process. It ascends, under cover of the parotid gland, on the styloid process of the temporal bone, to the groove between the cartilage of the ear and the mastoid process, immediately above which it divides into its two terminal branches, the auricular and mastoid. Just before arriving at the mastoid process, this artery is crossed by the facial nerve, and has beneath it the accessory nerve.

Branches.—Besides several small branches to the Digastric, Stylo-hyoid, and Sterno-mastoid muscles and to the parotid gland, this vessel gives off three branches:


The Stylo-mastoid Branch (a. stylomastoideæ) enters the stylo-mastoid foramen, and supplies the tympanum, mastoid cells, and semicircular canals. In the young subject a branch from this vessel forms, with the tympanic branch from the internal maxillary, a vascular circle, which surrounds the membrana tympani, and from which delicate vessels ramify on that membrane. It anastomoses with
the petrosal branch of the medidural artery by a twig, which enters the hiatus Fallopian.

The **Auricular Branch** (*ramus auricularis*), one of the terminal branches, ascends behind the ear, beneath the Retrahens auriculam muscle, and is distributed to the back part of the cartilage of the ear, upon which it ramifies minutely, some branches curving round the margin of the fibro-cartilage, others perforating it, to supply its anterior surface. It anastomoses with the posterior branch of the superficial temporal and also with the anterior auricular branches.

The **Mastoid Branch** (*ramus mastoideus*) passes backward, over the Sternomastoid muscle, to the scalp above and behind the ear. It supplies the posterior belly of the Occipito-frontalis muscles and the scalp in this situation. It anastomoses with the occipital artery.

The **Ascending Pharyngeal Artery** (*a. pharyngea ascendens*) (Figs. 394 and 395), the smallest branch of the external carotid, is a long, slender vessel, deeply seated in the neck, beneath the other branches of the external carotid and the Stylopharyngeus muscle. It arises from the back part of the external carotid, near the commencement of that vessel, and ascends vertically between the internal carotid and the side of the pharynx, to the under surface of the base of the skull, lying on the Rectus capitis anticus major muscle.

**Branches.**—Its branches may be subdivided into four sets:


The **Prevertebral Branches** are numerus small vessels which supply the Recti capitis antici and Longus colli muscles, the sympathetic, hypoglossal, and vagus nerves, and the lymphatic glands. They anastomose with the ascending cervical artery.

The **Pharyngeal Branches** (*rami pharyngei*) are three or four in number. Two of these descend to supply the middle and inferior Constrictors and the Stylopharyngeus, ramifying in the substance of the muscles and in the submucous tissue of the mucous membrane lining them. The largest of the pharyngeal branches passes inward, running upon the Superior constrictor, and sends ramifications to the soft palate and tonsil, which take the place of the ascending palatine branch of the facial artery when that vessel is of small size. A twig from this branch supplies the Eustachian tube.

The **Typanic Branch** (*a. tympanica inferior*) is a small artery which passes through a minute foramen in the petrous portion of the temporal bone, in company with the tympanic branch of the Glossopharyngeal nerve to supply the inner wall of the tympanum and anastomose with the other tympanic arteries.

The **Dural or Meningeal Branches** consist of several small vessels, which pass through foramina in the base of the skull, to supply the dura. One, the postdural or posterior meningeal (*a. meningea posterior*), enters the cranium through the foramen lacerum posterius; a second passes through the foramen lacerum medium; and occasionally a third through the anterior condyloid foramen. They are all distributed to the dura.

**Surgical Anatomy.**—The ascending pharyngeal artery has been wounded from the throat, as in the case in which the stem of a tobacco-pipe was driven into the vessel, causing fatal hemorrhage. After removal of the tonsil there is sometimes severe bleeding. This is almost never due to wounding of the internal carotid artery, as the latter vessel, if normally placed, is too far away to be damaged. The bleeding comes from branches of the ascending pharyngeal, tonsillar, or ascending palatine arteries.

The **Superficial Temporal Artery** (*a. temporalis superficialis*) (Fig. 394, 395, and 396), the smaller of the two terminal branches of the external carotid, appears, from its direction, to be the continuation of that vessel. It commences in the substance of the parotid gland, in the interspace between the neck of the lower jaw and the
external auditory meatus, crosses over the posterior root of the zygoma, passes beneath the Attrahens auriculam muscle, lying on the temporal fascia, and divides, about two inches above the zygomatic arch, into two branches, an anterior and a posterior. This vessel is accompanied by the auriculo-temporal nerve.

The Anterior Temporal runs tortuously upward and forward to the forehead, supplying the muscles, integument, and pericranium in this region, and anastomoses with the supra-orbital and frontal arteries. The terminal portion of the anterior branch is called the frontal artery (ramus frontalis).

The Posterior Temporal, larger than the anterior, curves upward and backward along the side of the head, lying superficial to the temporal fascia, and inosculates with its fellow of the opposite side, and with the posterior auricular and occipital arteries. The terminal portion of the posterior branch is named the parietal artery (ramus parietalis).

The superficial temporal artery, as it crosses the zygoma, is covered by the Attrahens auriculam muscle, and by a dense fascia given off from the parotid gland: it is crossed by the temporo-facial division of the facial nerve and one or two veins, and is accompanied by the auriculo-temporal nerve, which lies behind it. Besides some twigs to the parotid gland, the articulation of the jaw, and the Masseter muscle.

Branches.—The branches of the superficial temporal artery are the—

- Transverse Facial.
- Middle Temporal.
- Orbital.
- Anterior Auricular.

The Transverse Facial Branch (a. transversa faciei) is given off from the temporal before that vessel quits the parotid gland; running forward through its substance, it passes transversely across the face, between Stenson’s duct and the lower border of the zygoma, and divides on the side of the face into numerous branches, which supply the parotid gland, the Masseter muscle, and the integument, anastomosing with the facial, masseteric, and infra-orbital arteries. This vessel rests on the Masseter, and is accompanied by one or two branches of the facial nerve. It is sometimes a branch of the external carotid.

The Middle Temporal Artery (a. temporalis media) arises immediately above the zygomatic arch, and, perforating the temporal fascia, gives branches to the Temporal muscle, anastomosing with the deep temporal branches of the internal maxillary. It occasionally gives off an orbital branch, which runs along the upper border of the zygoma, between the two layers of the temporal fascia, to the outer angle of the orbit. This branch, which may arise directly from the superficial temporal artery, supplies the Orbicularis palpebrarum, and anastomoses with the lachrymal and palpebral branches of the ophthalmic artery.

The Orbital Artery (a. zygomatico-orbitalis) comes off from the temporal just above the zygoma and is distributed to the upper orbital margin.

The Anterior Auricular Branches (rami auriculares anteriores) are distributed to the anterior portion of the pinna, the lobule, and part of the external meatus, anastomosing with branches of the posterior auricular.

Surgical Anatomy.—Formerly the operation of arteriotomy was performed upon this vessel in cases of inflammation of the eye or brain, but at the present time the operation is obsolete. If the student will consider the relations of the trunk of the vessels as it crosses the zygomatic arch, with the surrounding structures, he will observe that it is covered by a thick and dense fascia, crossed by one of the main divisions of the facial nerve and one or two veins, and accompanied by the auriculo-temporal nerve. The anterior branch, on the contrary, is subcutaneous, and is a large vessel.

The Internal Maxillary Artery (a. maxillaris interna) (Figs. 399 and 400), the larger of the two terminal branches of the external carotid, arises from that vessel opposite the neck of the condyle of the lower jaw, and is at first imbedded in the
substance of the parotid gland; it passes inward between the ramus of the jaw and the internal lateral ligament, and then upon the outer surface of the External pterygoid muscle to the sphenomaxillary fossa, to supply the deep structures of the face. For convenience of description it is divided into three portions: a **maxillary**, a **pterygoid**, and **sphenomaxillary**.

In the first part of its course, the **maxillary portion**, the artery passes horizontally forward and inward, between the ramus of the jaw and the internal lateral ligament. The artery here lies parallel to and a little below the auriculo-temporal nerve; it crosses the inferior dental nerve, and lies along the lower border of the External pterygoid muscle.

In the second part of its course, the **pterygoid portion**, it runs obliquely forward, and upward upon the outer surface of the External pterygoid muscle, being covered by the ramus of the lower jaw and lower part of the Temporal muscle; or it may pass on the inner surface of the External pterygoid muscle to reach the interval between its two heads, between which it passes to reach the sphenomaxillary fossa.

In the third part of its course, the **sphenomaxillary portion**, it approaches the superior maxillary bone, and enters the sphenomaxillary fossa in the interval between the two heads of the External pterygoid muscle, where it lies in relation with Meckel's ganglion, and gives off its terminal branches.

The branches of this vessel may be divided into three groups, corresponding with its three divisions.
Branches of the First or Maxillary Portion (Fig. 400):

- Anterior Tympanic.
- Deep Auricular.
- Medial or Middle Meningeal.
- Parvudural or Small Meningeal.
- Inferior Dental.

The Anterior Tympanic Branch \(a.\) tympanica anterior \) passes upward behind the articulation of the lower jaw, enters the tympanum through the Glaserian fissure, and ramifies upon the membra tymbani, forming a vascular circle around the membrane with the stylo-mastoid artery, and anastomosing with the Vidian and the tympanic branch from the internal carotid.

The Deep Auricular Branch \(a.\) auricularis profunda \) often arises in common with the preceding. It passes upward in the substance of the parotid gland, behind the temporo-massily branch articulation, pierces the cartilaginous or bony wall of the external auditory meatus, and supplies its cuticular lining and the outer surface of the membra tympani.

The Medial or Middle Meningeal Branch \(a.\) mediduralis, a. meningea media \) is the largest of the branches which supply the dura. It arises from the internal maxillary, between the internal lateral ligament and the neck of the jaw, and passes vertically upward between the two roots of the auriculo-temporal nerve to the foramen spinosum of the sphenoid bone. On entering the cranium it divides into two branches, anterior and posterior. The anterior branch, the larger, crosses the great ala of the sphenoid, and reaches the groove, or canal, in the anterior inferior angle of the parietal bone; it then divides into two branches which spread out between the dura and internal surface of the cranium, one passing upward over the parietal bone as far as the vertex, and sending rami backward to the occipital bone, the other passing front to the inner surface of the frontal bone. The posterior branch crosses the squamous portion of the temporal, and on the inner surface of the parietal bone divides into branches which supply the posterior part of the dura and cranium. The branches of this vessel are distributed partly to the dura, but chiefly to the bones; they anastomose with the arteries of the opposite side, and with the predural and postdural arteries.

The medidural on entering the cranium gives off the following collateral branches: 1. Numerous small vessels to the Gasserian ganglion, and to the dura in this situation. 2. A branch, the petrosal branch \(ramus\) petrosus superficialis \), which enters the hiatus Fallopi, supplies the facial nerve, and anastomoses with the stylo-massoid branch of the posterior auricular artery. 3. A minute superior tympanic branch \(a.\) tympanica superior \), which runs in the canal for the Tensor tympani muscle, and supplies this muscle and the lining membrane of the canal. 4. Orbital branches, which pass through the sphenoidal fissure, or through separate canals in the great wing of the sphenoid to anastomose with the lacrimal or other branches of the ophthalmic artery. 5. Temporal or anastomotic branches, which pass through the foramina in the great wing of the sphenoid bone and anastomose in the temporal fossa with the deep temporal arteries.

Surgical Anatomy.—The medidural is an artery of considerable surgical importance, as it may be injured in fractures of the temporal region of the skull. The vessel may be ruptured by traumatism, even though the skull escapes fracture. Rupture of the medidural artery will be followed by considerable hemorrhage between the bone and dura, which may cause compression of the brain and require the operation of trephining for its relief. This artery crosses the anterior inferior angle of the parietal bone at a point \(\frac{1}{2}\) inches behind the external angular process of the frontal bone, and \(\frac{3}{4}\) inches above the zygoma. From this point the anterior branch passes upward and slightly backward to the sagittal suture, lying about \(\frac{1}{2}\) inch to \(\frac{3}{4}\) inch behind the coronal suture. The posterior branch passes upward and backward over the squamous portion of the temporal bone. In order to expose the artery as it lies in the groove in the parietal bone, a semilunar incision, with its convexity upward, should be made, commencing an inch behind the external angular process, and carried backward for two inches. The struc-
tures cut through are: (1) skin; (2) superficial fascia, with branches of the superficial temporal vessels and nerves; (3) the fascia continued down from the aponeurosis of the Occipito-frontalis; (4) the two layers of the temporal fascia; (5) the temporal muscle; (6) the deep temporal vessels; (7) the pericranium. The bone is trephined, the clot removed, and the vessel secured by ligatures, suture ligatures, or gauze packing.

The Parvidural or Small Meningeal Branch (parviduralis, ramus meningaeus accessorius) is sometimes derived from the preceding, usually from the internal maxillary. It enters the skull through the foramen ovale, and supplies the Gasserian ganglion and dura.

The Mandibular, Inferior Alveolar or Inferior Dental Branch (a. alveolaris inferior) descends with the inferior dental nerve to the foramen on the inner side of the ramus of the jaw. It runs along the dental canal in the substance of the bone, accompanied by the nerve, and opposite the first bicuspid tooth divides into two branches, the incisor and mental; the incisor branch is continued forward beneath the incisor teeth as far as the symphysis, where it anastomoses with the artery of the opposite side; the mental branch (a. mentalis) escapes with the nerve at the mental foramen, supplies the structures composing the chin, and anastomoses with the submental, inferior labial and inferior coronary arteries. Near its origin the inferior dental artery gives off a lingual branch, which descends with the lingual (gustatory) nerve and supplies the mucous membrane of the mouth. As the inferior dental artery enters the foramen it gives off a mylo-hyoid branch (ramus mylohyoideus), which runs in the mylo-hyoid groove, and ramifies on the under surface of the Mylo-hyoid muscle. The dental and incisor arteries during their course through the substance of the bone give off a few twigs which are lost in the cancellous tissue, and a series of branches which correspond in number to the roots of the teeth: these enter the minute apertures at the extremities of the fangs and supply the pulp of the teeth.

Branches of the Second or Pterygoid Portion (Fig. 400):

Deep Temporal. Masseteric.
Pterygoid. Buccal.

These branches are distributed, as their names imply, to the muscles in the maxillary region.

The Deep Temporal Branches, two in number, anterior (a. temporalis profunda anterior) and posterior (a. temporalis profunda posterior), each occupy that part of the temporal fossa indicated by its name. Ascending between the Temporal muscle and pericranium, they supply that muscle and anastomose with the middle temporal artery. The anterior branch communicates with the lachrymal artery through small branches which perforate the malar bone and great wing of the sphenoid.

The Pterygoid Branches (rami pterygoidei), irregular in their number and origin, supply the Pterygoid muscles.

The Masseteric (a. masseterica) is a small branch which passes outward, above the sigmoid notch of the lower jaw, to the deep surface of the Masseter muscle. It supplies that muscle, and anastomoses with the masseteric branches of the facial and with the transverse facial artery.

The Buccal (a. buccinatória) is a small branch which runs obliquely forward between the Internal pterygoid and the ramus of the jaw, to the outer surface of the Buccinator, to which it is distributed, anastomosing with branches of the facial artery.

Branches of the Third or Spheno-maxillary Portion (Fig. 400):

Superior Alveolar or Alveolar. Vidian.
Infraorbital. Pterygo-palatine.
Descending or Posterior Palatine. Naso- or Spheno-palatine.
The **Superior Alveolar, Alveolar or Posterior Dental Branch** (a. alveolaris superior posterior) is given off from the internal maxillary by a common branch with the infraorbital, and just as the trunk of the vessel is passing into the sphenomaxillary fossa. Descending upon the tuberosity of the superior maxillary bone, it divides into numerous branches, some of which enter the posterior dental canals, to supply the upper molar and bicuspid teeth and the lining of the antrum, and others are continued forward on the alveolar process to supply the gums of the upper jaw.

The **Infraorbital** (a. infraorbitalis) appears, from its direction, to be the continuation of the trunk of the internal maxillary. It arises from that vessel by a common trunk with the preceding branch, and runs along the infra-orbital canal with the superior maxillary nerve, emerging upon the face at the infra-orbital foramen, beneath the Levator labii superioris muscle. Whilst contained in the canal, it gives off branches which ascend into the orbit, and assist in supplying the Inferior rectus and Inferior oblique muscles and the lachrymal gland. Other branches, **anterior dental** (aa. alveolares superiores anteriores), descend through the anterior dental canals in the bone, to supply the mucous membrane of the antrum and the front teeth of the upper jaw. On the face, some branches pass upward to the inner angle of the orbit and the lachrymal sac, anastomosing with the angular branch of the facial artery; other branches pass inward toward the nose, anastomosing with the nasal branch of the ophthalmic; and other branches descend beneath the Levator labii superioris muscle, and anastomose with the transverse facial and buccal arteries.

The four remaining branches arise from that portion of the internal maxillary which is contained in the sphenomaxillary fossa.

The **Descending or Posterior Palatine** (a. palatina descendens) descends through the posterior palatine canal with the anterior palatine branch of Meckel’s ganglion, and, emerging from the posterior palatine foramen, runs forward in a groove on the inner side of the alveolar border of the hard palate to the anterior palatine canal, where the terminal branch of the artery passes upward through the foramen of Stenson to anastomose with the naso-palatine artery. Its branches are distributed to the gums, the mucous membrane of the hard palate, and the palatine glands. Whilst it is contained in the palatine canal it gives off branches which descend in the accessory palatine canals to supply the soft palate and tonsil, anastomosing with the ascending palatine artery.

**Surgical Anatomy.**—The position of the descending palatine artery on the hard palate should be borne in mind in performing an operation for the closure of a cleft in the hard palate, as the vessel is in danger of being wounded, and may give rise to formidable hemorrhage. In case it should be wounded it may be necessary to plug the posterior palatine canal in order to arrest the bleeding. This artery may bleed furiously in the operation of resection of the upper jaw.

The **Vidian Branch** (a. canalis pterygoidei) passes backward along the Vidian canal with the Vidian nerve. It is distributed to the upper part of the pharynx and Eustachian tube, sending a small branch into the tympanum, which anastomoses with the other tympanic arteries.

The **Pterygo-palatine** is a very small branch, which passes backward through the pterygo-palatine canal with the pharyngeal nerve, and is distributed to the upper part of the pharynx and Eustachian tube.

The **Naso- or Spheno-palatine** (a. sphenopalatina) passes through the sphenopalatine foramen into the cavity of the nose, at the back part of the superior meatus, and divides into two branches: one **internal**, the naso-palatine or artery of the septum, passes obliquely downward and forward along the septum nasi, supplies the mucous membrane, and anastomoses in front with the terminal branch of the descending palatine and the inferior artery of the septum, which is a branch of the superior coronary. The **external branches**, two or three in number, supply
the mucous membrane covering the lateral wall of the nose, the antrum, and the ethmoid and sphenoid cells.

**Surgical Anatomy of the Triangles of the Neck**

(Fig. 269).

The student having considered the relative anatomy of the large arteries of the neck and their branches, and the relations they bear to the veins and nerves, should now examine these structures collectively, as they present themselves in certain regions of the neck, in each of which important operations are constantly being performed.

The side of the neck presents a somewhat quadrilateral outline, limited, above, by the lower border of the body of the jaw, and an imaginary line extending from the angle of the jaw to the mastoid process; below, by the prominent upper border of the clavicle; in front, by the median line of the neck; behind, by the anterior margin of the Trapezius muscle. This space is subdivided into two large triangles by the Sterno-mastoid muscle, which passes obliquely across the neck, from the sternum and clavicle below to the mastoid process above. The triangular space in front of this muscle is called the anterior triangle; and that behind it, the posterior triangle.

**Anterior Triangle of the Neck.**—The anterior triangle is bounded in front, by an imaginary line extending from the chin to the sternum; behind, by the anterior margin of the Sterno-mastoid; its base, directed upward, is formed by the lower border of the body of the jaw and an imaginary line extending from the angle of the jaw to the mastoid process; its apex is below, at the sternum. This space is subdivided into three smaller triangles by the Digastric muscle above and the anterior belly of the Omo-hyoid below. These smaller triangles are named, from below upward, the inferior carotid, the superior carotid, and the submaxillary triangle.

The Inferior Carotid Triangle or the Triangle of Necessity is bounded, in front, by the median line of the neck; behind, by the anterior margin of the Sterno-mastoid; above, by the anterior belly of the Omo-hyoid; and is covered by the integument, superficial fascia, Platysma, and deep fascia, ramifying between which are some of the descending branches of the superficial cervical plexus. Beneath these superficial structures are the Sterno-hyoid and Sterno-thyroid muscles, which, together with the anterior margin of the Sterno-mastoid, conceal the lower part of the common carotid artery. The floor of this triangle is formed by the Longus colli muscle below and by the Scalenus anticus muscle above, between which muscles the vertebral artery and vein will be found passing into the foramen of the transverse process of the sixth cervical vertebra. A small portion of the origin of the Rectus capitis anticus major may also be seen on the floor of the space.

The common carotid artery is enclosed within its sheath, together with the internal jugular vein and vagus nerve; the vein lying on the outer side of the artery on the right side of the neck, but overlapping it below on the left side; the nerve lying between the artery and vein, on a plane posterior to both. In front of the sheath are a few filaments descending from the loop of communication between the Descendens and communicans hypoglossi; behind the sheath are seen the inferior thyroid artery, the recurrent laryngeal nerve, and the sympathetic nerve; and on its inner side, the trachea, the thyroid gland—much more prominent in the female than in the male—and the lower part of the larynx. By cutting into the upper part of this space and slightly displacing the Sterno-mastoid muscle the common carotid artery may be tied below the Omo-hyoid muscle.

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1 Thereupon the common carotid artery and internal jugular vein are not, strictly speaking, contained in this triangle, since they are covered by the Sterno-mastoid muscle; that is to say, lie behind the anterior border of that muscle, which forms the posterior border of the triangle. But, as they lie very close to the structures which are really contained in the triangle, and whose position it is essential to remember in operating on this part of the artery, it has seemed expedient to study the relations of all these parts together.—Ed. of 15th English edition.
The **Superior Carotid Triangle** or the **Triangle of Election** is bounded, *behind*, by the Sterno-mastoid; *below*, by the anterior belly of the Omo-hyoid; and *above*, by the posterior belly of the Digastric muscle. It is covered by the integument, superficial fascia, Platysma, and deep fascia, ramifying between which are branches of the facial and superficial cervical nerves. Its floor is formed by parts of the Thyro-hyoid and Hyo-glossus muscles, and the Inferior and Middle constrictor muscles of the pharynx. This space, when dissected, is seen to contain the upper part of the common carotid artery, which bifurcates opposite the upper border of the thyroid cartilage into the external and internal carotid. These vessels are occasionally somewhat concealed from view by the anterior margin of the Sterno-mastoid muscle, which overlaps them. The external and internal carotid lie side by side, the external being the more anterior of the two. The following branches of the external carotid are also met with in this space: the superior thyroid, running forward and downward; the lingual, directly forward; the facial, forward and upward; the occipital, backward; and the ascending pharyngeal directly upward on the inner side of the internal carotid. The veins met with are: the internal jugular, which lies on the outer side of the common and internal carotid arteries, and veins corresponding to the above-mentioned branches of the external carotid—viz., the superior thyroid, the lingual, facial, ascending pharyngeal, and sometimes the occipital, all of which accompany their corresponding arteries and terminate in the internal jugular. The nerves in this space are the following: In front of the sheath of the common carotid is the descendens hypoglossi. The hypoglossal nerve crosses both the internal and external carotids above, curving round the occipital artery at its origin. Within the sheath, between the artery and vein, and behind both, is the vagus nerve; behind the sheath, the sympathetic. On the outer side of the vessels the accessory nerve runs for a short distance before it pierces the Sterno-mastoid muscle; and on the inner side of the external carotid, just below the hyoid bone, may be seen the internal laryngeal nerve; and, still more inferiorly, the external laryngeal nerve. The upper part of the larynx and lower part of the pharynx are also found in the front part of this space.

The **Submaxilllary Triangle** corresponds to the part of the neck immediately beneath the body of the jaw. It is bounded, *above*, by the lower border of the body of the jaw and a line drawn from its angle to the mastoid process; *below*, by the posterior belly of the Digastric muscle and the Stylo-hyoid muscle; in *front*, by the anterior belly of the Digastric. It is covered by the integument, superficial fascia, Platysma, and deep fascia, ramifying between which are branches of the facial and ascending filaments of the superficial cervical nerves. Its floor is formed by the Mylo-hyoid and Hyo-glossus muscles. This space contains, in *front*, the sub-maxillary gland, superficial to which is the facial vein, while imbedded in it are the facial artery and its glandular branches; beneath this gland, on the surface of the Mylo-hyoid muscle, are the submental artery and the mylo-hyoid artery and nerve. The posterior part of this triangle is separated from the anterior part by the stylo-maxillary ligament: it contains the external carotid artery, ascending deeply in the substance of the parotid gland: this vessel here lies in front of, and superficial to, the internal carotid, being crossed by the facial nerve, and gives off in its course the posterior auricular, temporal, and internal maxillary branches: more deeply are the internal carotid artery, the internal jugular vein, and the vagus nerve, separated from the external carotid by the Stylo-glossus and Stylo-pharyngeus muscles and the glosso-pharyngeal nerve.  

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1 The same remark will apply to this triangle as was made about the inferior carotid triangle. The structures enumerated as contained in the back part of the space lie, strictly speaking, beneath the muscles which form the posterior boundary of the triangle; but as it is very important to bear in mind their close relation to the parotid gland and its boundaries (on account of the frequency of surgical operations on this gland), all these parts are spoken of together.—Ed. of 15th English edition.
**Posterior Triangle of the Neck.**—The posterior triangle is bounded, in *front*, by the Sterno-mastoid muscle; *behind*, by the anterior margin of the Trapezius; its *base* corresponds to the middle third of the clavicle; its *apex*, to the occiput. The space is crossed, about an inch above the clavicle, by the posterior belly of the Omo-hyoid, which divides it unequally into two, an *upper* or occipital and a *lower* or subclavian triangle.

The *Occipital Triangle*, the larger division of the posterior triangle, is bounded, in *front*, by the Sterno-mastoid; *behind*, by the Trapezius; *below*, by the Omo-hyoid. Its floor is formed from above downward by the Splenius, Levator anguli scapulae, and the Middle and Posterior scaleni muscles. It is covered by the integument, the Platysma below, the superficial and deep fascia; the accessory nerve is directed obliquely across the space from the Sterno-mastoid, which it pierces, to the under surface of the Trapezius; below, the descending branches of the cervical plexus and the transversalis colli artery and vein cross the space. A chain of lymphatic glands is also found running along the posterior border of the Sterno-mastoid, from the mastoid process to the root of the neck.

The *Subclavian Triangle*, the smaller of the two posterior triangles, is bounded, *above*, by the posterior belly of the Omo-hyoid; *below*, by the clavicle, its base, directed forward, being formed by the Sterno-mastoid. The size of the subclavian triangle varies according to the extent of attachment of the clavicular portion of the Sterno-mastoid and Trapezius muscles, and also according to the height at which the Omo-hyoid crosses the neck above the clavicle. Its height also varies much according to the position of the arm, being much diminished by raising the limb, on account of the ascent of the clavicle, and increased by drawing the arm downward, when that bone is depressed. This space is covered by the integument, the Platysma, the superficial and deep fascia, and crossed by the descending branches of the cervical plexus. Just above the level of the clavicle the third portion of the subclavian artery curves outward and downward from the outer margin of the Scalenum anticus, across the first rib, to the axilla. Sometimes this vessel rises as high as an inch and a half above the clavicle, or to any point intermediate between this and its usual level. Occasionally it passes in front of the Scalenum anticus or pierces the fibres of that muscle. The subclavian vein lies behind the clavicle, and is usually not seen in this space; but it occasionally rises as high up as the artery, and has even been seen to pass with that vessel behind the Scalenum anticus. The brachial plexus of nerves lies above the artery, and in close contact with it. Passing transversely behind the clavicle are the suprascapular vessels, and traversing its upper angle in the same direction, the transversalis colli artery and vein. The external jugular vein runs vertically downward behind the posterior border of the Sterno-mastoid muscle, to terminate in the subclavian vein; it receives the transverse cervical and suprascapular veins, which occasionally form a plexus in front of the artery, and a small vein which crosses the clavicle from the cephalic. The small nerve to the Subclavius muscle also crosses this triangle about its middle. A lymphatic gland is also found in the space. Its floor is formed by the first rib with the first digitation of the Serratus magnus.

**The Internal Carotid Artery (A. Carotis Interna).**

The internal carotid artery supplies the anterior part of the brain, the eye, and its appendages, and sends branches to the forehead and nose. Its size in the adult is equal to that of the external carotid, though in the child it is larger than that vessel. It is remarkable for the number of curvatures that it presents in different parts of its course. It occasionally has one or two flexures near the base of the skull, whilst in its passage through the carotid canal and along the side of the body of the sphenoid bone it describes a double curve which resembles somewhat the letter S placed horizontally. These curvatures most
probably diminish the velocity of the current of blood, by increasing the extent of surface over which it moves and adding to the impediment produced from friction.

In considering the course and relations of this vessel it may be conveniently divided into four portions: the **cervical**, **petrous**, **cavernous**, and **cerebral portions**.

**Cervical Portion.**—This portion of the internal carotid commences at the bifurcation of the common carotid, opposite the upper border of the thyroid cartilage, and runs perpendicularly upward, in front of the transverse processes of the three upper cervical vertebrae, to the carotid canal in the petrous portion of the temporal bone. It is superficial at its commencement, being contained in the superior carotid triangle, and lying on the same level as the external carotid, but behind that artery overlapped by the Sterno-mastoid and covered by the deep
fascia, Platysma, and integument: it then passes beneath the parotid gland, being crossed by the hypoglossal nerve, the Digastric and Stylo-hyoid muscles, and the occipital and posterior auricular arteries. Higher up, it is separated from the external carotid by the Stylo-glossus and Stylo-pharyngeus muscles, the glosso-pharyngeal nerve, and pharyngeal branch of the vagus.

Relations.—It is in relation, behind, with the Rectus capitis anticus major, the superior cervical ganglion of the sympathetic, and superior laryngeal nerve; externally, with the internal jugular vein and vagus nerve, the nerve lying on a plane posterior to the artery; internally, with the pharynx, tonsil, the superior laryngeal nerve, and ascending pharyngeal artery. At the base of the skull the glossopharyngeal, vagus, accessory, and hypoglossal nerves lie between the artery and the internal jugular vein.

Plan of the Relations of the Internal Carotid Artery in the Neck.

In front.
Skin, superficial and deep fasciae.
Platysma.
Sterno-mastoid.
Occipital and posterior auricular arteries.
Hypoglossal nerve.
Parotid gland.
Stylo-glossus and Stylo-pharyngeus muscles.
Glosso-pharyngeal nerve.
Pharyngeal branch of the vagus.

Externally.
Internal jugular vein.
Vagus nerve.

Internally.
Pharynx.
Superior laryngeal nerve.
Ascending pharyngeal artery.
Tonsil.

Behind.
Rectus capitis anticus major.
Sympathetic.
Superior laryngeal nerve.

Petrous Portion.—When the internal carotid artery enters the canal in the petrous portion of the temporal bone, it first ascends a short distance, then curves forward and inward, and again ascends as it leaves the canal to enter the cavity of the skull between the lingula and petrosal process. In this canal the artery lies at first in front of the cochlea and tympanum; from the latter cavity it is separated by a thin, bony lamella, which is cribriform in the young subject, and is often absorbed in old age. Farther forward it is separated from the Gasserian ganglion by a thin plate of bone, which forms the floor of the fossa for the ganglion and the roof of the horizontal portion of the canal. Frequently this bony plate is more or less deficient, and then the ganglion is separated from the artery by a fibrous membrane. The artery is separated from the bony wall of the carotid canal by a prolongation of the dura, and is surrounded by a number of small veins and by filaments of the carotid plexus, derived from the ascending branch of the superior cervical ganglion of the sympathetic.

Cavernous Portion.—The internal carotid artery in this part of its course is situated between the layers of the dura forming the cavernous sinus, but is covered by the lining membrane of the sinus. It at first ascends to the posterior clinoid process, then passes forward by the side of the body of the sphenoid bone, and again curves upward on the inner side of the anterior clinoid process, and perforates the dura, forming the roof of the sinus. In this part of its course it is surrounded by filaments of the sympathetic nerve, and has in relation with it externally the abducent nerve.
Cerebral Portion.—Having perforated the dura, on the inner side of the anterior clinoid process, the internal carotid passes between the optic and oculomotor nerves to the preperforatum at the inner extremity of the fissure of Sylvius, where it gives off its terminal or cerebral branches. This portion of the artery has the optic nerve on its inner side, and the oculomotor nerve externally.

Peculiarities.—The length of the internal carotid varies according to the length of the neck, and also according to the point of bifurcation of the common carotid. Its origin sometimes takes place from the arch of the aorta; in such rare instances this vessel has been found to be placed nearer the middle line of the neck than the external carotid, as far upward as the larynx, when the latter vessel crossed the internal carotid. The course of the vessel, instead of being straight, may be very tortuous. A few instances are recorded in which this vessel was altogether absent: in one of these the common carotid passed up the neck, and gave off the usual branches of the external carotid, the cranial portion of the internal carotid being replaced by two branches of the internal maxillary, which entered the skull through the foramen rotundum and the foramen ovale and joined to form a single vessel.

Surgical Anatomy.—The cervical part of the internal carotid is very rarely wounded. Mr. Cripps, in an interesting paper in the Medico-Chirurgical Transactions, compares the rareness of a wound of the internal carotid with one of the external carotid or its branches. It is, however, sometimes injured by a stab or gunshot wound in the neck; or even occasionally by a stab from within the mouth, as when a person receives a thrust from the end of a parasol or falls down with a tobacco-pipe in his mouth. It used to be believed that the internal carotid was occasionally wounded in the removal of the tonsil. Such an accident cannot happen if the artery is normally placed. The severe and sometimes fatal hemorrhage which has followed this operation in a few instances probably had as its source enlarged branches of the ascending pharyngeal, tonsillar, or ascending palatine arteries. Recently, however, Dr. Gwylm G. Davis, of Philadelphia, demonstrated a specimen in which the internal carotid could have been wounded by incision of the tonsil. The indications for ligature are wounds, when the vessel should be exposed by a careful dissection and tied above and below the bleeding point; and aneurism, which if non-traumatic may be treated by ligature of the common carotid, but if traumatic in origin by exposing the sac and tying the vessel above and below. The incision for ligature of the cervical portion of the internal carotid should be made along the anterior border of the Sterno-mastoid, from the angle of the jaw to the upper border of the thyroid cartilage. The superficial structures being divided and the Sterno-mastoid defined and drawn outward, the cellular tissue must be carefully separated and the posterior belly of the Digastric muscle and the hypoglossal nerve sought for as guides to the vessel. When the artery is found the external carotid should be drawn inward and the Digastric muscles upward, and the aneurism needle passed from without inward.

Branches.—The branches given off from the internal carotid artery are:

From the Petrous portion . Tympanic (internal or deep).
   Arteriae Receptaculi.

From the Cavernous portion
   Predural, or Anterior Meningeal.
   Ophthalmic.
   Pre- and Postcerebral, or Anterior Cerebral.
   Medicerebral, or Middle Cerebral.
   Postcommunicant, or Posterior Communicating.
   Prechoroid, or Anterior Choroid.

The cervical portion of the internal carotid gives off no branches.

The Tympanic (ramus caroticotympanicus) is a small branch from the petrous portion, which enters the cavity of the tympanum through a minute foramen in the carotid canal, and anastomoses with the tympanic branch of the internal maxillary, and with the stylo-mastoid artery.

The Arteriae Receptaculi are numerous small vessels, derived from the internal carotid in the cavernous sinus; they supply the pituitary body, the Gasserian ganglion, and the walls of the cavernous and inferior petrosal sinuses. Some of these branches anastomose with branches of the medidural.

The Predural or Anterior Meningeal (a. praeduralis, a. meningea anterior) is a small branch which passes over the lesser wing of the sphenoid to supply the dura of the anterior fossa; it anastomoses with the dural branch from the posterior ethmoidal artery.
The Ophthalmic Artery (a. ophthalmica) arises from the internal carotid, just as that vessel is emerging from the cavernous sinus, on the inner side of the anterior clinoid process, and enters the orbit through the optic foramen, below and on the outer side of the optic nerve. It then passes over the nerve to the inner wall of the orbit, and thence horizontally forward, beneath the lower border of the Superior oblique muscle, to a point behind the internal angular process of the frontal bone, where it divides into two terminal branches, the frontal and nasal branches. As the artery crosses the optic nerve it is accompanied by the nasal nerve, and is separated from the frontal nerve by the Rectus superior and Levator palpebræ superioris muscles.

Branches.—The branches of this vessel may be divided into an orbital group, which are distributed to the orbit and surrounding parts, and an ocular group, which supply the muscles and globe of the eye:

**Orbital Group.**
- Lachrymal.
- Supraorbital.
- Posterior Ethmoidal.
- Anterior Ethmoidal.
- Internal Palpebral.
- Frontal.
- Nasal.

**Ocular Group.**
- Short Ciliary.
- Long Ciliary.
- Anterior Ciliary.
- Arteria Centralis Retinæ.
- Muscular.

The Lachrymal (a. lachrimalis) is one of the largest branches derived from the ophthalmic, arising close to the optic foramen; not infrequently it is given off from the ophthalmic artery before it enters the orbit. It accompanies the lachrymal nerve along the upper border of the External rectus muscle, and is distributed to the
lachrymal gland. Its terminal branches, escaping from the gland, are distributed to the eyelids and conjunctiva; of those supplying the eyelids, two are of considerable size and are named the external palpebral; they run inward in the upper and lower lids respectively, and anastomose with the internal palpebral arteries, forming an arterial circle in this situation. The lachrymal artery gives off one or two malar branches, one of which passes through a foramen in the malar bone, to reach the temporal fossa, and anastomoses with the deep temporal arteries; the other appears on the cheek through the malar foramen, and anastomoses with the transverse facial. A branch, the recurrent, is also sent backward through the sphenoidal fissure to the dura, which anastomoses with a branch of the medidural artery.

Peculiarities.—The lachrymal artery is sometimes derived from one of the anterior branches of the medidural artery.

The Supraorbital Artery (a. supraorbitalis) arises from the ophthalmic as that vessel is crossing over the optic nerve. Ascending so as to arise above all the muscles of the orbit, it passes forward, with the supraorbital nerve, between the peristeum and Levator palpebræ muscle; and, passing through the supraorbital foramen, divides into a superficial and deep branch, which supply the integument, the muscles, and the pericranium of the forehead, anastomosing with the frontal, the anterior branch of the temporal, and the supraorbital artery of the opposite side. This artery in the orbit supplies the Superior rectus and the Levator palpebræ muscles, and sends a branch inward, across the pulley of the Superior oblique muscle, to supply the parts at the inner canthus. At the supraorbital foramen it frequently transmits a branch to the dipoë.

The Ethmoidal Branches are two in number—posterior (a. ethmoidalis posterior) and anterior (a. ethmoidalis anterior). The former, which is the smaller, passes through the posterior ethmoidal foramen, supplies the posterior ethmoidal cells, and, entering the cranium, gives off a dural or meningeal branch, which supplies the adjacent dura; and nasal branches which descend into the nose through apertures in the cribiform plate, anastomosing with branches of the spheno-palatine. The anterior ethmoidal artery accompanies the nasal nerve through the anterior ethmoidal foramen, supplies the anterior ethmoidal cells and frontal sinuses, and, entering the cranium, gives off a dural branch which supplies the adjacent dura; and nasal branches, which descend into the nose, through the slit by the side of the crista galli, and, running along the groove on the under surface of the nasal bone, supply the skin of the nose.

The Internal Palpebral Arteries (aa. palpebrales mediales), two in number, superior and inferior, arise from the ophthalmic, opposite the pulley of the Superior oblique muscle; they leave the orbit to encircle the eyelids near their free margin, forming a superior tarsal arch (arcus tarseus superior) and an inferior tarsal arch (arcus tarseus inferior), which lie between the Orbicularis muscle and the tarsal plates; the superior palpebral inosculating at the outer angle of the orbit with the orbital branch of the temporal artery, and with the upper of the two external palpebral branches from the lachrymal artery—the inferior palpebral inosculating at the outer angle of the orbit, with the lower of the two external palpebral branches from the lachrymal and with the transverse facial artery, and at the inner side of the lid with a branch from the angular artery. From this last anastomosis a branch passes to the nasal duct, ramifying in its mucous membrane, as far as the inferior meatus.

The Frontal Artery (a. frontalis), one of the terminal branches of the ophthalmic, passes from the orbit at its inner angle, and, ascending on the forehead, supplies the integument, muscles, and pericranium, anastomosing with the supraorbital artery and with the frontal artery of the opposite side.
The Nasal Artery (a. dorsalis nasi), the other terminal branch of the ophthalmic, emerges from the orbit above the tendo oculi, and, after giving a branch to the upper part of the lacrimal sac, divides into two branches, one of which crosses the root of the nose, the transverse nasal, and anastomoses with the angular artery; the other, the dorsalis nasi, runs along the dorsum of the nose, supplies its outer surface, and anastomoses with the artery of the opposite side and with the lateral nasal branch of the facial.

Fig. 403.—The arteries of the base of the brain. The right half of the cerebellum and pons have been removed. N.B.—It will be noticed that the two precerebral arteries have been drawn at a considerable distance from each other; this makes the precommunicant artery appear very much longer than it really is.
The Ciliary Arteries (a. ciliares) are divisible into three groups, the short, long, and anterior. The short ciliary arteries (aa. ciliaris posteriores breves), from six to twelve in number, arise from the ophthalmic or some of its branches; they surround the optic nerve as they pass forward to the posterior part of the eyeball, pierce the sclerotic coat around the entrance of the nerve, and supply the choroid coat and ciliary processes. The long ciliary arteries (aa. ciliaris posteriores longae), two in number, pierce the posterior part of the sclerotic at some little distance from the optic nerve, and run forward, along each side of the eyeball, between the sclerotic and choroid, to the ciliary muscle, where they divide into two branches; these form an arterial circle, the circulus major, around the circumference of the iris, from which numerous radiating branches pass forward, in its substance, to its free margin, where they form a second arterial circle, the circulus minor, around its pupillary margin. The anterior ciliary arteries (aa. ciliaris anteriores) are derived from the muscular branches; they pass to the front of the eyeball in company with the tendons of the Recti muscles, form a vascular zone beneath the conjunctiva, and then pierces the sclerotic a short distance from the cornea and terminate in the circulus major of the iris.

The Arteria Centralis Retinae is the first and one of the smallest branches of the ophthalmic artery. It runs for a short distance within the dural sheath of the optic nerve, but about half an inch behind the eyeball it pierces the optic nerve obliquely, and runs forward in the centre of its substance, and enters the globe of the eye through the porus opticus. Its mode of distribution will be described in the account of the anatomy of the eye.

The Muscular Branches (rami musculares), two in number, superior and inferior, frequently spring from a common trunk. The superior, the smaller, often wanting,
supplies the Levator palpebræ, Superior rectus, and Superior oblique. The inferior, more constant in its existence, passes forward between the optic nerve and the Inferior rectus muscle, and is distributed to the External, Internal, and Inferior recti, and Inferior oblique. This vessel gives off most of the ciliary arteries. Additional muscular branches are given off from the lachrymal and supraorbital arteries or from the ophthalmic itself. (For the Circulus or Circle of Willis, the postcerebral artery, and the blood-vessels of the cerebellum, see page 642.)

The Precerebral or Anterior Cerebral (a. praecerebralis, a. cerebri anterior) arises from the internal carotid at the inner extremity of the fissure of Sylvius. It passes forward and inward across the preperforatum, above the optic nerve, to the commencement of the intercerebral fissure. Here it comes into close relationship with the precerebral artery of the opposite side, and the two vessels are connected together by a short anastomosing trunk, about two lines in length, the precommunicant or anterior communicating artery. From this point the two vessels run side by side in the intercerebral fissure, curve round the genu of the callosum, and, turning backward, continue along its upper surface to its posterior part, where they terminate by anastomosing with the postcerebral arteries.

Branches.—In their course the precerebral arteries give off the following branches:

- Antero-median ganglionic.
- Anterior internal frontal.
- Inferior internal frontal.
- Middle internal frontal.
- Posterior internal frontal.

The Antero-median Ganglionic is a group of small arteries which arise at the commencement of the precerebral artery; they pierce the preperforatum and terma, and supply the head of the caudatum.

The Inferior Internal Frontal Branches or the Internal Orbital Arteries, two or three in number, are distributed to the orbital surface of the frontal lobe, where they supply the olfactory lobe, gyrus rectus, and internal orbital convolution.

The Anterior Internal Frontal supplies a part of the marginal convolution, and sends branches over the edge of the hemisphere to the superfrontal and medifrontal gyre and upper part of the precentral gyre.
The Middle Internal Frontal supplies the callosum, the callosal gyr, the mesial surface of the superfrontal convolution, and the dorsal part of the precentral gyr.

The Posterior Internal Frontal supplies the quadrate lobe and adjacent outer surface of the hemisphere.

The Precommunicant or Anterior Communicating Artery (a. praecommunicans, a. communicans anterior) is a short branch, about two lines in length, but of moderate diameter, connecting together the two precerebral arteries across the intercerebral fissure. Sometimes this vessel is wanting, the two arteries joining together to form a single trunk, which afterward divides. Or the vessel may be wholly or partially divided into two; frequently it is longer and smaller than usual. It gives off some of the antero-median ganglionic group of vessels, which are, however, principally derived from the precerebral.

The Medicerebral or Middle Cerebral Artery (a. medicerebralis, a. cerebri media) (Fig. 407), the largest branch of the internal carotid, passes obliquely outward along the fissure of Sylvius, and opposite the island of Reil divides into temporal and parieto-temporal terminal branches.

**Branches.**—The branches of the medicerebral artery are—

- Antero-lateral ganglionic.
- Inferior external frontal.
- Parieto-temporal.
- Ascending frontal.
- Ascending parietal.

The Antero-lateral Ganglionic Branches are a group of small arteries which arise at the commencement of the medicerebral artery; they pierce the preperforatum and supply the greater part of the caudatum, the lenticular nucleus, the internal...
capsule, and a part of the optic thalamus. One artery of this group (one of the lenticulo-striate arteries) is of larger size than the rest, and is of special importance, as being the artery in the brain most frequently ruptured; it has been termed by Charcot the artery of cerebral hemorrhage. It passes up between the lenticular nucleus and the external capsule, and ultimately ends in the caudatum.

The Inferior External Frontal supplies the third or subfrontal convolution (Broca's convolution) and the outer part of the orbital surface of the frontal lobe.

The Ascending Frontal supplies the precentral gyre.

The Ascending Parietal supplies the ascending parietal convolution and the lower part of the superior parietal convolution.

The Parieto-temporal or Parieto-sphenoidal supplies the supramarginal, the supertemporal, and part of the meditemporal gyre, and the angular gyrus.

The Postcommunicant or Posterior Communicating Artery (a. postcommunicans, a. communicates posterior) arises from the back part of the internal carotid, runs directly backward, and anastomoses with the postcerebral, a branch of the basilar. This artery varies considerably in size, being sometimes small, and occasionally so large that the postcerebral may be considered as arising from the internal carotid rather than from the basilar. It is frequently larger on one side than on the other side. From the posterior half of this vessel are given off a number of small branches, the postero-median ganglionic branches, which, with similar vessels from the postcerebral, pierce the postperforatum and supply the internal surfaces of the optic thalami and the walls of the third ventricle.

The Prechoroid or Anterior Choroid (a. prechoroidea, a. chorioidea) is a small but constant branch which arises from the back part of the internal carotid, near the postcommunicant artery. Passing backward and outward between the temporal lobe and the crus, it enters the medicornu of the lateral ventricle through the choroid fissure and ends in the paraplexus. It is distributed to the hippocampus, fimbria, velum, and paraplexus.

**THE BLOOD-VESSELS OF THE BRAIN.**

Recent investigations have tended to show that the mode of distribution of the vessels of the brain has an important bearing upon a considerable number of
the anatomical lesions of which this part of the nervous system may be the seat; it therefore becomes important to consider a little more in detail the way in which the cerebral vessels are distributed.

The cerebral arteries are derived from the internal carotid and the vertebral, which at the base of the brain form a remarkable anastomosis known as the circulus or circle of Willis (see page 642). The tortuosity of the constituent vessels of the anastomosis lessens the impact of the circulation and saves the brain from damage. The outline of the vessels forming the so-called circle is said by Sappey to be hexagonal, and by Testut to be heptagonal. The circulus is formed in front by the precerebral arteries, branches of the internal carotid, which are connected together by the precommunicant; behind by the two postcerebrals, branches of the basilar, which are connected on each side to the internal carotid by the postcommunicant (Fig. 403). The parts of the brain included within this arterial circle are the terma, the chiasm or commissure of the optic nerves, the tuber, the albi-

cantia, and the postperforatum. This arrangement of the vessels of the circulus is not invariable; according to Windle it is maintained in little more than half the recorded cases. In the other cases there are various anomalies.

From the circulus arise the three trunks which together supply each cerebral hemisphere. From its anterior part proceed the two precerebrials, from its anterolateral part the medicerebrai, and from its posterior part the postcerebrai. Each of these principal arteries gives origin to two very different systems of secondary vessels. One of these systems has been named the central ganglionic system, and the vessels belonging to it supply the central ganglia of the brain; the other has been named the cortical arterial system, and its vessels ramify in the pia and supply the cortex and subjacent medullary matter. These two systems, although they have a common origin, do not communicate at any point of their peripheral distribution, and are entirely independent of each other. Though some of the arteries of the cortical system approach, at their terminations, the regions

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**Fig. 408.**—Diagram of the arterial circulation at the base of the brain. I. Antero-median group of ganglionic branches. II. Postero-median group. III. Right and left antero-lateral group. IV. Right and left postero-lateral group. The dotted line shows the limit of the ganglionic circle. (After Charcot.)
supplied by the central ganglionic system, no communication between the two sets of vessels takes place, and there is between the parts supplied by the two systems a borderland of diminished nutritive activity. In the brains of old people softening is especially apt to occur in this ill-nourished territory.

The Central Ganglionic System.—All the vessels belonging to this system are given off from the circulus or from the vessels immediately after their origin from it, so that if a circle is drawn at a distance of about an inch from the circulus, it will include the origin of all the arteries belonging to this system (Fig. 408). The vessels of this system form six principal groups: (I.) the antero-median group, derived from the precerebrals and precommunicans; (II.) the postero-median group, from the postcerebrals and postcommunicans; (III.) the right and left anterolateral group, from the medicerebrals; and (IV.) the right and left postero-lateral group, from the postcerebrals, after they have wound round the crura. The vessels belonging to this system are larger than those of the cortical system, and are what Cohnheim has termed terminal arteries; that is to say, vessels which from their origin to their termination neither supply nor receive any anastomotic branches, so that by one of the small vessels only a limited area of the central ganglia can be injected; and the injection cannot be driven beyond the area of the part supplied by the particular vessel which is the subject of the experiment.

The Cortical Arterial System.—The vessels forming this system are the terminal branches of the pre-, medi-, and postcerebral arteries, described above. These vessels divide and ramify in the substance of the pia, and give off nutrient arteries which penetrate the cortex perpendicularly. These nutrient vessels are divisible into two classes—the long and short. The long—or, as they are sometimes called, the medullary—arteries pass through the gray matter to penetrate the centrum ovale to the depth of about an inch and a half, without intercommunicating otherwise than by very fine capillaries, and thus constitute so many

![Diagram of Distribution of the cortical arteries](image-url)
independent small systems. The short vessels are confined to the cortex, where they form with the long vessels a compact network in the middle zone of the gray matter, the outer and inner zones being sparingly supplied with blood (Fig. 409). The vessels of the cortical arterial system are not so strictly terminal as those of the central ganglionic system, but they approach this type very closely, so that injection of one area from the vessel of another area, though it may be possible, is frequently very difficult, and is only effected through vessels of small calibre. As a result of this, obstruction of one of the main branches or its divisions may have the effect of producing softening in a very limited area of the cortex.  

ARTERIES OF THE UPPER EXTREMITY.

The artery which supplies the upper extremity continues as a single trunk from its commencement down to the elbow, but different portions of it have received different names according to the region through which it passes. That part of the vessel which extends from its origin to the outer border of the first rib is termed the subclavian artery; beyond this point to the lower border of the axilla-it is termed the axillary artery; and from the lower margin of the axillary space to the bend of the elbow it is termed the brachial artery; here the single trunk terminates by dividing into two branches, the radial and ulnar—an arrangement precisely similar to what occurs in the lower limb.

THE SUBCLAVIAN ARTERY (A. SUBCLAVIA) (Fig. 410).

The subclavian artery on the right side arises from the innominate artery opposite the right sterno-clavicular articulation; on the left side it arises from the arch of the aorta. It follows, therefore, that these two vessels must, in the first part of their course, differ in their length, their direction, and their relation with neighboring parts.

In order to facilitate the description of these vessels, more especially from a surgical point of view, each subclavian artery has been divided into three parts. The first portion, on the right side, passes upward and outward from the origin of the vessel to the inner border of the Scalenus anticus. On the left side it ascends nearly vertically, to gain the inner border of that muscle. The second part passes outward, behind the Scalenus anticus; and the third part passes from the outer margin of that muscle, beneath the clavicle, to the outer border of the first rib, where it becomes the axillary artery. The first portion of these two vessels differs so much in its course and in its relations with neighboring parts that it will be described separately. The second and third parts are alike on the two sides.

First Part of the Right Subclavian Artery (Figs. 389, 390, 394, 410).

On the right side the subclavian artery arises from the arteria innominata, opposite the upper part of the right sterno-clavicular articulation, and passes upward and outward to the inner margin of the Scalenus anticus muscle (Figs. 389, 390, and 410). In this part of its course it ascends a little above the clavicle, the extent to which it does so varying in different cases.

Relations.—It is covered, in front, by the integument, superficial fascia, Platysma, deep fascia, the clavicular origin of the Sterno-mastoid, the Sterno-hyoid, and the Sterno-thyroid muscles, and a second layer of deep fascia. It is crossed by the internal jugular and vertebral veins, and by the vagus nerve and the

1 The student who desires further information on this subject is referred to Charcot's Localization of Cerebral and Spinal Diseases, p. 42 et seq., whence the facts above given have been principally derived.—Ed. of 15th English edition.
cardiac branches of the sympathetic nerve. A loop of the sympathetic nerve itself also crosses the artery, forming a ring around the vessels. The anterior jugular vein passes outward in front of the artery but is not in contact with it, being separated from it by the Sterno-hyoid and Sterno-thyroid muscles. Below and behind the artery is the pleura, which separates it from the apex of the lung; behind is the cord of the sympathetic nerve; the recurrent laryngeal nerve winds round the lower and back part of the vessel.

Fig. 410.—The subclavian artery, showing its relations. (From a preparation in the Museum of the Royal College of Surgeons of England.)

PLAN OF THE RELATIONS OF FIRST PORTION OF THE RIGHT SUBCLAVIAN ARTERY.

**In front.**

- Skin, superficial fascia.
- Platysma, deep fascia.
- Clavicular origin of Sterno-mastoid.
- Sterno-hyoid and Sterno-thyroid.
- Anterior jugular, Internal jugular, and vertebral veins.
- Vagus and cardiac nerves.
- Loop from the sympathetic.

**Beneath.**

- Pleura.
- Recurrent laryngeal nerve.
Behind.
   Recurrent laryngeal nerve.
   Sympathetic.
   Pleura and apex of lung.

First Part of the Left Subclavian Artery (Figs. 388, 389).

The left subclavian artery arises from the end of the arch of the aorta, opposite the fourth thoracic vertebra, and ascends nearly vertically to the inner margin of the Scalenus anticus muscle. This part of the vessel is, therefore, longer than the right, is situated deeply in the cavity of the chest, and is directed nearly vertically upward, instead of arching outward like the vessel of the opposite side.

Relations.—It is in relation, in front, with the vagus, cardiac, and phrenic nerves, which lie parallel with it, the left carotid artery, left internal jugular and vertebral veins, and the commencement of the left innominate vein and is covered by the Sterno-thyroid, Sterno-hyoid, and Sterno-mastoid muscles; behind, it is in relation with the oesophagus, thoracic duct, inferior cervical ganglion of the sympathetic, and Longus colli muscle; higher up, however, the oesophagus and thoracic duct lie to its right side; the latter ultimately arching over the vessel to join the angle of union between the subclavian and internal jugular veins. To its inner side are the oesophagus, trachea, and thoracic duct; to its outer side, the left pleura and lung.

Plan of the Relations of First Portion of the Left Subclavian Artery.

In front.
   Vagus, cardiac, and phrenic nerves.
   Left carotid artery.
   Thoracic duct.
   Left internal jugular, vertebral, and innominate veins.
   Sterno-thyroid, Sterno-hyoid, and Sterno-mastoid muscles.

Inner side.
   Trachea.
   Oesophagus.
   Thoracic duct.

Left Subclavian Artery

Outer side.
   Pleura and left lung.

Behind.
   Oesophagus and thoracic duct.
   Inferior cervical ganglion of sympathetic.
   Longus colli.

Second and Third Parts of the Subclavian Artery (Figs. 392, 410).

The Second Portion of the Subclavian Artery lies behind the Scalenus anticus muscle; it is very short, and forms the highest part of the arch described by that vessel.

Relations.—It is covered, in front, by the skin, superficial fascia, Platysma, deep cervical fascia, the Sterno-mastoid and the Scalenus anticus muscles. On the right side the phrenic nerve is separated from the second part of the artery by the Scalenus anticus muscle, while on the left side the nerve crosses the first part of the artery immediately to the inner edge of the muscle. Behind, it is in relation with the pleura and the Scalenus medius muscle. Above, with the brachial plexus of nerves. Below, with the pleura. The subclavian vein lies below and in front of the artery, separated from it by the Scalenus anticus muscle.
THE BLOOD- VASCULAR SYSTEM

Plan of the Relations of Second Portion of Subclavian Artery.

In front.
Skin and superficial fascia.
Platysma and deep cervical fascia.
Sterno-mastoid.
Phrenic nerve.
Scalenus anticus.
Subclavian vein.

Above.
Brachial plexus.

Below.
Pleura.

Behind.
Pleura and Middle Scalenus.

The Third Portion of the Subclavian Artery passes downward and outward from the outer margin of the Scalenus anticus muscle to the outer border of the first rib, where it becomes the axillary artery. This portion of the vessel is the most superficial, and is contained in the subclavian triangle (see page 620).

Relations.—It is covered, in front, by the skin, the superficial fascia, the Platysma, the descending clavicular branches of the cervical plexus, and the deep cervical fascia; by the clavicle, the Subclavius muscle, the suprascapular artery and vein, and the transverse cervical vein; the nerve to the Subclavius muscle passes vertically downward in front of the artery. The external jugular vein crosses the artery at its inner side, and receives the suprascapular and transverse cervical veins, which frequently form a plexus in front of it. The subclavian vein is below and in front of the artery, lying close behind the clavicle. Behind, it lies on the Middle scalenus muscle and the lowest cord of the brachial plexus, formed by the union of the last cervical and first thoracic nerves. Above it, and to its outer side, is the brachial plexus and Omo-hyoid muscle. Below, it rests on the upper surface of the first rib.

Plan of the Relations of Third Portion of Subclavian Artery.

In front.
Skin and superficial fascia.
Platysma and deep cervical fascia.
Subclavius muscle, suprascapular artery, and vein.
The external jugular and transverse cervical veins.
The clavicle.

Above.
Brachial plexus.
Omo-hyoid.

Below.
First rib.

Behind.
Scalenus medius.
Lower cord of brachial plexus.

Peculiarities.—The subclavian arteries vary in their origin, their course, and the height to which they rise in the neck.
The origin of the right subclavian from the innominate takes place, in some cases, above the sterno-clavicular articulation, and occasionally, but less frequently, in the cavity of the thorax, below that point. Or the artery may arise as a separate trunk from the arch of the aorta. In such cases it may be either the first, second, third, or even the last branch derived from that vessel; in the majority of cases it is the first or last, rarely the second or third. When it is the first branch, it occupies the ordinary position of the innominate artery; when the second or third, it gains its usual position by passing behind the right carotid; and when the last branch, it arises from the left extremity of the arch, at its upper or back part, and passes obliquely toward the
right side, usually behind the trachea, oesophagus, and right carotid, sometimes between the oesophagus and trachea to the upper border of the first rib, whence it follows its ordinary course. In very rare instances this vessel arises from the thoracic aorta, as low down as the fourth thoracic vertebra. Occasionally it perforates the Scalenus anticus muscle; more rarely it passes in front of that muscle. Sometimes the subclavian vein passes with the artery behind the Scalenus anticus muscle. The artery may ascend as high as an inch and a half above the clavicle or any intermediate point between this and the upper border of the bone, the right subclavian usually ascending higher than the left.

The left subclavian is occasionally joined at its origin with the left carotid.

Surface Marking.—The course of the subclavian artery in the neck may be mapped out by describing a curve, with its convexity upward at the base of the posterior triangle. The inner end of this curve corresponds to the sterno-clavicular joint, the outer end of the centre of the lower border of the clavicle. The curve is to be drawn with such an amount of convexity that its mid-point reaches half an inch above the upper border of the clavicle. The left subclavian artery is more deeply placed than the right in the first part of its course, and, as a rule, does not reach quite as high a level in the neck. It should be borne in mind that the posterior border of the Sterno-mastoid muscle corresponds to the outer border of the Scalenus anticus muscle, so that the third portion of the artery, that part most accessible for operation, lies immediately external to the posterior border of the Sterno-mastoid muscle.

Surgical Anatomy.—The relations of the subclavian arteries of the two sides having been examined, the student should direct his attention to a consideration of the best position in which compression of the vessel may be effected, or in what situation a ligature may be best applied in cases of aneurism or wound.

Compression of the subclavian artery is required in cases of operations about the shoulder, in the axilla, or at the upper part of the arm; and the student will observe that there is only one situation in which it can be effectually applied—viz., where the artery passes across the upper surface of the first rib. In order to compress the vessel in this situation, the shoulder should be depressed, and the surgeon, grasping the side of the neck, should press with his thumb in the angle formed by the posterior border of the Sterno-mastoid with the upper border of the clavicle, downward, backward, and inward against the rib; if from any cause the shoulder cannot be sufficiently depressed, pressure may be made from before backward, so as to compress the artery against the Scalenus medius muscle and the transverse process of the seventh cervical vertebra. In appropriate cases, a preliminary incision may be made through the cervical fascia, and the finger may be pressed down directly upon the artery.

Ligature of the subclavian artery may be required in cases of wounds or of aneurism in the axilla, or in cases of aneurism on the cardiac side of the point of ligature; and the third part of the artery is that which is most favorable for an operation, on account of its being comparatively superficial and most remote from the origin of the large branches. In those cases where the clavicle is not displaced, this operation may be performed with comparative facility; but where the clavicle is pushed up by a large aneurismal tumor in the axilla the artery is placed at a great depth from the surface, which materially increases the difficulty of the operation. Under these circumstances it becomes a matter of importance to consider the height to which this vessel reaches above the bone. In ordinary cases its arch is about half an inch above the clavicle, occasionally it is as high as an inch and a half, and sometimes so low as to be on a level with the upper border of the clavicle. If the clavicle is displaced, these variations will necessarily make the operation more or less difficult according as the vessel is more or less accessible.

The chief points in the operation of tying the third portion of the subclavian artery are as follows: The patient being placed on a table in the supine position, with the head drawn over to the opposite side and the shoulder depressed as much as possible, the integument should be drawn downward over the clavicle, and an incision made through it, upon that bone, from the anterior border of the Trapezius to the posterior border of the Sterno-mastoid, to which may be added a short vertical incision meeting the inner end of the preceding. The object in drawing the skin downward is to avoid any risk of wounding the external jugular vein, for as it perforates the deep fascia above the clavicle, it cannot be drawn downward with the skin. The soft parts should now be allowed to glide up, and the cervical fascia should be divided upon a director, and if the interval between the Trapezius and Sterno-mastoid muscles be insufficient for the performance of the operation, a portion of one or both may be divided. The external jugular vein will now be seen toward the inner side of the wound: this and the suprascapular and transverse cervical veins, which terminate in it, should be held aside. If the external jugular vein is at all in the way and exposed to injury, it should be tied in two places and divided. The suprascapular artery should be avoided, and the Omo-hyoid muscle held aside if necessary. In the space beneath this muscle careful search must be made for the vessel: a deep layer of fascia and some connective tissue having been divided carefully, the outer margin of the Scalenus anticus muscle must be felt for, and, the finger being guided by it to the first rib, the pulsation of the subclavian artery will be felt as it passes over the rib. The sheath of the vessels having been opened, the aneurism needle may then be passed around the artery from above downward and inward, so as to avoid including any of the branches of the brachial plexus. If the clavicle is so raised by
the tumor that the application of the ligature cannot be effected in this situation, the artery may be tied above the first rib, or even behind the Scalenus anticus muscle; the difficulties of the operation in such a case will be materially increased, on account of the greater depth of the artery and the alteration in position of the surrounding parts.

The second part of the subclavian artery, from being that portion which rises highest in the neck, has been considered favorable for the application of the ligature when it is difficult to tie the artery in the third part of its course. There are, however, many objections to the operation in this situation. It is necessary to divide the Scalenus anticus muscle, upon which lies the phrenic nerve, and at the inner side of which is situated the internal jugular vein; and a wound of either of these structures might lead to the most dangerous consequences. Again, the artery is in contact, below, with the pleura, which must also be avoided; and, lastly, the proximity of so many of its large branches arising internal to this point must be a still further objection to the operation. In cases, however, where the sac of an axillary aneurism encroaches on the neck, it may be necessary to divide the outer half or two-thirds of the Scalenus anticus muscle, so as to place the ligature on the vessel at a greater distance from the sac. The operation is performed exactly in the same way as a ligature of the third portion, until the Scalenus anticus is exposed, when it is to be divided on a director (never to a greater extent than its outer two-thirds), and it immediately retracts. The operation is therefore merely an extension of ligature of the third portion of the vessel.

In those cases of aneurism of the axillary or subclavian artery in which the aneurism encroaches upon the outer portion of the Scalenus muscle to such an extent that a ligature cannot be applied in that situation, it may be deemed advisable, as a last resource, to tie the first portion of the subclavian artery. On the left side this operation has been regarded as almost imppectable; the great depth of the artery from the surface, its intimate relation with the pleura, and its close proximity to the thoracic duct and to so many important veins and nerves, present a series of difficulties which it is very difficult to overcome. Nevertheless, Professor Halsted and Schumpert have each tied successfully the first portion of the left subclavian for aneurism. J. K. Rodgers, of New York, also did it successfully. On the right side the operation is practicable, and has been performed. Dr. Nassau, of Philadelphia, successfully ligated the first part of the right subclavian. The main objection to the operation in this situation is the smallness of the interval which usually exists between the commencement of the vessel and the origin of the nearest branch. The operation may be performed in the following manner: The patient being placed on the table in the supine position with the neck extended, an incision should be made along the upper border of the inner part of the clavicle, and a second along the inner border of the Sterno-mastoid, meeting the former at an angle. The attachment of both heads of the Sterno-mastoid must be divided on a director and turned outward; a few small arteries and veins, and occasionally the anterior jugular vein, must be avoided, or, if necessary, ligatured in two places and divided, and the Sterno-hyoid and Sterno-thyroid muscles are to be divided in the same manner as the preceding muscle. After tearing through the deep fascia with the finger-nail, the internal jugular vein will be seen crossing the subclavian artery; this should be pressed aside and the artery secured by passing the needle from below upward, by which the pleura is more effectually avoided. The exact position of the vagus, the recurrent laryngeal, the phrenic and sympathetic nerves should be remembered, and the ligature should be applied near the origin of the vertebral, in order to afford as much room as possible for the formation of a coagulum between the ligature and the origin of the vessel. It should be remembered that the right subclavian artery is occasionally deeply placed in the first part of its course when it arises from the left side of the aortic arch, and passes in such cases behind the oesophagus or between it and the trachea.

Collateral Circulation.—After ligature of the third part of the subclavian artery the collateral circulation is mainly established by three sets of vessels, thus described in a dissection:

1. A posterior set, consisting of the suprascapular and posterior scapular branches of the subclavian, anastomosing with the subscapular from the axillary.

2. An internal set produced by the connection of the internal mammary on the one hand, with the superior and long thoracic arteries, and the branches from the subscapular on the other.

3. A middle or axillary set, which consisted of a number of small vessels derived from branches of the subclavian, above, and, passing through the axilla, terminated either in the main trunk or some of the branches of the axillary below. This last set presented most conspicuously the peculiar character of the newly formed or, rather, dilated arteries, being excessively tortuous, and forming a complete plexus.

"The chief agent in the restoration of the axillary artery below the tumor was the subscapular artery, which communicated most freely with the internal mammary, suprascapular, and posterior scapular branches of the subclavian, from all of which is received so great an influx of blood as to dilate it to three times its natural size."
When a ligature is applied to the first part of the subclavian artery, the collateral circulation is carried on by—1, the anastomosis between the superior and inferior thyroid; 2, the anastomosis of the two vertebrales; 3, the anastomosis of the internal mammary with the deep epigastric and the aortic intercostals; 4, the superior intercostal anastomosing with the aortic intercostals; 5, the profunda cervicas anastomosing with the princeps cervicis; 6, the scapular branches of the thyroid axis anastomosing with the branches of the axillary; and 7, the thoracic branches of the axillary anastomosing with the aortic intercostals.

Branches.—The branches given off from the subclavian artery are:

Vertebral.

Thyroid axis.

Internal mammary.

Superior intercostal.

On the left side all four branches generally arise from the first portion of the vessel; but on the right side, the superior intercostal usually arises from the second portion of the vessel. On both sides of the body the first three branches arise close together at the inner margin of the Scalenus anticus; in the majority of cases a free interval of from half an inch to an inch exists between the commencement of the artery and the origin of the nearest branch; in a smaller number of cases an interval of more than an inch exists, but it never exceeds an inch and three-quarters. In a very few instances the interval has been found to be less than half an inch. The vertebral artery arises from the upper and posterior part of the subclavian artery, the internal mammary from the lower part of the artery; the thyroidea axis from in front and the superior intercostal from behind.

The Vertebral Artery (a. vertebralis) (Figs. 401 and 411) is generally the first and largest branch of the subclavian; it arises from the upper and back part of the first portion of the vessel, and, passing upward, enters the foramen in the transverse process of the sixth cervical vertebra, and ascends through the foramina in the transverse processes of all the vertebrae above this. Above the upper border of the axis it inclines outward and upward to the foramen in the transverse process of the atlas, through which it passes; it then winds backward behind its articular process, runs in a deep groove on the upper surface of the posterior arch of this bone (Fig. 16), and, passing beneath the posterior occipito-atlantal ligament (Figs. 199 and 202), pierces the dura and arachnoid, and enters the skull through the foramen magnum. It then passes forward and upward, inclining from the lateral aspect to the front of the oblongata. It unites in the middle line with the vessel of the opposite side at the lower border of the pons to form the basilar artery (Fig. 403).

Relations.—At its origin it is situated behind the internal jugular and vertebral veins, and is crossed by the inferior thyroid artery; it lies between the Longus colli and Scalenus anticus muscles, having the thoracic duct in front of it on the left side. It rests on the transverse process of the seventh cervical vertebra and the sympathetic nerve. Within the foramina formed by the transverse processes of the vertebrae it is accompanied by a plexus of nerves from the inferior cervical ganglion of the sympathetic, and is surrounded by a dense plexus of veins which unite to form the vertebral vein at the lower part of the neck. It is situated in front of the cervical nerves, as they issue from the intervertebral foramina. While

1 The vertebral artery sometimes enters the foramen in the transverse process of the fifth vertebra. Dr. Smyth, who tied this artery in the living subject, found it, in one of his dissections, passing into the foramen in the seventh vertebra.—Ed. of 19th English edition.
winding round the articular process of the atlas, it is contained in a triangular space, the suboccipital triangle, formed by the Rectus capitis posticus major, the Superior oblique and the Inferior oblique muscles; and at this point is covered by the Complexus muscle (Fig. 282). The suboccipital nerve here lies between the artery and the bone. Within the skull, as the artery winds round the oblongata, it is placed between the hypoglossal nerve and the anterior root of the suboccipital nerve, beneath the first digitation of the ligamentum denticulatum, and finally ascends between the basilar process of the occipital bone and the anterior surface of the oblongata.

**Branches.**—These may be divided into two sets—those given off in the neck and those within the cranium.

**Cervical Branches.**
- Spinal Rami, or Lateral Spinal. Muscular.
- Cranial Branches.
- Meningeal Ramus, or Posterior Meningeal. Ventral Spinal, or Anterior Spinal.
- Dorsal Spinal, or Posterior Spinal. Postereebellar, or Posterior Inferior Cerebellar. Bulbar.

The Spinal Rami, or Lateral Spinal Branches (*rami spinales*), enter the spinal canal through the intervertebral foramina and divide into two branches. Of these, one passes along the roots of the nerves to supply the spinal cord and its membranes, anastomosing with the other arteries of the spinal cord; the other divides into an ascending and a descending branch, which unite with similar branches from the artery above and below, so that two lateral anastomotic chains are formed on the posterior surface of the bodies of the vertebrae near the attachment of the pedicles. From these anastomotic chains branches are given off to supply the periosteum and the bodies of the vertebrae, and to communicate with similar branches from the opposite side; from these communicating branches small branches are given off which join similar branches above and below, so that a central anastomotic chain is formed on the posterior surface of the bodies of the vertebrae.

**Muscular Branches** are given off to the deep muscles of the neck, where the vertebral artery curves round the articular process of the atlas. They anastomose with the occipital and with the ascending and deep cervical arteries.

The Meningeal Ramus or Posterior Meningeal (*ramus meningaeus*), is a small branch given off from the vertebral opposite the foramen magnum. It ramifies between the bone and dura in the cerebellar fossa, and supplies the falcula.

The Ventral or Anterior Spinal (*a. spinalis ventralis, a. spinalis anterior*) is a small branch which arises near the termination of the vertebral, and, descending in front of the oblongata, unites with its fellow on the opposite side at about the level of the foramen magnum. One of these vessels is usually larger than the other, but occasionally they are about equal in size. The single trunk thus formed descends on the front of the spinal cord, and is reinforced by a succession of small branches which enter the spinal canal through the intervertebral foramina; these branches are derived from the vertebral artery and the ascending cervical branch of the inferior thyroid artery in the neck; from the intercostal in the thoracic region; and from the lumbar, ilio-lumbar, and lateral sacral arteries in the lower part of the spine. They unite, by means of ascending and descending branches, to form a single termatic artery, which extends as far as the lower part of the spinal cord. This vessel is placed in the pia along the anterior median fissure; it supplies that membrane and the substance of the cord, and sends off branches at its lower part to be distributed to the cauda, and ends on the central fibrous prolongation of the cord.
The Dorsal or Posterior Spinal (a. spinalis dorsalis, a. spinalis posterior) arises from the vertebral at the side of the oblongata: passing backward to the posterior aspect of the spinal cord, it descends on each side, lying behind the posterior roots of the spinal nerves, and is reinforced by a succession of small branches which enter the spinal canal through the intervertebral foramina, and by which it is continued to the lower part of the cord and to the cauda. Branches from these vessels form a free anastomosis round the posterior roots of the spinal nerves, and communicate, by means of very tortuous transverse branches, with the vessels of the opposite side. At its commencement it gives off an ascending branch, which terminates on the side of the fourth ventricle.

The Postcerebellar or Posterior Inferior Cerebellar Artery (a. postcerebellaris, a. cerebelli inferior posterior) (Fig. 403), the largest branch of the vertebral, winds backward round the upper part of the oblongata, passing between the origin of the vagus and accessory nerves, over the restis to the under surface of the cerebellum, where it divides into two branches—an internal, which is continued backward to the notch between the two hemispheres of the cerebellum; and an external, which supplies the under surface of the cerebellum as far as its outer border, where it anastomoses with the medicerebellar and the precerebellar branches of the basilar artery. Branches from this artery supply the paraplexus of the fourth ventricle.

The Bulbar Arteries comprise several minute vessels which spring from the vertebral and its branches and are distributed to the oblongata.

Surgical Anatomy.—The vertebral artery has been tied in several instances: 1, for wounds or traumatic aneurism; 2, after ligation of the innominate, either immediately to prevent hemorrhage, or later on to arrest bleeding where it has occurred at the seat of ligation; and 3, in epilepsy. In these latter cases the treatment has been recommended by Dr. Alexander, of Liverpool, in the hope that by diminishing the supply of blood to the posterior part of the brain and the spinal cord a diminution or cessation of the epileptic fits would result. But, on account of the uncertainty as to what cases, if any, derived benefit from the operation, it has now been abandoned as a treatment for epilepsy. The operation of ligation of the vertebral is performed by making an incision along the posterior border of the Sterno-mastoid muscle, just above the clavicle. The muscle is pulled to the inner side, and the anterior tubercle of the transverse process of the sixth cervical vertebra is sought for. A deep layer of fascia being now divided, the interval between the Scalenus anticus and the Longus colli muscles just below their attachment to the tubercle is defined, and the artery and vein are found in the interspace. The vein is to be drawn to the outer side, and the aneurism needle is passed from without inward. Drs. Ramskill and Bright have pointed out that severe pain at the back of the head may be symptomatic of disease of the vertebral artery just before it enters the skull. This is explained by the close connection of the artery with the suboccipital nerve in the groove on the posterior arch of the atlas. Disease of the same artery has been also said to affect speech, from pressure on the hypoglossal nerve where it is in relation with the vessel, leading to paralysis of the muscles of the tongue.

The Basilar Artery (a. basilaris) (Fig. 403), so named from its position at the base of the skull, is a single trunk formed by the junction of the two vertebral arteries; it extends from the posterior to the anterior border of the pons, lying in the median pontine groove, under cover of the arachnoid. It ends by dividing into the two postcerebral arteries.

Branches.—Its branches are, on each side, the following:

Transverse.  
Medicerebellar, or Anterior Inferior Cerebellar.

Internal Auditory.  
Precerebellar, or Superior Cerebellar.

Postcerebral, or Posterior Cerebral.

The Transverse or Pontal Branches (rami ad pontem) supply the substance of the pons.

The Internal Auditory (a. auditiva interna) accompanies the auditory nerve into the internal auditory meatus. It supplies the internal ear.
The **Medi cerebellar** or **Anterior Inferior Cerebellar Artery** (a. medi cerebellaris, a. cerebelli inferior anterior) passes backward across the peduncle, to be distributed to the anterior border of the under surface of the cerebellum, anastomosing with the post cerebellar branch of the vertebral.

The **P r e c e r e b e l l a r** or **S uperior Cerebellar Artery** (a. praecerebellaris, a. cerebelli superior) on each side arises near the termination of the basilar. It passes outward, immediately behind the oculomotor nerve, which separates it from the post cerebral, winds round the crus, close to the trochlear nerve, and, arriving at the upper surface of the cerebellum, divides into branches which ramify in the pia and, reaching the circumference of the cerebellum, anastomose with the branches of the medi cerebellar arteries. Several branches are given to the pineal gland, the valve of Vieussens, and the velum.

The **P o s t c e r e b r a l** or **P o sterior Cerebral Artery** (a. post cerebra lis, a. cerebri posterior) (Figs. 403, 405, 406, and 408), on each side, is the terminal branch of the basilar. It is larger than the preceding, from which it is separated near its origin by the oculomotor nerve. Passing outward, parallel to the precerebellar artery, and receiving the postcommunicant from the internal carotid, it winds round the crus, and passes under the surface of the occipital lobes of the cerebrum, and breaks up into branches for the supply of the temporal and occipital lobes. The **branches** of the post cerebral artery are:

- Postero-median ganglionic.
- Postchoroid or Posterior choroid. Three terminal
- Postero-lateral ganglionic

The **postero-median ganglionic branches** (Fig. 408) are a group of small arteries which arise at the commencement of the post cerebral artery; these, with similar branches from the postcommunicant, pierce the postperforatum, and supply the internal surfaces of the thalamus and the walls of the third ventricle. The post choroid enters the interior of the brain beneath the splenium of the callosum, and supplies the velum and the paraplexus. The **postero-lateral ganglionic branches** are a group of small arteries which arise from the post cerebral artery, after it has turned round the crus; they supply a considerable portion of the thalamus. The **terminal branches** are distributed as follows: the **first**, or the **anterior temporal branches**, to the basal surface of the anterior portion of the temporal lobe; the **second**, or the **posterior temporal branches**, to the external surface of the occipital lobe and the subtemporal convolution; and the **third**, or the **occipital branches**, to the mesial and lateral surfaces of the occipital lobe.

**Circulus or Circle of Willis** (circleus arteriosus [Willisii]).—The remarkable anastomosis which exists between the branches of the internal carotid and vertebral arteries at the base of the brain constitutes the circulus. It is formed in **front**, by the pre cerebral arteries, branches of the internal carotid, which are connected together by the precommunicant; **behind**, by the two post cerebra ls, branches of the basilar, which are connected on each side with the internal carotid by the postcommunicant arteries (Fig. 403). It is by this anastomosis that the cerebral circulation is equalized, and provision made for effectually carrying it on if one or more of the branches are obliterated. The parts of the brain included within this arterial circle are—the ter ma, the chiasm, the tuber, the tuber cinereum, the albicans, and the post perforatum.

The **Thyroid Axis** (truncus thyr ecocervicalis) (Figs. 394 and 413) is a short thick trunk which arises from the fore part of the first portion of the subclavian artery, close to the inner border of the Scal enus anticus muscle, and divides, almost immediately after its origin, into three branches—the **inferior thyroid**, supra scapular, and transversalis colli.
THE SUBCLAVIAN ARTERY

The **Inferior Thyroid Artery** (*a. thyreoidea inferior*) (Fig. 394) passes upward, in front of the vertebral artery and Longus colli muscle; then turns inward behind the sheath of the common carotid artery and internal jugular vein, and also behind the sympathetic nerve, the middle cervical ganglion resting upon the vessel, and reaching the lower border of the lateral lobe of the thyroid gland it divides into two branches, which supply the posterior and under part of the organ, and anastomose in its substance with the superior thyroid and with the corresponding artery of the opposite side. (See page 605.) The recurrent laryngeal nerve passes upward, generally behind but occasionally in front of the artery. Its **branches** are:

- **Inferior Laryngeal.**
- **Tracheal.**
- **Esophageal.**
- **Ascending Cervical.**

Muscular.

The **inferior laryngeal branch** (*a. laryngea inferior*) ascends upon the trachea to the back part of the larynx, in company with the recurrent laryngeal nerve, and supplies the muscles and mucous membrane of this part, anastomosing with the laryngeal branch from the superior thyroid artery and with the inferior laryngeal branch from the opposite side. The **tracheal branches** (*rami tracheales*) are distributed upon the trachea, anastomosing below with the bronchial arteries. The **oesophageal branches** (*rami oesophagei*) are distributed to the oesophagus, and anastomose with the oesophageal branches of the aorta. The **ascending cervical** (*a. cervicalis ascendens*) is a small branch which arises from the inferior thyroid just where that vessel is passing behind the common carotid artery, and runs up on the anterior tubercles of the transverse processes of the cervical vertebrae in the interval between the Scalenus anticus and Rectus capitis anticus major muscles. It gives **muscular branches** (*rami musculares*) to the muscles of the neck, which anastomose with branches of the vertebral, and sends one or two branches (*rami spinalis*) into the spinal canal through the intervertebral foramina to be distributed to the spinal cord and its membranes, and to the bodies of the vertebrae in the same manner as the lateral spinal branches from the vertebral. It anastomoses with the ascending pharyngeal and occipital arteries. The muscular branches supply the depressors of the hyoid bone, the Longus colli, the Scalenus anticus, and the Inferior constrictor of the pharynx. One of the muscular branches passes between the transverse processes of the fourth and fifth cervical vertebrae and reaches the deep muscles of the neck. It is called the **ramus profundus.**

**Surgical Anatomy.**—The inferior thyroid artery has been tied, in conjunction with the superior thyroid, in cases of bronchocele. An incision is made along the anterior border of the Sterno-mastoid down to the clavicle. After the deep fascia has been divided, the Sterno-mastoid and carotid vessels are drawn outward and the **carotid tuberele** (*Chassaignac's tuberele*) sought for. The vessel will be found just below this tuberele, between the carotid sheath on the outer side of the trachea and oesophagus on the inner side. In passing the ligature great care must be exercised to avoid including the recurrent laryngeal nerve, which is occasionally found crossing in front of the vessel. Before extirpating a goitreous lobe of the thyroid the superior and inferior thyroid arteries of the diseased side are to be ligated.

The **Suprascapular** or **Transversalis Humeri Artery** (*a. transversa scapular*) (Figs. 394 and 412), smaller than the transversalis colli, passes obliquely from within outward, across the root of the neck. It at first passes downward and outward across the Scalenus anticus muscle and phrenic nerve, being covered by the Sterno-mastoid; it then crosses the subclavian artery and the cords of the brachial plexus, and runs outward, behind and parallel with the clavicle and Subclavius muscle, and beneath the posterior belly of the Omo-hyoid, to the superior border of the scapula, where it passes over the transverse ligament of the scapula, which separates it from the suprascapular nerve, and reaches the suprascapular fossa. In this situation it lies close to the bone, and ramifies between it and the Supraspinatus muscle, to which it
supplies branches. It then passes downward behind the neck of the scapula, to reach the infraspinous fossa, where it anastomoses with the dorsalis scapular branch of the subscapular artery and branches of the posterior scapular arteries. Besides distributing branches to the Sterno-mastoid, Subclavius, and neighboring muscles, it gives off a suprasternal branch, which crosses over the sternal end of the clavicle to the skin of the upper part of the chest; and a supra-acromial branch (ramus acromialis), which, piercing the Trapezius muscle, supplies the skin over the acromion, anastomosing with the acromial thoracic artery. As the artery passes over the transverse ligament of the scapula, a branch descends into the subscapular fossa, ramifies beneath the subscapular muscle, and anastomoses with the posterior and subscapular arteries. The suprascapular artery also sends branches to the acromio-clavicular and shoulder joints, and a nutrient artery to the clavicle.

![Diagram of blood vessels](image)

**Fig. 412.**—The subscapular arteries.

The **Transverse Cervical or Transversalis Colli Artery** (*a. transversa colli*) (Fig. 394) passes transversely outward, across the upper part of the subclavian triangle, to the anterior margin of the Trapezius muscle, beneath which it divides into two branches, the **superficial cervical** and the **posterior scapular**. In its passage across the neck it crosses in front of the phrenic nerve, Scleni muscles, and the brachial plexus, between the divisions of which it sometimes passes, and is covered by the Platysma, Sterno-mastoid, Omo-hyoid, and Trapezius muscles. The **superficial cervical** (ramus ascendens) ascends beneath the anterior margin of the Trapezius, distributing branches to it and to the neighboring muscles and glands in the neck, and anastomosing with the superficial branch of the arteria princeps cervicis. The **posterior scapular** (ramus descendens) (Fig. 412) passes beneath the Levator anguli scapulae muscle to the superior angle of the scapula, and then descends along the posterior border of that bone as far as the inferior angle. In its course it is covered by the Rhomboid muscles, supplying them and the Latissimus dorsi and Trapezius, and anastomosing with the suprascapular and subscapular arteries, and with the posterior branches of some of the intercostal arteries.

**Peculiarities.**—The superficial cervical frequently arises as a separate branch from the thyroid axis; and the posterior scapular, from the third, more rarely from the second, part of the subclavian.
The **Internal Mammary** (*a. mammaria interna*) (Fig. 413) arises from the under surface of the first portion of the subclavian artery, opposite the thyroid axis. It passes downward and inward behind the costal cartilage of the first rib to the inner surface of the anterior wall of the chest, resting against the costal cartilages about half an inch from the margin of the sternum; and, at the interval
between the sixth and seventh cartilages, divides into two branches, the *musculo-
phrenic* and *superior epigastric*.

**Relations.**—At its origin it is covered by the internal jugular and subclavian
veins, and as it enters the thorax is crossed from without inward by the phrenic
nerve, and then passes forward close to the outer side of the innominate vein. In
the upper part of the thorax it lies behind the costal cartilages and Internal inter-
costal muscles, and is crossed by the terminations of the upper six intercostal
nerves. At first it lies upon the pleura, but at the lower part of the thorax the
Triangularis sterni separates the artery from this membrane. It has two vena
comiens; these unite into a single vein, which joins the innominate vein of its own
side.

**Branches.**—The branches of the internal mammary are—

- **Comes Nervi Phrenici (Superior Phrenic).** Anterior Intercostal.
- Mediastinal.
- Pericardiac.
- Sternal.

The *Comes Nervi Phrenici* or *Superior Phrenic* (*a. pericardiacophrenica*) is a long
slender branch which accompanies the phrenic nerve, between the pleura and
pericardium, to the Diaphragm. It gives branches to the pericardium and is
distributed upon the Diaphragm, anastomosing with the other phrenic branches
from the internal mammary and with phrenic branches of the abdominal aorta.

The *Mediastinal Branches* (*aa. mediastinales anteriores*) are small vessels
which are distributed to the areolar tissue and lymphatic glands in the anterior
mediastinum and to the remains of the thymus gland.

The *Pericardiac Branches* supply the upper part of the anterior surface of the
pericardium, the lower part receiving branches from the musculo-phrenic artery.

The *Sternal Branches* (*rami sterna*) are distributed to the Triangularis sterni
and to the posterior surface of the sternum.

The mediastinal, pericardiac, and sternal branches, together with some twigs
from the comes nervi phrenicii, Anastomose with branches from the intercostal and
bronchial arteries, and form a minute plexus beneath the pleura, which has been
named by Turner the *subpleural mediastinal plexus*.

The *Anterior Intercostal Arteries* (*rami intercostales*) supply the five or six upper
intercostal spaces. The branch corresponding to each space soon divides into
two, or the two branches may come off separately from the parent trunk. The
small vessels pass outward in the intercostal spaces, one, the larger, lying near
the lower margin of the rib above, and the other, the smaller, near the upper
margin of the rib below, and anastomose with the intercostal arteries from the
aorta. They are at first situated between the pleura and the Internal intercostal
muscles, and then between the Internal and External intercostal muscles. They
supply the Intercostal muscles, and, by branches which perforate the External
intercostal muscle, reach the Pectoral muscles and the mammary gland.

The *Perforating* or *Anterior Perforating Arteries* (*rami perforantes*) correspond
to the five or six upper intercostal spaces. They arise from the internal mam-
mary, pass forward through the intercostal spaces, and, curving outward, supply
the Pectoralis major and the integument. Those which correspond to the second,
third, and fourth spaces are distributed to the mammary gland. In females,
during lactation, these branches are of large size.

The *Musculo-phrenic Artery* (*a. musculophrenica*) is directed obliquely down-
ward and outward, behind the cartilages of the false ribs, perforating the Dia-
aphragm at the eighth or ninth rib, and terminating, considerably reduced in size,
opposite the last intercostal space. It gives off anterior intercostal arteries to
each of the intercostal spaces across which it passes; these diminish in size as the
spaces decrease in length, and are distributed in a manner precisely similar to the anterior intercostals from the internal mammary. The musculo-phrenic also gives branches to the lower part of the pericardium, and others which run backward to the Diaphragm and downward to the abdominal muscles.

The Superior Epigastric (a. epigastrica superior) continues in the original direction of the internal mammary; it descends through the cellular interval between the costal and sternal attachments of the Diaphragm, and enters the sheath of the Rectus abdominis muscle, at first lying behind the muscle, and then perforating it and supplying it, and anastomosing with the deep epigastric artery from the external iliac. Some branches perforate the sheath of the Rectus, and supply the muscles of the abdomen and the integument, and a small branch, which passes inward upon the side of the ensiform appendix, anastomoses in front of that cartilage with the superior epigastric artery of the opposite side. It also gives some twigs to the Diaphragm, while from the artery of the right side small branches extend into the falciform ligament of the liver and anastomose with the hepatic artery.

Surgical Anatomy.—The course of the internal mammary artery may be defined by drawing a line across the six upper intercostal spaces half an inch from and parallel with the sternum. The position of the vessel must be remembered, as it is liable to be wounded in stabs of the chest-wall. It is most easily reached by a transverse incision in the second intercostal space.

The Superior Intercostal (truncus costocervicalis) (Figs. 401 and 419) arises from the upper and back part of the subclavian artery, behind the Scalenus anticus muscle on the right side and to the inner side of that muscle on the left side. Passing backward, it gives off the deep cervical branch, and then descends behind the pleura in front of the necks of the first two ribs, and inosculates with the first aortic intercostal. As it crosses the neck of the first rib it lies to the inner side of the anterior division of the first thoracic nerve and to the outer side of the first thoracic ganglion of the sympathetic. In the first intercostal space it gives off a branch which is distributed in a manner similar to the distribution of the aortic intercostals. The branch for the second intercostal space usually joins with one from the highest aortic intercostal. Each intercostal gives off a branch to the posterior spinal muscles, and a small branch which passes through the corresponding intervertebral foramen to the spinal cord and its membranes.

The Deep Cervical Branch (a. cervicalis profunda) arises, in most cases, from the superior intercostal, and is analogous to the posterior branch of an aortic intercostal artery; occasionally it arises as a separate branch from the subclavian artery. Passing backward, above the eighth cervical nerve and between the transverse process of the seventh cervical vertebra and the first rib, it runs up the back part of the neck, between the Complexus and Semispinalis colli muscles, as high as the axis vertebra, supplying these and adjacent muscles, and anastomosing with the deep branch of the arteria princeps cervicis of the occipital, and with branches which pass outward from the vertebral. It gives off a special branch which enters the spinal canal through the intervertebral foramen between the seventh cervical and first thoracic vertebrae.

SURGICAL ANATOMY OF THE AXILLA.

The axilla is a pyramidal space, situated between the upper and lateral part of the chest and the inner side of the arm.

Boundaries.—Its apex, which is directed upward toward the root of the neck, corresponds to the interval between the first rib, the upper edge of the scapula, and the clavicle, through which the axillary vessels, the brachial plexus of nerves, and the long thoracic nerve pass. This interval is the cervico-axillary passage.
The base, directed downward, is formed by the integument and a thick layer of fascia, the \textit{axillary fascia} (fascia axillaris) (Fig. 312), extending between the lower border of the Pectoralis major in front and the lower border of the Latissimus dorsi behind (page 465). The axillary fascia is perforated at several points. The large central opening is called the \textit{foramen of Langer}. The inner margin of the foramen of Langer is dense and constitutes a part of the \textit{axillary arch}, which is a fibro-muscular slip derived from the latissimus dorsi. The axilla is broad internally at the chest, but narrow and pointed externally at the arm. The \textit{anterior boundary} is formed by the Pectoralis major and minor muscles, the former covering the whole of the anterior wall of the axilla, the latter covering only its central part, the costo-coracoid membrane, the clavicle, and the Subclavious muscle. The \textit{posterior boundary}, which extends somewhat lower than the anterior, is formed by the Subscapularis above, the Teres major and Latissimus dorsi below. On the \textit{inner side} are the first four ribs with their corresponding Intercostal muscles, and part of the Serratus magnus. On the \textit{outer side}, where the anterior and posterior boundaries converge, the space is narrow, and bounded by the humerus, the Coraco-brachialis and Biceps muscles.

\textbf{Contents}.—This space contains the axillary vessels and brachial plexus of nerves, with their branches, some branches of the intercostal nerves, and a large number of lymphatic glands, all connected together by a quantity of fat and loose areolar tissue.

\textbf{Position of the Contents}.—The axillary artery and vein, with the brachial plexus of nerves, extend obliquely along the outer boundary of the axillary space, from its apex to its base, and are placed much nearer the anterior than the posterior wall, the vein lying to the inner or thoracic side of the artery and partially concealing it. At the forepart of the axillary space, in contact with the Pectoral muscles, and along the anterior margin are the thoracic branches of the axillary artery, and along the lower margin of the Pectoralis minor the long thoracic artery extends to the side of the chest. At the back part, in contact with the lower margin of the Subscapularis muscle, are the subscapular vessels and nerves; winding around the outer border of this muscle is the dorsalis scapule artery and veins; and, close to the neck of the humerus, the posterior circumflex vessels and the circumflex nerve are seen curving backward to the shoulder.

Along the inner or thoracic side no vessel of any importance exists, the upper part of the space being crossed merely by a few small branches from the superior thoracic artery. There are some important nerves, however, in this situation—viz., the long thoracic or external respiratory nerve, descending on the surface of the Serratus magnus, to which it is distributed; and perforating the upper and anterior part of this wall, the intercosto-humeral nerve or nerves, passing across the axilla to the inner side of the arm.

The cavity of the axilla is filled by a quantity of loose areolar tissue and a large number of small arteries and veins, all of which are, however, of inconsiderable size, and numerous lymphatic glands, the position and arrangement of which are described on a subsequent page.

\textbf{Surgical Anatomy}.—The axilla is a space of considerable surgical importance. It transmits the large vessels and nerves to the upper extremity, and these may be the seat of injury or disease; it contains numerous lymphatic glands which may require removal when diseased; in it is a quantity of loose connective and adipose tissue which may be readily infiltrated with blood or pus. The axilla may be the seat of rapidly growing tumors. Moreover, it is covered at its base by thin skin, largely supplied with sebaceous and sweat glands, which is frequently the seat of small cutaneous \textit{abscesses} and \textit{boils}, and of eruptions due to irritation.

In \textit{suppuration} in the axilla the arrangement of the fascia plays a very important part in the direction which the pus takes. As described on page 406, the costo-coracoid membrane, after covering in the space between the clavicle and the upper border of the Pectoralis minor, splits
to enclose this muscle, and, reblending at its lower border, becomes incorporated with the axillary fascia at the anterior fold of the axilla. This is known as the clavi-pectoral fascia. Suppuration may take place either superficial to or beneath this layer of fascia; that is, either between the Pectoralis or below the Pectoralis minor; in the former case, the pus would point either at the anterior border of the axillary fold or in the groove between the Deltoïd and the Pectoralis major; in the latter, the pus would have a tendency to surround the vessels and nerves and ascend into the neck, that being the direction in which there is least resistance. Its progress toward the skin is prevented by the axillary fascia; its progress backward, by the Serratus magnus; forward, by the clavi-pectoral fascia; inward, by the wall of the thorax; and outward, by the upper limb. The pus in these cases, after extending into the neck, has been known to spread through the superior opening of the thorax into the mediastinum.

In opening an axillary abscess the knife should be entered in the floor of the axilla, midway between the anterior and posterior margins and near the thoracic side of the space. It is well to use a director and dressing forceps after an incision has been made through the skin and fascia in the manner directed by the late Mr. Hilton.

The student should attentively consider the relation of the vessels and nerves in the several parts of the axilla, for it is the universal plan, at the present day, to remove the glands from the axilla in operating for cancer of the breast. In performing such an operation it will be necessary to proceed with much caution in the direction of the outer wall and apex of the space, as here the axillary vessels will be in danger of being wounded. Toward the posterior wall it will be necessary to avoid the subscapular, dorsalis scapulae, and posterior circumflex vessels. Along the anterior wall it will be necessary to avoid the thoracic branches. In clearing out the axilla the axillary vein should be first defined and cleared up to the apex of the axilla. When the apex of the space is reached, all fat and glands must be carefully removed and the whole axilla cleared by separating the tissues along the inner and posterior walls, so that when the proceeding is completed, the axilla is cleared of all its contents except the main vessels and nerves.

**THE AXILLARY ARTERY (A. AXILLARIS) (Fig. 414)**.

The axillary artery, the continuation of the subclavian, commences at the outer border of the first rib, and terminates at the lower border of the tendon.
of the Teres major muscle, where it takes the name of brachial. Its direction varies with the position of the limb: when the arm lies by the side of the chest, the vessel forms a gentle curve, the convexity being upward and outward; when the arm is directed at right angles with the trunk, the vessel is nearly straight; and when the arm is elevated still higher, the arteries describe a curve the concavity of which is directed upward. At its commencement the artery is very deeply situated, but near its termination it is superficial, being covered only by the skin and fascia. The description of the relations of this vessel is facilitated by its division into three portions, the first portion being above the Pectoralis minor; the second portion behind; and the third below that muscle.

**Relations.**—The first portion of the axillary artery is in relation, in front, with the clavicular portion of the Pectoralis major, the costo-coracoid membrane, the external anterior thoracic nerve, and the acromio-thoracic and cephalic veins; behind, with the first intercostal space, the corresponding Intercostal muscle, the second and a portion of the third digitation of the Serratus magnus, and the long thoracic and internal anterior thoracic nerves; on its outer side, with the brachial plexus, from which it is separated by a little cellular interval; on its inner or thoracic side, with the axillary vein, which overlaps the artery.

**Relations of the First Portion of the Axillary Artery.**

*In front.*
- Pectoralis major.
- Costo-coracoid membrane.
- External anterior thoracic nerve.
- Acromio-thoracic and cephalic veins.

*Outer side.*
- Brachial plexus.

*Inner side.*
- Axillary vein.

*Behind.*
- First Intercostal space and Intercostal muscle.
- Second and third digitations of Serratus magnus.
- Long thoracic and Internal anterior thoracic nerves.

The second portion of the axillary artery lies beyond the Pectoralis minor. It is covered, in front, by the Pectoralis major and minor muscles; behind, it is separated from the Subscapularis by a cellular interval; on the inner side is the axillary vein, separated from the artery by the inner cord of the plexus and the internal anterior thoracic nerve. The brachial plexus of nerves surrounds the artery on three sides, and separates it from direct contact with the vein and adjacent muscles.

**Relations of the Second Portion of the Axillary Artery.**

*In front.*
- Pectoralis major and minor.

*Outer side.*
- Outer cord of plexus.

*Inner side.*
- Axillary vein.
- Inner cord of plexus.
- Internal anterior thoracic nerve.

*Behind.*
- Subscapularis.
- Posterior cord of plexus.
The third portion of the axillary artery lies below the Pectoralis minor. It is in relation, in front, with the lower part of the Pectoralis major above, being covered only by the integument and fascia below, where it is crossed by the inner head of the median nerve; behind, with the lower part of the Subscapularis and the tendons of the Latissimus dorsi and Teres major; on its outer side, with the Coraco-brachialis; on its inner or thoracic side, with the axillary vein. The nerves of the brachial plexus bear the following relation to the artery in this part of its course: on the outer side is the median nerve, and the musculo-cutaneous for a short distance; on the inner side, the ulnar nerve (between the vein and artery) and the lesser internal cutaneous nerve (to the inner side of the vein); in front is the internal cutaneous nerve, and behind, the musculo-spiral and circumflex, the latter extending only to the lower border of the Subscapularis muscle.

Relations of the Third Portion of the Axillary Artery.

In front.
Integument and fascia.
Pectoralis major.
Inner head of median nerve.
Internal cutaneous nerve.

Outer side.
Coraco-brachialis.
Median nerve.
Musculo-cutaneous nerve.

Axillary Artery.
Third portion.

Inner side.
Ulnar nerve.
Axillary vein.
Lesser internal cutaneous nerve.

Behind.
Subscapularis.
Tendons of Latissimus dorsi and Teres major.
Musculo-spiral and circumflex nerves.

Peculiarities.—The axillary artery, in about one case out of every ten, gives off a large branch, which forms either one of the arteries of the forearm or a large muscular trunk. In the first set of cases this artery is most frequently the radial (1 in 33), sometimes the ulnar (1 in 72), and, very rarely, the interosseous (1 in 506). In the second set of cases the trunk has been found to give origin to the subscapular, circumflex, and profunda arteries of the arm. Sometimes only one of the circumflex, or one of the profunda arteries, arose from the trunk. In these cases the brachial plexus surrounded the trunk of the branches and not the main vessel.

Surface Marking.—The course of the axillary artery may be marked out by raising the arm to a right angle with the body and drawing a line from the middle of the clavicle to the point where the tendon of the Pectoralis major crosses the prominence caused by the Coraco-brachialis as it emerges from under cover of the anterior fold of the axilla. The third portion of the artery can be felt pulsating beneath the skin and fascia, at the junction of the anterior with the middle third of the space between the anterior and posterior folds of the axilla, close to the inner border of the Coraco-brachialis muscle.

Surgical Anatomy.—The student, having carefully examined the relations of the axillary artery in its various parts, should now consider in what situation compression of this vessel may be most easily effected, and the best position for the application of a ligature to it when necessary.

Compression of the vessel may be required in the removal of tumors or in amputation of the upper part of the arm; and the only situation in which this can be effectually made is in the lower part of its course; by pressing on it in this situation from within outward against the humerus the circulation may be effectually arrested.

The axillary artery is perhaps more frequently lacerated than any other artery in the body, with the exception of the popliteal, by violent movements of the extremity, especially in those cases where its coats are diseased. It has occasionally been ruptured in attempts to reduce old dislocations of the shoulder-joint. This accident is most likely to occur during the preliminary breaking down of adhesions, in consequence of the artery having become fixed to the capsule of the joint. Aneurism of the axillary artery is of frequent occurrence, a large percentage of the cases being traumatic in their origin, due to the violence to which the vessel is exposed in the varied, extensive, and often violent movements of the limb.

The application of a ligature to the axillary artery may be required in cases of aneurism of the upper part of the brachial or as a distal operation for aneurism of the sub-
clavian; and there are only two situations in which the vessel can be secured—viz., in the first and in the third parts of its course; for the axillary artery at its central part is so deeply seated, and, at the same time, so closely surrounded with large nerve trunks, that the application of a ligature to it in that situation would be almost impracticable.

In the third part of its course the operation is most simple, and may be performed in the following manner: The patient being placed on a bed and the arm separated from the side, with the hand supinated, an incision about two inches in length is made through the integument forming the floor of the axilla, the cut being a little nearer to the anterior than the posterior fold of the axilla. After carefully dissecting through the areolar tissue and fascia, the median nerve and axillary vein are exposed; the former having been displaced to the outer and the latter to the inner side of the arm, the elbow being at the same time bent, so as to relax the structures and facilitate their separation, the ligature may be passed round the artery from the ulnar to the radial side.

This portion of the artery is occasionally crossed by a muscular slip, the axillary arch, derived from the Latissimus dorsi, which may mislead the surgeon during an operation. The occasional existence of this muscular fasciculus was spoken of in the description of the muscles. It may easily be recognized by the transverse direction of its fibres.

The first portion of the axillary artery may be tied in cases of aneurism encroaching so far upward that a ligature cannot be applied in the lower part of its course. Notwithstanding that this operation has been performed in some few cases, and with success, its performance is attended with much difficulty and danger. The student will remark that in this situation it would be necessary to divide a thick muscle, and, after incising the costo-coracoid membrane, the artery would be exposed at the bottom of a more or less deep space, with the cephalic and axillary veins in such relation with it as must render the application of a ligature to this part of the vessel particularly hazardous. Under such circumstances it is an easier, and at the same time more advisable, operation to tie the subclavian artery in the third part of its course.

The vessel in the first part of its course can best be secured through a curved incision the convexity of which is downward. This incision passes from a point half an inch external to the sterno-clavicular joint to a point half an inch internal to the coracoid process. The limb is to be well abducted and the head inclined to the opposite side, and this incision is carried through the superficial structures, care being taken to avoid the cephalic vein at the outer angle of the incision. The clavicular origin of the Pectoralis major is then divided in the whole extent of the wound. The arm is now to be brought to the side, and the upper edge of the Pectoralis minor defined and drawn downward. The costo-coracoid membrane is to be carefully divided close to the coracoid process, and the axillary sheath exposed; this is to be opened with especial care on account of the vein overlapping the artery. The needle should be passed from below, so as to avoid wounding the vein.

In a case of wound of the vessel the general practice of cutting down upon and tying it above and below the wounded point should be adopted in all cases.

Collateral Circulation after Ligature of the Axillary Artery.—If the artery be tied above the origin of the acromial thoracic, the collateral circulation will be carried on by the same branches as after the ligature of the subclavian; if at a lower point, between the acromial thoracic and subscapular arteries, the latter vessel, by its free anastomoses with the other scapular arteries, branches of the subclavian, will become the chief agent in carrying on the circulation, to which the long thoracic, if it be below the ligature, will materially contribute by its anastomoses with the intercostal and internal mammary arteries. If the point included in the ligature be below the origin of the subscapular artery, it will most probably also be below the origins of the circumflex arteries. The chief agents in restoring the circulation will then be the subcapular and the two circumflex arteries anastomosing with the superior profunda from the brachial, which will be afterward referred to as performing the same office after ligation of the brachial. The cases in which the operation has been performed are few in number, and no published account of dissections of the collateral circulation appears to exist.

Branches.—The branches of the axillary artery are—

**From first part**

- Superior Thoracic
- Acromial Thoracic

**From second part**

- Long Thoracic
- Alar Thoracic

**From third part**

- Subscapular
- Posterior Circumflex
- Anterior Circumflex

The **Superior Thoracic** (*a. thoracalis suprema*) is a small artery which arises from the axillary separately or by a common trunk with the acromial thoracic. Running forward and inward along the upper border of the Pectoralis minor, it
passes between it and the Pectoralis major to the side of the chest. It supplies these muscles and the parietes of the thorax, anastomosing with the internal mammary and intercostal arteries.

The **Acromial Thoracic** or the **Thoracic Axis** (*a. thoracoacromialis*) is a short trunk which *arises* from the forepart of the axillary artery, its origin being generally overlapped by the upper edge of the Pectoralis minor. Projecting forward to the upper border of the Pectoralis minor, it divides into four sets of branches—*thoracic, acromial, descending, and clavicular*.

The **Thoracic Branches** (*rami pectorales*), two or three in number, are distributed to the Serratus magnus and Pectoral muscles, anastomosing with the intercostal branches of the internal mammary.

The **Acromial Branch** (*ramus acromialis*) is directed outward toward the acromion, supplying the Deltoid muscle, and anastomosing, on the surface of the acromion, with the suprascapular and posterior circumflex arteries.

The **Descending or Humeral Branch** (*ramus deltoideus*) passes in the space between the Pectoralis major and Deltoid, in the same groove as the cephalic vein, and supplies both muscles.

The **Clavicular Branch** (*ramus clavicularis*), which is very small, passes upward to the Subclavius muscle.

The **Long Thoracic** or the **External Mammary** (*a. thoracalis lateralis*) passes downward and inward along the lower border of the Pectoralis minor to the side of the chest, supplying the Serratus magnus, the Pectoral muscles, and mammary gland, and sending branches across the axilla to the axillary glands and Subscapularis; it anastomoses with the internal mammary and intercostal arteries.

The **Alar Thoracic** is a small branch which supplies the glands and areolar tissue of the axilla. Its place is frequently supplied by branches from some of the other thoracic arteries.

The **Subscapular** (*a. subscapularis*), the largest branch of the axillary artery, *arises* opposite the lower border of the Subscapularis muscle, and passes downward and backward along its lower margin to the inferior angle of the scapula, where it anastomoses with the long thoracic and intercostal arteries and with the posterior scapular, a branch of the transversalis colli, from the thyroid axis of the subclavian. About an inch and a half from its origin it gives off a large branch, the **dorsalis scapulae**, and terminates by supplying branches to the muscles in the neighborhood.

The **Dorsalis Scapulae** (*a. circumflexa scapulae*) is given off from the subscapular about an inch and a half from its origin, and is generally larger than the continuation of the vessel. It curves round the axillary border of the scapula, leaving the axilla through the space between the Teres minor above, the Teres major below, and the long head of the Triceps externally (Fig. 412), and enters the infraspinous fossa by passing under cover of the Teres minor, where it anastomoses with the posterior scapular and suprascapular arteries. In its course it gives off two sets of branches: one enters the subscapular fossa beneath the Subscapularis, which it supplies, anastomosing with the posterior scapular and suprascapular arteries; the other is continued along the axillary border of the scapula, between the Teres major and minor, and, at the dorsal surface of the inferior angle of the bone, anastomoses with the posterior scapular. In addition to these, small branches are distributed to the back part of the Deltoid muscle and the long head of the Triceps, anastomosing with an ascending branch of the superior profunda of the brachial.

The **Circumflex Arteries** wind round the surgical neck of the humerus. The **posterior circumflex** (*a. circumflexa humeri posterior*) (Fig. 412), the larger of the two, *arises* from the back part of the axillary opposite the lower border of the Subscapularis muscle, and, passing backward with the circumflex veins and nerve
through the quadrangular space bounded by the Teres major and minor, the scapular head of the Triceps and the humerus, winds round the neck of that bone and is distributed to the Deltoid muscle and shoulder-joint, anastomosing with the anterior circumflex and acromial thoracic arteries, and with the superior profunda branch of the brachial artery. The anterior circumflex (a. circumflexa humeri anterior) (Figs. 412 and 414), considerably smaller than the preceding, arises nearly opposite that vessel from the outer side of the axillary artery. It passes horizontally outward beneath the Coraco-brachialis and short head of the Biceps, lying upon the forepart of the neck of the humerus, and, on reaching the bicipital groove, gives off an ascending branch which passes upward along the groove to supply the head of the bone and the shoulder-joint. The trunk of the vessel is then continued outward beneath the Deltoid, which it supplies, and anastomoses with the posterior circumflex artery.

**THE BRACHIAL ARTERY (A. BRACHIALIS) (Fig. 415).**

The brachial artery (a. brachialis) commences at the lower margin of the tendon of the Teres major, and, passing down the inner and anterior aspect of the arm, terminates about half an inch below the bend of the elbow, where it divides into the radial and ulnar arteries. At first the brachial artery lies internal to the humerus; but as it passes down the arm it gradually gets in front of the bone, and at the bend of the elbow it lies midway between the two condyles.

**Relations.**—This artery is superficial throughout its entire extent, being covered, in front, by the integument, the superficial and deep fasciae; the bicipital fascia separates it opposite the elbow from the median basilic vein; the median nerve crosses it at its middle; behind, it is separated from the long head of the Triceps by the musculo-spiral nerve and superior profunda artery. It then lies upon the inner head of the Triceps, next upon the insertion of the Coraco-brachialis, and lastly on the Brachialis anticus; by its outer side, it is in relation with the commencement of the median nerve and the Coraco-brachialis and Biceps muscles, which overlap the artery to a considerable extent; by its inner side, its upper half is in relation with the internal cutaneous and ulnar nerves, its lower half with the median nerve. The basilic vein lies on the inner side of the artery, but is separated from it in the lower part of the arm by the deep fascia. The brachial artery is accompanied by
two vena comites, which lie in close contact with the artery, being connected together at intervals by short transverse communicating branches.

**Plan of the Relations of the Brachial Artery.**

*In front.*

Integument and fasciae.
Brachial fascia, median basilic vein.
Median nerve.
Overlapped by Coraco-brachialis and Biceps.

**Outer side.**

Median nerve (above).
Coraco-brachialis.
Biceps.

**Inner side.**

Internal cutaneous and Ulnar nerves.
Median nerve (below).
Basilic vein.

**Behind.**

Triceps (long and inner heads).
Muscuto-spiral nerve.
Superior profunda artery.
Coraco-brachialis.
Brachialis anticus.

**Surgical Anatomy of the Bend of the Elbow.**

At the bend of the elbow the brachial artery sinks deeply into a triangular interval, the antecubital space, the base of which is directed upward, and may be represented by a line connecting the two condyles of the humerus; the sides are bounded, externally, by the inner edge of the Supinator longus; internally, by the outer margin of the Pronator radii teres; its floor is formed by the Brachialis anticus and Supinator brevis. This space contains the brachial artery with its accompanying veins, the radial and ulnar arteries, the median and musculo-spiral nerves, and the tendon of the Biceps. The brachial artery occupies the middle line of this space, and divides opposite the neck of the radius into the radial and ulnar arteries; it is covered, in front, by the integument, the superficial fascia, and the median basilic vein, the vein being separated from direct contact with the artery by the bicipital fascia. Behind, it lies on the Brachialis anticus, which separates it from the elbow-joint. The median nerve lies on the inner side of the artery, close to it above, but separated from it below by the coronoid origin of the Pronator radii teres. The tendon of the Biceps lies to the outer side of the space, and the musculo-spiral nerve still more externally, situated upon the Supinator brevis and partly concealed by the Supinator longus.

**Peculiarities of the Brachial Artery as Regards its Course.**—The brachial artery, accompanied by the median nerve, may leave the inner border of the Biceps and descend toward the inner condyle of the humerus, where it usually curves round a prominence of bone, the supracondylar process. From this process, in most subjects, a fibrous arch is thrown over the artery. The vessel then inclines outward, beneath or through the substance of the Pronator radii teres muscle, to the bend of the elbow. The variation bears considerable analogy to the normal condition of the artery in some of the carnivora; it has been referred to in the description of the humerus (page 181).

**As Regards its Division.**—Occasionally, the artery is divided for a short distance at its upper part into two trunks, which are united above and below. A similar peculiarity occurs in the main vessel of the lower limb.

The point of bifurcation may be above or below the usual point, the former condition being by far the more frequent. Out of 481 examinations recorded by Mr. Quain, some made on the right and some on the left side of the body, in 386 the artery bifurcated in its normal position. In one case only was the place of division lower than usual, being two or three inches below the elbow-joint. "In 94 cases out of 481, or about 1 in 5½, there were two arteries instead of one in some part or in the whole of the arm."
THE BLOOD-VASCULAR SYSTEM

There appears, however, to be no correspondence between the arteries of the two arms with respect to their irregular division; for in 61 bodies it occurred on one side only in 43; on both sides, in different positions, in 13; on both sides, in the same position, in 3.

The point of bifurcation takes place at different parts of the arm, being most frequent in the upper part, less so in the lower part, and least so in the middle, the most usual point for the application of a ligature; under any of these circumstances two large arteries would be found in the arm instead of one. The most frequent (in three out of four) of these peculiarities is the high origin of the radial. That artery often arises from the inner side of the brachial, and runs parallel with the main trunk to the elbow, where it crosses it, lying beneath the fascia; or it may perforate the fascia and pass over the artery immediately beneath the integument.

The ulnar sometimes arises from the brachial high up, and accompanies that vessel to the lower part of the arm, and descends toward the inner condyle. In the forearm it generally lies beneath the deep fascia, superficial to the flexor muscles; occasionally between the integument and deep fascia, and very rarely beneath the flexor muscles.

The interosseous artery sometimes arises from the upper part of the brachial or axillary; as it passes down the arm it lies behind the main trunk, and at the bend of the elbow regains its usual position.

In some cases of high origin of the radial the remaining trunk (ulnar interosseous) occasionally passes, together with the median nerve, along the inner margin of the arm to the inner condyle, and then passing from within outward, beneath or through the Pronator radii teres, regains its usual position at the bend of the elbow.

Occasionally the two arteries representing the brachial are connected at the bend of the elbow by a short transverse branch, and are even sometimes reunited.

Sometimes, long slender vessels, *vasa aberrantia*, connect the brachial or axillary arteries with one of the arteries of the forearm or a branch from them. These vessels usually join the radial.

**Varieties in Muscular Relations.**—The brachial artery is occasionally concealed in some part of its course by muscular or tendinous slips derived from the Coraco-brachialis, Biceps, Brachialis anticus, and Pronator radii teres muscles.

**Surface Marking.**—The direction of the brachial artery is marked by a line drawn along the inner edge of the Biceps from the junction of the anterior and middle thirds of the axillary outlet to the middle of the front of the elbow-joint.

**Surgical Anatomy.**—Compression of the brachial artery is required in cases of amputation and some other operations in the arm and forearm; and it will be observed that it may be effected in almost any part of the course of the artery. If pressure is made in the upper part of the limb, it should be directed from within outward; and if in the lower part, from before backward, as the artery lies on the inner side of the humerus above and in front of the humerus below. The most favorable situation is about the middle of the arm, where it lies on the tendon of the Coraco-brachialis on the inner flat side of the humerus.

The application of a ligature to the brachial artery may be required in case of wound of the vessel and in some cases of wound of the palmar arch. It is also sometimes necessary in cases of aneurism of the brachial, the radial, ulnar, or interosseous arteries. The artery may be secured in any part of its course. The chief guides in determining its position are the surface markings produced by the inner margin of the Coraco-brachialis and Biceps, the known course of the vessel, and its pulsation, which should be carefully felt for before any operation is performed, as the vessel occasionally deviates from its usual position in the arm. In whatever situation the operation is performed, great care is necessary, on account of the extreme thinness of the parts covering the artery and the intimate connection which the vessel has throughout its whole course with important nerves and veins. Sometimes a thin layer of muscular fibre is met with concealing the artery; if such is the case, it must be cut across in order to expose the vessel.

In the upper third of the arm the artery may be exposed in the following manner: The patient being placed supine upon a table, the affected limb should be raised from the side and the hand supinated. An incision about two inches in length should be made on the inner side of the Coraco-brachialis muscle, and the subjacent fascia cautiously divided, so as to avoid wounding the internal cutaneous nerve or basilic vein, which sometimes runs on the surface of the artery as high as the axillary. The fascia having been divided, it should be remembered that the ulnar and internal cutaneous nerves lie on the inner side of the artery, the median on the outer side, the latter nerve being occasionally superficial to the artery in this situation, and that the venous comites are also in relation with the vessel, one on either side. These being carefully separated, the aneurism needle should be passed round the artery from the inner to the outer side.

If two arteries are present in the arm in consequence of a high division, they are usually placed side by side: and if they are exposed in an operation, the surgeon should endeavor to

1 See Struther’s Anatomical and Physiological Observations.
ascertain, by alternately pressing on each vessel, which of the two communicates with the wound or aneurism, when a ligature may be applied accordingly; or if pulsation or hemorrhage ceases only when both vessels are compressed, both vessels may be tied, as it may be concluded that the two communicate above the seat of disease or are reunited.

It should also be remembered that two arteries may be present in the arm in a case of high division, and that one of these may be found along the inner intermuscular septum, in a line toward the inner condyle of the humerus, or in the usual position of the brachial, but deeply placed beneath the common trunk: a knowledge of these facts will suggest the precautions necessary in every case, and indicate the measures to be adopted when anomalies are met with.

In the middle of the arm the brachial artery may be exposed by making an incision along the inner margin of the Biceps muscle. The forearm being bent so as to relax the muscle, it should be drawn slightly aside, and, the fascia being carefully divided, the median nerve will be exposed lying upon the artery (sometimes beneath); this being drawn inward and the muscle outward, the artery should be separated from its accompanying veins and secured. In this situation the inferior profunda may be mistaken for the main trunk, especially if enlarged, from the collateral circulation having become established; this may be avoided by directing the incision externally toward the Biceps, rather than inward or backward toward the Triceps.

The lower part of the brachial artery is of interest in a surgical point of view, on account of the relation which it bears to the veins most commonly opened in venesection. Of these vessels, the median basilic is the largest and most prominent, and, consequently, the one usually selected for the operation. It should be remembered that this vein runs parallel with the brachial artery, from which it is separated by the bicipital fascia, and that care should be taken in opening the vein not to carry the incision too deeply, so as to endanger the artery.

Collateral Circulation.—After the application of a ligature to the brachial artery in the upper third of the arm, the circulation is carried on by branches from the circumflex and subscapular arteries, anastomosing with ascending branches from the superior profunda. If the brachial is tied below the origin of the profunda arteries, the circulation is maintained by the branches of the profunda, anastomosing with the recurrent radial, ulnar, and interosseous arteries. In two cases described by Mr. South,1 in which the brachial artery had been tied some time previously, in one "a long portion of the artery had been obliterated, and the vessels are descending on either side from above the obliteration, to be received into others which ascend in a similar manner from below it. In the other the obliteration is less extensive, and a single curved artery about as big as a crow-quin passes from the upper to the lower open part of the artery."

Branches.—The branches of the brachial artery are—the

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<td>Nutrient.</td>
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<td>Muscular.</td>
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The Superior Profunda Artery (a. profunda brachii) arises from the inner and back part of the brachial, just below the lower border of the Teres major, and passes backward to the interval between the outer and inner heads of the Triceps muscle; accompanied by the musculo-spiral nerve it winds around the back part of the shaft of the humerus in the spiral groove, between the outer head of the Triceps and the bone, to the outer side of the humerus, where it reaches the external intermuscular septum and divides into two terminal branches. One of these pierces the external intermuscular septum, and descends, in company with the musculo-spiral nerve, to the space between the Brachialis anticus and Supinator longus, where it anastomoses with the recurrent branch of the radial artery; while the other, much the larger of the two, descends along the back of the external intermuscular septum to the back of the elbow-joint, where it anastomoses with the posterior interosseous recurrent, and across the back of the humerus with the posterior ulnar recurrent, the anastomotica magna, and inferior profunda (Fig. 418). The superior profunda supplies the Triceps muscle and gives off a nutrient artery which enters the bone at the upper end of the musculo-spiral groove. Near its commencement it sends off a branch which passes upward between the external and long heads of the Triceps muscle to anastomose with the posterior circumflex

1 Chellus's Surgery, vol. ii. p. 254. See also White's engravings, referred to by Mr. South, of the anastomosing branches after ligature of the brachial, in White's Cases in Surgery. Porta also gives a case (with drawings) of the circulation after ligature of both brachial and radial (Alterazioni Patologiche delle Arterie).—En. of 15th English edition.
artery, and, while in the groove, a small branch which accompanies a branch of the musculo-spiral nerve through the substance of the Triceps muscle and ends in the Anconeus below the outer condyle of the humerus.

The Nutrient Artery (a. nutricia humeri) of the shaft of the humerus arises from the brachial, about the middle of the arm. Passing downward it enters the nutrient canal of that bone near the insertion of the Coraco-brachialis muscle.

The Inferior Profunda (a. collateralis ulnaris superior), of small size, arises from the brachial, a little below the middle of the arm; piercing the internal intermuscular septum, it descends on the surface of the inner head of the Triceps muscle to the space between the inner condyle and olecranon, accompanied by the ulnar nerve, and terminates by anastomosing with the posterior ulnar recurrent and anastomotica magna. It sometimes supplies a branch to the front of the internal condyle, which anastomoses with the anterior ulnar recurrent.

The Anastomotica Magna (a. collateralis ulnaris inferior) arises from the brachial about two inches above the elbow-joint. It passes transversely inward upon the Brachialis anticus, and, piercing the internal intermuscular septum, winds round the back of the humerus between the Triceps and the bone, forming an arch above the olecranon fossa by its junction with the posterior articular branch of the superior profunda. As this vessel lies on the Brachialis anticus, branches ascend to join the inferior profunda, and others descend in front of the inner condyle to anastomose with the anterior ulnar recurrent. Behind the internal condyle an offset is given off which anastomoses with the inferior profunda and posterior ulnar recurrent arteries and supplies the Triceps.

The Muscular (rami musculares) are three or four large branches, which are distributed to the muscles in the course of the artery. They supply the Coraco-brachialis, Biceps, and Brachialis anticus muscles.
The Anastomosis around the Elbow-joint (Fig. 418).—The vessels engaged in this anastomosis may be conveniently divided into those situated in front and behind the internal and external condyles. The branches anastomosing in front of the internal condyle are the anastomotica magna, the anterior ulnar recurrent, and the anterior terminal branch of the inferior profunda. Those behind the internal condyle are the anastomotica magna, the posterior ulnar recurrent, and the posterior terminal branch of the inferior profunda. The branches anastomosing in front of the external condyle are the radial recurrent and the anterior terminal branch of the superior profunda. Those behind the external condyle (perhaps more properly described as being situated between the external condyle and the olecranon) are the anastomotica magna, the interosseous recurrent, and the posterior terminal branch of the superior profunda. There is also a large arch of anastomosis above the olecranon, formed by the interosseous recurrent, joining with the anastomotica magna and posterior ulnar recurrent.

From this description it will be observed that the anastomotica magna is the vessel most engaged, the only part of the anastomosis in which it is not employed being that in front of the external condyle.

The Radial Artery (A. Radialis) (Figs. 416, 417).

The radial artery appears, from its direction, to be the continuation of the brachial, but in size it is smaller than the ulnar. It commences at the bifurcation of the brachial, just below the bend of the elbow, and passes along the radial side of the forearm to the wrist; it then winds backward, round the outer side of the carpus, beneath the extensor tendons of the thumb, to the upper end of the space between the metacarpal bones of the thumb and index finger, and finally passes forward, between the two heads of the First dorsal interosseous muscle, into the palm of the hand, where it crosses the metacarpal bones to the ulnar border of the hand, to form the deep palmar arch. At its termination it inosculates with the deep branch of the ulnar artery. The relations of this vessel may thus be conveniently divided into three parts—viz., in the forearm, at the back of the wrist, and in the hand.

Relations.—In the forearm this vessel extends from opposite the neck of the radius to the forepart of the styloid process, being placed to the inner side of the shaft of the bone above and in front of it below. It is overlapped in the upper part of its course by the fleshy belly of the Supinator longus muscle; throughout the rest of its course it is superficial, being covered by the integument, the superficial and deep fasciae. In its course downward it lies upon the tendon of the Biceps, the Supinator brevis, the Pronator radii teres, the radial origin of the Flexor sublimis digitorum, the Flexor longus pollicis, the Pronator quadratus, and the lower extremity of the radius. In the upper third of its course it lies between the Supinator longus and the Pronator radii teres; in the lower two-thirds, between the tendons of the Supinator longus and the Flexor carpi radialis. The radial nerve lies close to the outer side of the artery in the middle third of its course, and some filaments of the musculo-cutaneous nerve, after piercing the deep fascia, run along the lower part of the artery as it winds round the wrist. The vessel is accompanied by vena comites throughout its whole course.

Plan of the Relations of the Radial Artery in the Forearm.

In front.

Skin, superficial and deep fasciae.
Supinator longus.

Inner side.
Pronator radii teres.
Flexor carpi radialis.

Radial Artery in Forearm.

Outer side.
Supinator longus.
Radial nerve (middle third).
At the wrist, as it winds round the outer side of the carpus from the styloid process to the first interosseous space, it lies upon the external lateral ligament, and then upon the scaphoid bone and trapezium, being covered by the extensor tendons of the thumb, subcutaneous veins, some filaments of the radial nerve, and the integument. It is accompanied by two veins and a filament of the musculo-cutaneous nerve.

In the hand it passes from the upper end of the first interosseous space, between the heads of the Adductor indicis or First dorsal interosseous muscle, transversely across the palm, to the base of the metacarpal bone of the little finger, where it inosculates with the communicating branch from the ulnar artery, forming the deep palmar arch.

The Deep Palmar Arch (arcus volaris profundus) (Fig. 417).—It lies upon the carpal extremities of the metacarpal bones and the Interossei muscles, being covered by the Adductor obliquus pollicis, the flexor tendons of the fingers, the Lumbricales, the Opponens, and Flexor brevis minimi digiti. Alongside of it is the deep branch of the ulnar nerve, but running in the opposite direction; that is to say, from within outward. The branches of the deep palmar arch are the palmar interosseous, perforating and palmar recurrent vessels (page 662).

Peculiarities.—The origin of the radial artery, according to Quain, is, in nearly one case in eight, higher than usual; more frequently arising from the axillary or upper part of the brachial than from the lower part of this vessel. The variations in the position of this vessel in the arm and at the bend of the elbow have been already mentioned. In the forearm it deviates less frequently from its position than the ulnar. It has been found lying over the fascia instead of beneath it. It has also been observed on the surface of the Supinator longus, instead of under its inner border; and in turning round the wrist it has been seen lying over, instead of beneath, the extensor tendons of the thumb.

Surface Marking.—The position of the radial artery in the forearm is represented by a line drawn from the outer border of the tendon of the Biceps in the centre of the hollow in front of the elbow-joint with a straight course to the inner side of the forepart of the styloid process of the radius.

Surgical Anatomy.—The radial artery is much exposed to injury in its lower third, and is frequently wounded by the hand being driven through a pane of glass, by the slipping of a knife or chisel held in the other hand, and similar accidents. The injury is often followed by a traumatic aneurism, for which the operation of extirpating or laying open the sac after securing the vessel above and below is required.

The operation of tying the radial artery is required in cases of wounds either of its trunk or of some of its branches, or for aneurism; and it will be observed that the vessel may be exposed in any part of its course through the forearm without the division of any muscular fibres. The operation in the middle or inferior third of the forearm is easily performed, but in the upper third, near the elbow, it is attended with some difficulty, from the greater depth of the vessel and from its being overlapped by the Supinator longus muscle.

To tie the artery in the upper third an incision three inches in length should be made through the integument, in a line drawn from the centre of the bend of the elbow to the front of the styloid process of the radius, avoiding the branches of the median vein; the fascia of the arm being divided and the Supinator longus drawn a little outward, the artery will be exposed. The vena comites should be carefully separated from the vessel, and the ligature passed from the radial to the ulnar side.

In the middle third of the forearm the artery may be exposed by making an incision of similar length on the inner margin of the Supinator longus. In this situation the radial nerve lies in close relation with the outer side of the artery, and should, as well as the veins, be carefully avoided.

In the lower third the artery is easily secured by dividing the integument and fascia in the interval between the tendons of the Supinator longus and Flexor carpi radialis muscles.
THE RADIAL ARTERY

Branches (Figs. 416, 417, and 418).—The branches of the radial artery may be divided into three groups, corresponding with the three regions in which the vessel is situated.

In the Forearm

|------------------|-----------|------------------------|---------------------|

In the Wrist

<table>
<thead>
<tr>
<th>Posterior Radial Carpal.</th>
<th>Metacarpal.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsales Pollicis.</td>
<td>Dorsalis Indicis.</td>
</tr>
</tbody>
</table>

Hand

<table>
<thead>
<tr>
<th>Princeps Pollicis.</th>
<th>Radialis Indicis.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforating.</td>
<td>Palmar Interosseous.</td>
</tr>
<tr>
<td>Palmar Recurrent.</td>
<td></td>
</tr>
</tbody>
</table>

The Radial Recurrent (a. recurrens radialis) (Fig. 417) is given off immediately below the elbow. It ascends between the branches of the musculo-spiral nerve lying on the Supinator brevis, and then between the Supinator longus and Brachialis anticus, supplying these muscles and the elbow-joint, and anastomosing with the terminal branches of the superior profunda.

The Muscular Branches (rami musculares) are distributed to the muscles on the radial side of the forearm.

The Anterior Radial Carpal (ramus carpeus volaris) (Fig. 417) is a small vessel which arises from the radial artery near the lower border of the Pronator quadratus, and, running inward in front of the radius, anastomoses with the anterior carpal branch of the ulnar artery. In this way an arterial anastomosis, the anterior carpal arch (rete carpi volare), is formed in front of the wrist; it is joined by branches from the anterior interosseous above, and by recurrent branches from the deep palmar arch below, and gives off branches which descend to supply the articulations of the wrist and carpus.

The Superficialis Volæ (ramus volaris superficialis) (Fig. 417) arises from the radial artery, just where this vessel is about to wind round the wrist. Running forward, it passes between, occasionally over, the muscles of the thumb, which it supplies, and sometimes anastomoses with the palmar portion of the ulnar artery, completing the superficial palmar arch. This vessel varies considerably in size; usually it is very small, and terminates in the muscles of the thumb; sometimes it is as large as the continuation of the radial.

The Posterior Radial Carpal (ramus carpeus dorsalis) (Fig. 418) is a small vessel which arises from the radial artery beneath the extensor tendons of the thumb; crossing the carpus transversely to the inner border of the hand, it anastomoses with the posterior carpal branch of the ulnar, forming the posterior carpal arch (rete carpi dorsale), which is joined by the termination of the anterior interosseous artery. From this arch are given off descending branches, the dorsal interosseous arteries (aa. metacarpeae dorsales) for the second, third, and fourth interosseous spaces, which run forward on the Second, Third, and Fourth dorsal interossei muscles, and divide into dorsal digital branches (aa. digitales dorsales), which supply the adjacent sides of the index, middle, ring, and little fingers respectively, communicating with the digital arteries of the superficial palmar arch. The dorsal interosseous arteries anastomose with the perforating branches from the deep palmar arch.

The Dorsales Pollicis (Fig. 418) are two vessels which run along the sides of the dorsal aspect of the thumb. They arise separately, or occasionally by a common trunk, near the base of the first metacarpal bone.

The Dorsalis Indicis (Fig. 418), also a small branch, runs along the radial side of the back of the index finger, sending a few branches to the Abductor indicis.
The Princeps Pollicis (a. princeps pollicis) (Fig. 417) arises from the radial just as it turns inward to the deep part of the hand; it descends between the Abductor indicis and Adductor obliquus pollicis, then between the Adductor transversus pollicis and Adductor obliquus pollicis, along the ulnar side of the metacarpal bone of the thumb, to the base of the first phalanx, where it divides into two branches, which run along the sides of the palmar aspect of the thumb, and form an arch on the palmar surface of the last phalanx, from which branches are distributed to the integument and pulp of the thumb.

The Radialis Indicis (a. volaris indicis radialis) (Fig. 417) arises close to the preceding, descends between the Abductor indicis and Adductor transversus pollicis, and runs along the radial side of the index finger to its extremity, where it anastomoses with the collateral digital artery from the superficial palmar arch. At the lower border of the Adductor transversus pollicis this vessel anastomoses with the princeps pollicis, and gives a communicating branch to the superficial palmar arch.

The Perforating Arteries (rami perforantes) (Fig. 417), three in number, pass backward from the deep palmar arch between the heads of the last three Dorsal interossei muscles, to inosculate with the dorsal interosseous arteries.

The Palmar Interosseous (aa. metacarpeae volares) (Fig. 417), three or four in number, arise from the convexity of the deep palmar arch; they run forward upon the Interossei muscles, and anastomose at the clefts of the fingers with the digital branches of the superficial arch.

The Palmar Recurrent Branches arise from the concavity of the deep palmar arch. They pass upward in front of the wrist, supplying the carpal articulations and anastomosing with the anterior carpal arch.

The Ulnar Artery (A. Ulnaris) (Figs. 416, 417).

The ulnar artery, the larger of the two terminal branches of the brachial, commences a little below the bend of the elbow, and crosses obliquely the
inner side of the forearm to the commencement of its lower half; it then runs along its ulnar border to the wrist, crosses the annular ligament on the radial side of the pisiform bone, and immediately beyond this bone divides into two branches which enter into the formation of the superficial and deep palmar arches.

Relations. In the Forearm.—In its upper half it is deeply seated, being covered by all the superficial Flexor muscles, excepting the Flexor carpi ulnaris; the median nerve is in relation with the inner side of the artery for about an inch and then crosses the vessel, being separated from it by the deep head of the Pronator radii teres; it lies upon the Brachialis anticus and Flexor profundus digitorum muscles. In the lower half of the forearm it lies upon the Flexor profundus, being covered by the integument, the superficial and deep fasciae, and is placed between the Flexor carpi ulnaris and Flexor sublimis digitorum muscles. It is accompanied by two vene comites; the ulnar nerve lies on its inner side for the lower two-thirds of its extent, and a small branch from the nerve descends on the lower part of the vessel to the palm of the hand.

Plan of Relations of the Ulnar Artery in the Forearm.

In front.

Superficial layer of flexor muscles.
Median nerve.
Superficial and deep fasciae.

Upper half.

Lower half.

Inner side.

Flexor carpi ulnaris.
Ulnar nerve (lower two-thirds).

Ulnar Artery in Forearm.

Outer side.

Flexor sublimis digitorum.

Behind.

Brachialis anticus.
Flexor profundus digitorum.

At the wrist (Fig. 416) the ulnar artery is covered by the integument and fascia, and lies upon the anterior annular ligament. On its inner side is the pisiform bone. The ulnar nerve lies at the inner side, and somewhat behind the artery; here the nerve and artery are crossed by a band of fibres, which extends from the pisiform bone to the anterior annular ligament.

Peculiarities.—The ulnar artery has been found to vary in its origin nearly in the proportion of one in thirteen cases, in one case arising lower than usual, about two or three inches below the elbow, and in all other cases much higher, the brachial being a more frequent source or origin than the axillary.

Variations in the position of this vessel are more frequent than in the radial. When its origin is normal the course of the vessel is rarely changed. When it arises high up it is almost invariably superficial to the Flexor muscles in the forearm, lying commonly beneath the fascia, more rarely between the fascia and integument. In a few cases its position was subcutaneous in the upper part of the forearm, subaponeurotic in the lower part.

Surface Marking.—On account of the curved direction of the ulnar artery the line on the surface of the body which indicates its course is somewhat complicated. First, draw a line from the front of the internal condyle of the humerus to the radial side of the pisiform bone; the lower two-thirds of this line represents the course of the middle and lower third of the ulnar artery. Secondly, draw a line from the centre of the antecubital space to the junction of the upper and middle third of the first line; this represents the course of the upper third of the artery.

Surgical Anatomy.—The application of a ligature to this vessel is required in cases of wound of the artery or of its branches, or in consequence of aneurism. In the upper half of the forearm the artery is deeply seated beneath the superficial flexor muscles, and the application of a ligature in this situation is attended with some difficulty. An incision is to be made in the course of a line drawn from the front of the internal condyle of the humerus to the outer side
of the pisiform bone, so that the centre of the incision is three fingers' breadth below the internal condyle. The skin and superficial fascia having been divided and the deep fascia exposed, the white line which separates the Flexor carpi ulnaris from the other flexor muscles is to be sought for, and the fascia incised in this line. The Flexor carpi ulnaris is now to be carefully separated from the other muscles, when the ulnar nerve will be exposed, and must be drawn aside. Some little distance below the nerve the artery will be found accompanied by its venae comites, and it may be ligatured by passing the needle from within outward. In the middle and lower third of the forearm this vessel may be easily secured by making an incision on the radial side of the tendon of the Flexor carpi ulnaris: the deep fascia being divided, and the Flexor carpi ulnaris and its companion muscle, the Flexor sublimis, being separated from each other, the vessel will be exposed, accompanied by its venae comites, the ulnar nerve lying on its inner side. The veins being separated from the artery, the ligature should be passed from the ulnar to the radial side, taking care to avoid the ulnar nerve.

Branches (Figs. 416, 417, and 418).—The branches of the ulnar artery may be arranged in the following groups:

- **Forearm**:
  - Anterior Ulnar Recurrent.
  - Posterior Ulnar Recurrent.
  - Interosseous:
    - Anterior Interosseous.
    - Posterior Interosseous.
  - Muscular.

- **Wrist**:
  - Anterior Carpal.
  - Posterior Carpal.

- **Hand**:
  - Deep Palmar or Communicating.
  - Superficial Palmar Arch.

The **Anterior Ulnar Recurrent** (*a. recurrentes ulnaris anterior*) (Fig. 417) arises immediately below the elbow-joint, passes upward and inward between the Brachialis anticus and Pronator radii teres, supplies twigs to those muscles, and, in front, of the inner condyle anastomoses with the anastomotica magna and inferior profunda.

The **Posterior Ulnar Recurrent** (*a. recurrentes ulnaris posterior*) (Figs. 417 and 418) is much larger, and arises somewhat lower than the preceding. It passes backward and inward, beneath the Flexor sublimis, and ascends behind the inner condyle of the humerus. In the interval between this process and the olecranon it lies beneath the Flexor carpi ulnaris, and ascending between the heads of that muscle, in relation with the ulnar nerve; it supplies the neighboring muscles and joint, and anastomoses with the inferior profunda, anastomotica magna, and interosseous recurrent arteries.

The **Interosseous Artery** (*a. interossea communis*) (Fig. 417) is a short trunk about half an inch in length, and of considerable size, which arises immediately, below the tuberosity of the radius, and, passing backward to the upper border of the interosseous membrane, divides into two branches, the anterior and posterior interosseous.

The **Anterior Interosseous** (*a. interossea volaris*) (Fig. 417) passes down the forearm on the anterior surface of the interosseous membrane, to which it is connected by a thin aponeurotic arch. It is accompanied by the interosseous branch of the median nerve, and overlapped by the contiguous margins of the Flexor profundus digitorum and Flexor longus pollicis muscles, giving off in this situation muscular branches and the nutrient arteries of the radius and ulna. At the upper border of the Pronator quadratus a branch, anterior communicating artery, descends beneath the muscle to anastomose in front of the carpus with the anterior carpal arch. The continuation of the artery passes behind the Pronator quadratus, and, piercing the interosseous membrane, reaches the back of the forearm, and anastomoses with the posterior interosseous artery (Fig. 418). It then descends to the back of the wrist to join the posterior carpal arch. The anterior interosseous gives
off a long, slender branch, the median artery or artery comes nervi mediana (a. mediana), which accompanies the median nerve and gives offsets to its substance. This artery is sometimes much enlarged, and accompanies the nerve into the palm of the hand.

The Posterior Interosseous Artery (a. interossea dorsalis) (Figs. 417 and 418) passes backward through the interval between the oblique ligament and the upper border of the interosseous membrane. It appears between the contiguous borders of the Supinator brevis and the Extensor ossis metacarpi pollicis, and runs down the back part of the forearm, between the superficial and deep layer of muscles, to both of which it distributes branches. At the lower part of the forearm it anastomoses with the termination of the anterior interosseous artery. Then, continuing its course over the head of the ulna, it joins the posterior carpal branch of the ulnar artery. This artery gives off, near its origin, the interosseous recurrent branch.

The interosseous recurrent artery (a. interossea recurrens) (Fig. 418) is a large vessel which ascends to the interval between the external condyle and olecranon, on or through the fibres of the Supinator brevis, but beneath the Anconeus, anastomosing with a branch from the superior profunda, and with the posterior ulnar recurrent and anastomotica magna.

The Muscular Branches (rami musculares) are distributed to the muscles along the ulnar side of the forearm.

The Anterior Carpal (ramus carpeus volaris) (Fig. 417) is a small vessel which crosses the front of the carpus beneath the tendons of the Flexor profundus, and inosculates with a corresponding branch of the radial artery.

The Posterior Carpal (ramus carpeus dorsalis) (Fig. 418) arises immediately above the pisiform bone, and winds backward beneath the tendon of the Flexor carpi ulnaris; it passes across the dorsal surface of the carpus beneath the extensor
tendons, anastomosing with a corresponding branch of the radial artery, and forming the posterior carpal arch (rete carpi dorsale) (Fig. 418). Immediately after its origin it gives off a small branch which runs along the ulnar side of the metacarpal bone of the little finger, forming one of the metacarpal arteries, and supplies the ulnar side of the dorsal surface of the little finger.

The Deep or Communicating Branch to the Deep Palmar Arch (ramus volaris profundus) (Fig. 417) passes deeply inward between the Abductor minimi digiti and Flexor brevis minimi digitii, near their origins; it anastomoses with the termination of the radial artery, completing the deep palmar arch.

The continuation of the trunk of the ulnar artery in the hand forms the greater part of the superficial palmar arch.

The Superficial Palmar Arch (arcus volaris superficialis) (Fig. 416) is formed by the ulnar artery in the hand, and is completed on the outer side by this vessel anastomosing with a branch from the radialis indicis, though sometimes the arch is completed by the ulnar anastomosing with the superficialis volae or the princeps pollicis of the radial artery. The arch passes across the palm, describing a curve, with its convexity forward, to the space between the ball of the thumb and the index finger, where the above-mentioned anastomosis takes place.

Relations.—The superficial palmar arch is covered by the skin, the Palmaris brevis, and the palmar fascia. It lies upon the annular ligament, the Flexor brevis of the little finger, the tendons of the superficial flexor of the fingers, and the divisions of the median and ulnar nerves.

Plan of the Relations of the Superficial Palmar Arch.

In front.
Skin.
Palmaris brevis.
Palmar fascia.

Behind.
Annular ligament.
Flexor brevis of little finger.
Superficial flexor tendons.
Divisions of median and ulnar nerves.

Branches.—The branches of the Superficial Palmar Arch are the Digital.

The Digital Branches (aa. digitales volares communes) (Fig. 416), four in number, are given off from the convexity of the superficial palmar arch. They supply the ulnar side of the little finger and the adjoining sides of the little, ring, middle, and index fingers, the radial side of the index finger and thumb being supplied from the radial artery. The digital arteries at first lie superficial to the flexor tendons, but as they pass forward with the digital nerves to the clefts between the fingers they lie between them, and are there joined by the interosseous branches from the deep palmar arch. The digital arteries on the sides of the fingers lie beneath the digital nerves; and about the middle of the last phalanx the two branches for each finger form an arch, from the convexity of which branches pass to supply the pulp of the finger.
Surface Marking.—The superficial palmar arch is represented by a curved line, starting from the outer side of the pisiform bone and carried downward as far as the middle third of the palm, and then curved outward on a level with the upper end of the cleft between the thumb and index finger. The deep palmar arch is situated about half an inch nearer to the carpus.

Surgical Anatomy.—Wounds of the palmar arches are of special interest, and are always difficult to deal with. When the superficial arch is wounded it is generally possible, by enlarging the wound if necessary, to secure the vessel and tie it; or in cases where it is found impossible to encircle the vessel with a ligature, a pair of hemostatic forceps may be applied and left on for twenty-four or forty-eight hours. Wounds of the deep arch are not so easily dealt with. It may be possible to secure the vessel by ligature or by forcipressure forceps, which may be left on; or, failing in this, the wound may be carefully plugged with gauze and an outside dressing carefully bandaged on. The plug should be allowed to remain untouched for three or four days. In wounds of the deep palmar arch a ligature may be applied to the bleeding points from the dorsum of the hand by resection of the upper part of the third metacarpal bone. It is use less in these cases to ligate one of the arteries of the forearm alone, and indeed simultaneous ligation of both radial and ulnar arteries above the wrist is often unsuccessful, on account of the anastomosis carried on by the carpal arches. Therefore, if unable to ligate the divided ends of the arch, upon the failure of pressure to arrest hemorrhage, it is expedient to apply a ligature to the brachial artery.

ARteries OF the TRUNK.

THE DESCENDING AORTA (Figs. 419, 420).

The descending aorta is divided into two portions, the thoracic and abdominal, in correspondence with the two great cavities of the trunk in which it is situated.

The Thoracic Aorta (Aorta Thoracalis) (Fig. 419).

The thoracic aorta commences at the lower border of the fourth thoracic vertebra, on the left side, and terminates at the aortic opening in the Diaphragm, in front of the lower border of the last thoracic vertebra. At its commencement it is situated on the left side of the spine; it approaches the median line as it descends, and at its termination lies directly in front of the spinal column. The direction of this vessel being influenced by the spine, upon which it rests, it describes a curve which is concave forward in the thoracic region. As the branches given off from it are small, the diminution in the size of the vessel is inconsiderable. It is contained in the back part of the posterior mediastinum.

Relations.—It is in relation, in front, from above downward, with the root of the left lung, the pericardium, the oesophagus, and the Diaphragm: behind, with the vertebral column and the vena azygos minor; on the right side, with the vena azygos major and thoracic duct; on the left side, with the left pleura and lung. The oesophagus, with its accompanying nerves, lies on the right side of the aorta above; but at the lower part of the thorax it gets in front of the aorta, and close to the Diaphragm is situated to its left side.

Plan of the Relations of the Thoracic Aorta.

In front.
Root of left lung.
Pericardium.
Oesophagus.
Diaphragm.

Right side.
Oesophagus (above).
Vena azygos major.
Thoracic duct.

Thoracic Aorta.

Left side.
Pleura.
Left lung.
Oesophagus (below).

Ventral column.
Superior and inferior azygos minor veins.
The aorta is occasionally found to be obliterated at a particular spot—viz., at the junction of the arch with the thoracic aorta just below the ductus arteriosus. Whether this is the result of disease or of congenital malformation is immaterial to our present purpose; it affords an interesting opportunity of observing the resources of the collateral circulation. The course of the anastomosing vessels, by which the blood is brought from the upper to the lower part of the artery, will be found well described in an account of two cases in the Pathological Transactions, vols. viii. and x. In the former (p. 162) Mr. Sydney Jones thus sums up the detailed description of the anastomosing vessels: "The principal communications by which the circulation was carried on, were—Firstly, the internal mammary, anastomosing with the intercostal arteries, with the phrenic of the abdominal aorta by means of the musculo-phrenic and comes nervi phrenici, and largely with the deep epigastric. Secondly, the superior intercostal, anastomosing anteriorly by means of a large branch with the first aortic intercostal, and posteriorly with the posterior branch of the same artery. Thirdly, the inferior thyroid, by means of a branch about the size of an ordinary radial, formed a communication with the first aortic intercostal. Fourthly, the transversalis colli, by means of very large communications with the posterior branches of the intercostals. Fifthly, the branches (of the subclavian and axillary) going to the side of the chest were large, and anastomosed freely with the lateral branches of the intercostals." In the second case also (vol. x. p. 97) Mr. Wood describes the anastomoses in a somewhat similar manner, adding the remark that "the blood which was brought into the aorta through the anastomoses of the intercostal arteries appeared to be expended principally in supplying the abdomen and pelvis, while the supply to the lower extremities had passed through the internal mammary and epigastrics."

**Surgical Anatomy.**—The student should now consider the effects likely to be produced by aneurism of the thoracic aorta, a disease of common occurrence. When we consider the great depth of the vessel from the surface and the number of important structures which surround it on every side, it may easily be conceived what a variety of obscure symptoms may arise from disease of this part of the arterial system, and how they may be liable to be mistaken for those of other affections. Aneurism of the thoracic aorta most usually extends backward along the left side of the spine, producing absorption of the bodies of the vertebrae, with curvature of the spine; whilst the irritation or pressure on the cord will give rise to pain, either in the chest, back, or loins, with radiating pain in the left upper intercostal spaces, from pressure on the intercostal nerves; at the same time the tumor may project backward on each side of the spine, beneath the integument, as a pulsating swelling, simulating abscess connected with diseased bone, or it may displace the oesophagus and compress the lung on one or the other side. If the tumor extend forward, it may press upon and displace the heart, giving rise to palpitation and other symptoms of disease of that organ; or it may displace, or even compress, the oesophagus, causing pain and difficulty of swallowing, as in stricture of that tube; and ultimately even open into it by ulceration, producing fatal hemorrhage. If the disease extends to the right side, it may press upon the thoracic duct; or it may burst into the pleural cavity or into the trachea or lung; and, lastly, it may open into the posterior mediastinum.

**Branches.**—Branches of the thoracic aorta supply the thoracic viscera. They are known as **rami viscerales**. The rami viscerales are the **bronchial**, **oesophageal, pericardial**, and **mediastinal arteries**. Other branches of the thoracic aorta supply the walls of the chest. They are known as **rami parietales** or **intercostal arteries**.

The **Bronchial Arteries** (aa. bronchiales) are the nutrient vessels of the lungs, and vary in number, size, and origin. That of the right side arises from the first aortic intercostal, or by a common trunk with the left bronchial from the front of the thoracic aorta. Those of the left side, usually two in number, arise from the thoracic aorta, one a little lower than the other. Each vessel is directed to the back part of the corresponding bronchus along which it runs, dividing and subdividing along the bronchial tube, supplying them, the cellular tissue of the lungs, the bronchial glands, and the oesophagus.

The **Oesophageal Arteries** (aa. oesophageae), usually four or five in number, arise from the front of the aorta, and pass obliquely downward to the oesophagus, forming a chain of anastomoses along that tube, anastomosing with the oesophageal branches of the inferior thyroid arteries above, and with ascending branches from the phrenic and gastric arteries below.

The **Pericardiac** (rami pericardiaci) are a few small vessels, irregular in their origin, distributed to the pericardium.

The **Posterior Mediastinal Arteries** (rami mediastinales) are numerous small vessels which supply the glands and loose areolar tissue in the mediastinum.
The lower mediastinal branches are known as the superior phrenic arteries (aa. phrenicae superiores), and are distributed to the posterior portion of the Diaphragm.

The Intercostal Arteries (aa. intercostales) (Fig. 419) arise from the back of the aorta. The aortic intercostals are usually nine in number on each side, the two superior intercostal spaces being supplied by the superior intercostal, a branch of the subclavian. The second space usually receives a considerable branch from the first aortic intercostal, which joins with the branch from the superior intercostal of the subclavian. The branch which runs along the lower border of the last rib is named the subcostal artery. The right intercostals are longer than the left, on account of the position of the aorta on the left side of the spine: they pass outward, across the bodies of the vertebrae, to the intercostal spaces, being covered by the pleura, the esophagus, thoracic duct, sympathetic nerve, and the vena azygos major; the left, passing outward, are crossed by the sympathetic; the upper two are also crossed by the superior intercostal vein, the lower by the azygos minor veins. In each intercostal space the artery passes outward, the External intercostal muscle being behind, the pleura and a thin fascia being in front. It then passes between the two layers of Intercostal muscles, and, having ascended obliquely to the lower border of the rib above it, is continued forward in the groove on its lower border and anastomoses with the anterior intercostal branches of the internal mammary. The first aortic intercostal anastomoses with the superior intercostal branch of the subclavian, and the last three intercostals pass between the abdominal muscles, inosculating with the epigastric in front and with the phrenic and lumbar arteries. Each intercostal artery is accompanied by a vein and nerve, the former being above, and the latter below, except in the upper intercostal spaces, where the nerve is at first above the artery. The arteries are protected from pressure during the action of the Intercostal muscles by fibrous arches thrown across, and attached by each extremity to the bone. The lower intercostal arteries are continued anteriorly from the intercostal spaces into the abdominal wall, except the subcostal, which lies throughout its whole course in the abdominal wall, since it is placed below the last rib. They pass behind the costal cartilages between the Internal oblique and Transversalis muscle to the sheath of the Rectus, where they anastomose with the internal mammary and the deep epigastric arteries. Behind, the subcostal artery anastomoses with the first lumbar artery.

Branches.—Each intercostal artery gives off numerous muscular branches (rami musculares).

Lateral cutaneous.
Posterior or dorsal branch.

Muscular.
Collateral intercostal.
Lateral Cutaneous Branches (rami cutanei laterales) come off from each intercostal and take a similar course to that of the lateral cutaneous branch of the intercostal nerve. These arteries are distributed to the walls of the chest and to the mammary gland (rami mammarii laterales).

Small branches pass to the mammary gland through the fourth, fifth, and sixth interspaces (rami mammarii medialis), and to the skin to the inner side of the nipple (rami cutanei anteriores).

The portion of the artery considered here as the prolongation of the main trunk is called by Spalteholz and others the anterior branch (ramus anterior).

The Posterior or Dorsal Branch (ramus posterior) of each intercostal artery passes backward to the inner side of the anterior costo-transverse ligament, and divides into an external branch (ramus cutaneus lateralis), and an internal branch (ramus cutaneus medialis), which are distributed to the muscles and integument of the back. Muscular branches (rami musculares) are given off by the dorsal branch soon after its origin. A spinal branch (ramus spinalis) comes off from the dorsal branch of the intercostal. It traverses the vertebral arches and enters the spinal canal through the intervertebral foramen, is distributed to the spinal cord and its membranes, and to the bodies of the vertebrae in the same manner as the lateral spinal branches from the vertebra. It gives off three branches, the neural, which accompanies the spinal nerve-roots, and is distributed to the membranes of the spinal cord. The post-central branch divides into ascending and descending branches, which, anastomosing with similar branches above and below, form a series of vertical arches in the back of the bodies of the vertebrae. The prelaminar branch is distributed to "the posterior wall of the spinal canal." 1

The Collateral Intercostal Branch comes off from the intercostal artery near the angle of the rib, and descends to the upper border of the rib below, along which it courses to anastomose with the anterior intercostal branch of the internal mammary or its branch, the musculo-phrenic.

The two lower intercostals on each side have not constant collateral branches. Even when present they are of small size and end in the wall of the abdomen. Each collateral intercostal branch gives off muscular branches.

Surgical Anatomy.—The position of the intercostal vessels should be borne in mind in performing the operation of paracentesis thoracis. The puncture should never be made nearer the middle line posteriorly than the angle of the rib, as the artery crosses the space internal to this point. In the lateral portion of the chest, where the puncture is usually made, the artery lies at the upper part of the intercostal space, and therefore the puncture should be made just above the upper border of the rib forming the lower boundary of the space.

The Abdominal Aorta (Aorta Abdominalis) (Fig. 420).

The abdominal aorta commences at the aortic opening of the Diaphragm, in front of the lower border of the body of the last thoracic vertebra, and, descending a little to the left side of the vertebral column, terminates on the body of the fourth lumbar vertebra, commonly a little to the left of the middle line, 2 where it divides into the two common iliac arteries. It diminishes rapidly in size, in consequence of the many large branches which it gives off. As it lies upon the bodies of the vertebrae, the curve which it describes is convex forward, the greatest convexity corresponding to the third lumbar vertebra, which is a little above and to the left side of the umbilicus.

1 Cunningham's Text-book of Anatomy.
2 Lord Lister, having accurately examined 30 bodies in order to ascertain the exact point of termination of this vessel, found it "either absolutely, or almost absolutely, mesial in 15, while in 13 it deviated more or less to the left, and in 2 was slightly to the right" (System of Surgery, edited by T. Holmes, 2d ed., vol. v, p. 632). —Ed. of 19th English edition.
Relations.—It is covered, in front, by the lesser omentum and stomach, behind which are the branches of the celiac axis and the solar plexus; below these, by the splenic vein, the pancreas, the left renal vein, the transverse portion of the duodenum, the mesentery, and aortic plexus. Behind, it is separated from the lumbar vertebrae and intervening disks by the anterior common ligament and left lumbar veins. On the right side it is in relation with the postcava (the right crus of the Diaphragm being interposed above), the vena azygos major, thoracic duct, and right semilunar ganglion; on the left side, with the sympathetic nerve and left semilunar ganglion.
THE BLOOD-VASCULAR SYSTEM

PLAN OF THE RELATIONS OF THE ABDOMINAL AORTA.

In front.
Lesser omentum and stomach.
Branches of the celiac axis and solar plexus.
Spleenic vein.
Pancreas.
Left renal vein.
Transverse duodenum.
Mesentery.
Aortic plexus.

Right side.
Right crus of Diaphragm.
Postcava.
Vena azygos major.
Thoracic duct.
Right semilunar ganglion.

Abdominal Aorta.

Left side.
Sympathetic nerve.
Left semilunar ganglion.

Behind.
Left lumbar veins.
Vertebral column.

Surface Marking.—In order to map out the abdominal aorta on the surface of the abdomen, a line must be drawn from the middle line of the body, on a level with the distal extremity of the seventh costal cartilage, downward and slightly to the left, so that it just skirts the umbilicus, to a zone drawn round the body opposite the highest point of the crest of the ilium. This point is generally half an inch below and to the left of the umbilicus, but as the position of this structure varies with the obesity of the individual, it is not a reliable landmark as to the situation of the bifurcation of the aorta.

Surgical Anatomy.—Aneurisms of the abdominal aorta near the celiac axis communicate in nearly equal proportion with the anterior and posterior parts of the artery.

When an aneurismatic sac is connected with the back part of the abdominal aorta, it usually produces absorption of the bodies of the vertebrae, and forms a pulsating tumor that presents itself in the left hypochondriac or epigastric regions, and is accompanied by symptoms of disturbance in the alimentary canal. Pain is invariably present, and is usually of two kinds—a fixed and constant pain in the back, caused by the tumor pressing on or displacing the branches of the solar plexus and splanchnic nerves; and a sharp lancinating pain, radiating along those branches of the lumbar nerves which are pressed on by the tumor; hence the pain in the loins, the testes, the hypogastrium, and in the lower limb (usually of the left side). This form of aneurism usually bursts into the peritoneal cavity or behind the peritoneum in the left hypochondriac region; or it may form a large aneurismatic sac, extending down as low as Poupart’s ligament; hemorrhage in these cases being generally very extensive, but slowly produced, and not rapidly fatal.

When an aneurismatic sac is connected with the front of the aorta near the celiac axis it forms a pulsating tumor in the left hypochondriac or epigastric regions, usually attended with symptoms of disturbance of the alimentary canal, as sickness, dyspepsia, or constipation, and is accompanied by pain, which is constant, but nearly always fixed in the loins, epigastrium, or some part of the abdomen; the radiating pain being rare, as the lumbar nerves are seldom implicated. This form of aneurism may burst into the peritoneal cavity or behind the peritoneum, between the layers of the mesentery, or, more rarely, into the duodenum; it seldom extends backward so as to affect the spine.

The abdominal aorta has been tied 15 times, and although none of the patients permanently recovered, still, as Prof. Keen’s lived 48 days, the possibility of the re-establishment of the circulation is proved. In the lower animals this artery has been often successfully tied. The vessel may be reached in several ways. In the original operation, performed by Sir A. Cooper, in 1817, an incision was made in the linea alba, the peritoneum opened in front, the finger carried down amongst the intestines toward the spine, the peritoneum again opened behind by scratching through the mesentery, and the vessel thus reached. Or either of the operations described below for securing the common iliac artery may, by extending the dissection a sufficient distance upward, be made use of to expose the aorta. The chief difficulty in the dead subject consists in isolating the artery in consequence of its great depth; but in the living subject the embarrassment resulting from the proximity of the aneurismal tumor, and the great probability of disease in the vessel itself, add to the dangers and difficulties of this formidable operation so greatly that it is very doubtful whether it ought ever to be performed.

The collateral circulation would be carried on by the anastomosis between the internal mam-
mary and the deep epigastric; by the free communication between the superior and inferior mesenteries if the ligature were placed above the latter vessel; or by the anastomosis between the inferior mesenteric and the internal pudic when (as is more common) the point of ligature is below the origin of the inferior mesenteric; and possibly by the anastomoses of the lumbar arteries with the branches of the internal iliac.

During an amputation at the hip the circulation through the abdominal aorta may be commanded by an assistant, who throws the entire weight of his body upon his rigidly extended forearm, the fist of which lies directly upon the patient's aorta (MacBurney's method). The abdominal tourniquet is no longer used, as modern methods enable the surgeon to do a practically bloodless hip-joint amputation (Wyeth's method, Senn's method, McBurney's method).

**Branches** (Fig. 420).—The branches of the abdominal aorta are—the

- Phrenic
- Coeliac Axis
- Gastric
- Hepatic
- Splenic
- Superior Mesenteric
- Suprarenal
- Renal
- Spermatic in male.**
- Ovarian in female.
- Lumbar.
- Sacra Media.

**Branches.**—The branches of the abdominal aorta may be divided into two sets: 1. Those supplying the visceræ (rami vicales). 2. Those distributed to the walls of the abdomen (rami parietales).

**Visceral Branches.**

- Coeliac Axis
- Gastric
- Hepatic
- Splenic
- Superior Mesenteric
- Inferior Mesenteric
- Suprarenal
- Renal
- Spermatic or Ovarian.

**Parietal Branches.**

- Inferior Phrenic.
- Lumbar.
- Sacra Media.

To expose the coeliac axis raise the liver, draw down the stomach, and then tear through the layers of the lesser omentum.

**The Coeliac Axis or Artery** *(a. coeliaca)* (Figs. 420, 421, and 422).—The coeliac axis is a short thick trunk, about half an inch in length, which arises from the aorta, close to the margin of the opening in the Diaphragm, behind the posterior parietal peritoneum, above the pancreas, and below the twelfth thoracic vertebra, and, passing nearly horizontally forward (in the erect posture), divides into three large branches, the *gastric*, *hepatic*, and *splenic*, occasionally giving off one of the phrenic arteries.

**Relations.**—It is covered by the lesser omentum. On the *right side* it is in relation with the right semilunar ganglion and the lobus Spigelii; on the *left side*, with the left semilunar ganglion and cardiac end of the stomach. *Below*, it rests upon the upper border of the pancreas.

The *Gastric* or *Coronary Artery* *(a. gastrica sinistra)* (Figs. 421 and 422), the smallest of the three branches of the coeliac axis, passes upward and to the left side, behind the peritoneum of the lesser peritoneal cavity, raising this portion of the peritoneum into a fold, known as the *left or secondary pancreatico-gastric fold*. It continues this course until it nearly reaches the lesser curvature of the stomach just below the cardia. It then turns to the front and curves forward to the cardiac orifice of the stomach, distributing branches to the oesophagus which Anastomose with the aortic oesophageal arteries; others supply the cardiac end of the stomach, inosculating with branches of the splenic artery; it then passes from left to right, along and upon the lesser curvature of the stomach and beneath the peritoneum to the pylorus, lying in its course between the layers of the lesser omentum, and sometimes dividing into two vessels, which run along each side
of the lesser curvature. One vascular arch gives branches to the anterior wall of the stomach and the other to the posterior wall, and both give them to the lesser omentum or the single artery gives branches to both surfaces of the organ and to the lesser omentum: at its termination it anastomoses with the pyloric branch or the two pyloric branches of the hepatic. It gives off **gastric branches** to both the anterior and posterior surfaces of the stomach, branches to the lesser omentum, a **small hepatic branch**, to the left lobe of the liver and **esophageal branches** (*rami oesophagei*) which anastomose with esophageal branches from the thoracic aorta and the inferior phrenic.

![Diagram of the blood vascular system](image)

**Fig. 421.**—The cœlic axis and its branches, the liver having been raised and the lesser omentum removed.

The **Hepatic Artery** (*a. hepatica*) (Figs. 421 and 422) in the adult is intermediate in size between the gastric and splenic; in the foetus it is the largest of the three branches of the cœlic axis. It is first directed forward and to the right, in the right pancreatico-gastric fold, to the upper margin of the pyloric end of the stomach, forming the lower boundary of the foramen of Winslow. It then passes upward between the layers of the lesser omentum, and in front of the foramen of Winslow, to the transverse fissure of the liver, where it divides into two branches, right and left, which supply the corresponding lobes of that organ, accompanying the ramifications of the vena portæ and hepatic duct. The hepatic artery, in its course along the right border of the lesser omentum, is in relation with the ductus communis choledochus and portal veins, the duct lying to the right of the artery and the vena portæ behind.
Its branches (Figs. 421 and 422) are—the
Pyloric.
Gastro-duodenalis  { Gastro-epiploica Dextra.
                { Pancreatico-duodenalis Superior
Cystic.

The pyloric or superior pyloric branch (a. gastrica dextra) arises from the hepatic, above the pylorus, descends between the layers of the lesser omentum to the pyloric end of the stomach, and passes from right to left along its lesser curvature, supplying it with branches and inosculating with the gastric branches of the coronary artery. The vessel often divides into two vascular arches to anastomose with two vascular arches from the gastric.

The gastro-duodenalis (Fig. 422) is a short but large branch, which descends near the pylorus, behind the first portion of the duodenum, and divides at the lower border of this viscus into two branches, the gastro-epiploica dextra and the pancreatico-duodenalis superior. Previous to its division, it gives off two or three small inferior pyloric branches, to the pyloric end of the stomach and pancreas.

The gastro-epiploica dextra runs from right to left along but distinctly below the greater curvature of the stomach, between the layers of the great omentum, anastomosing about the middle of the lower border of the stomach with the gastro-epiploica sinistra from the splenic artery. This vessel gives off numerous branches,
some of which ascend to supply both surfaces of the stomach, whilst others descend to supply the great omentum (rami epiploici).

The pancreatico-duodenalis superior descends between the contiguous margins of the duodenum and pancreas. It supplies the head of the pancreas by means of the rami pancreatica, and the duodenum by means of the rami duodenalis, and anastomoses with the inferior pancreatico-duodenal branch of the superior mesenteric artery and with the pancreatic branches of the splenic.

The cystic artery (a. cystica) (Fig. 421), usually a branch of the right hepatic, passes downward and forward along the cystic duct to the gall-bladder, and divides into two branches, one of which ramifies on its free surface beneath the peritoneum, the other between the gall-bladder and the substance of the liver.

The Splenic Artery (a. lienalis) (Figs. 421 and 422), in the adult, is the largest of the three branches of the celiac axis, and is remarkable for the extreme tortuosity of its course. It passes horizontally to the left side, behind the peritoneum and along the upper border of the pancreas, accompanied by the splenic vein, which lies below it, and on arriving near the spleen divides into branches, some of which enter the hilum of that organ to be distributed to its structure, whilst others are distributed to the pancreas and great end of the stomach. Its branches are—the

<table>
<thead>
<tr>
<th>Pancreatice Parvae.</th>
<th>Gastric (Vasa Brevia).</th>
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<tr>
<td>Rami Lienalis.</td>
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The pancreatic branches (rami pancreatici) are numerous small branches derived from the splenic as it runs behind the upper border of the pancreas, supplying its middle and left parts. One of these, larger than the rest, is given off from the splenic near the left extremity of the pancreas; it runs from left to right near the posterior surface of the gland, following the course of the pancreatic duct, and is called the pancreatica magna. The others are called the pancreaticae parvae. These vessels anastomose with the pancreatic branches of the pancreatico-duodenal arteries, derived from the hepatic on the one hand and superior mesenteric on the other.

The gastric branches or vasa brevia (aa. gastricae breves) consists of from five to seven small branches, which arise either from the termination of the splenic artery or from its terminal branches, and, passing from left to right, between the layers of the gastro-splenic omentum, are distributed to the great curvature of the stomach, anastomosing with branches of the gastric and gastro-epiploica sinistra arteries.

The gastro-epiploica sinistra, the largest branch of the splenic, runs from left to right along but distinctly below the great curvature of the stomach, between the layers of the great omentum, and anastomoses with the gastro-epiploica dextra. In its course it distributes several branches to the stomach, which ascend upon both surfaces; others descend to supply the omentum.

The rami lienales leave the splenic artery in the hilum and pass into the spleen.

Surgical Anatomy.—The operation of pylorectomy can be made an almost bloodless procedure by tying the gastric, the pyloric, and the right and left gastro-epiploic arteries. "The gastric is doubly tied about one inch below the cardiac orifice at a point where it joins the lesser curvature and is divided between the ligatures. The superior pyloric is doubly tied and divided. The fingers are passed beneath the pylorus, raising the gastro-colic omentum from the transverse mesocolon, and in this way safe ligation behind the pylorus of the right gastro-epiploic artery, or in most cases its parent vessel, the gastro-duodenal, is secured. The left gastro-epiploic is now tied at an appropriate point, and the necessary amount of gastro-colic omentum doubly tied and cut."1

The Superior Mesenteric Artery (*a. mesenterica superior*) (Figs. 420 and 423).—The superior mesenteric artery supplies the whole length of the small intestine, except the first part of the duodenum; it also supplies the cæcum and the ascending and transverse colon; it is a vessel of large size, arising from the forepart of the aorta about a quarter of an inch below the cæliac axis; being covered at its origin by the splenic vein and pancreas. It passes forward, between the pancreas and the transverse portion of the duodenum, crosses in front of this portion of the intestine, and descends between the layers of the mesentery to the right iliac fossa, where, considerably diminished in size, it anastomoses with one of its own branches—viz., the ileo-colic. In its course it forms an arch, the convexity of which is directed forward and downward to the left side, the concavity backward and upward to the right. It is accompanied by the superior mesenteric vein, and is surrounded by the superior mesenteric plexus of nerves.

In order to expose the superior mesenteric artery raise the great omentum and transverse colon, draw down the small intestines, and cut through the peritoneum where the transverse mesocolon and mesentery join; the artery will then be exposed just as it issues from beneath the lower border of the pancreas.

**Branches.**—Its branches are—the

- **Inferior Pancreatice-duodenal.**
- **Vasa Intestini Tenuis.**
- **Ileo-colic.**
- **Right Colic.**
- **Middle Colic.**

The **Inferior Pancreatice-duodenal** (*a. pancreatice-duodenalis inferior*) is given off from the superior mesenteric, or from its first intestinal branch behind the pancreas. It courses to the right between the head of the pancreas and duodenum, and then ascends to anastomose with the superior pancreatica-duodenal artery. It distributes branches to the head of the pancreas and to the transverse and descending portions of the duodenum.

The **Vasa Intestini Tenuis** (*aa. intestinales*) arise from the convex side of the superior mesenteric artery. They are usually from twelve to fifteen in number, and are distributed to the jejunum (*aa. jejunales*) and ileum (*aa. ileae*). They run parallel with one another between the layers of the mesentery, each vessel dividing into two branches, which unite with similar branches on each side, forming a series of arches the convexities of which are directed toward the intestine. From this first set of arches branches arise, which again unite with similar branches from either side, and thus a second series of arches is formed; and from these latter, a third and a fourth, or even a fifth, series of arches is constituted, diminishing in size the nearer they approach the intestine. From the terminal arches numerous small straight vessels arise which encircle the intestine, upon which they are distributed, ramifying between its coats. Throughout their course small branches are given off to the glands and other structures between the layers of the mesentery. (See the description of the vascular loops in the section upon the Intestines. The form and arrangement of the loops have been studied by Monks, of Boston.)

The **Ileo-colic Artery** (*a. ileocolica*) is the lowest branch given off from the concavity of the superior mesenteric artery. It descends between the layers of the mesentery to the right iliac fossa, where it divides into two branches. Of these, the inferior division inosculates with the termination of the superior mesenteric artery, forming with it an arch, from the convexity of which branches proceed to supply the termination of the ileum, the cæcum, the vermiform appendix, and the ileo-cecal valve. The superior division inosculates with the colica dextra and supplies the commencement of the colon.

The **Right Colic Artery** (*a. colica dextra*) arises from about the middle of the concavity of the superior mesenteric artery, and, passing behind the peritoneum
to the middle of the ascending colon, divides into two branches—a descending branch, which inosculates with the ileo-colic, and an ascending branch, which anastomoses with the colica media. These branches form arches, from the convexity of which vessels are distributed to the ascending colon. The branches of this vessel are covered with peritoneum only on their anterior aspect.

The Middle Colic Artery (a. colica media) arises from the upper part of the concavity of the superior mesenteric, and, passing forward between the layers of the transverse mesocolon, divides into two branches, the one on the right side inosculating with the colica dextra; that on the left side, with the colica sinistra, a branch of the inferior mesenteric. From the arches formed by their inosculation branches are distributed to the transverse colon. The branches of this vessel lie between the two layers of the transverse mesocolon.

Blood-supply of the Right Iliac Fossa.—The descending branch of the right colic artery by anastomosing with the ascending branch of the ileo-colic artery forms a vascular loop. The union of the descending branch of the ileo-colic artery with the terminal vessel of the superior mesenteric artery forms another vascular loop. These two loops give off secondary loops, and from the secondary loops come the vessels which supply the appendix, the cecum, and the lower end of the ileum. The branch which goes to the appendix is called the appendicular artery (a. appendicularis). If there is a distinct meso-appendix the artery passes along its unattached edge. If there is a rudimentary meso-appendix or no meso-appendix the artery

FIG. 423.—The superior mesenteric artery and its branches.
THE ABDOMINAL AORTA

usually lies upon the appendix from base to tip beneath the peritoneal covering. In females the appendix may receive an additional vessel from the ovarian, which vessel lies in the appendiculio-ovarian ligament.

The Inferior Mesenteric Artery (a. mesenterica inferior) (Figs. 420 and 424).—
The inferior mesenteric artery supplies the descending colon, the sigmoid flexure of the colon and the greater part of the rectum. It is smaller than the superior mesenteric, and arises from the left side of the aorta, between one and two inches above the division of that vessel into the common iliacs. It passes downward to the left iliac fossa, and then descends between the layers of the mesorectum,

into the pelvis, under the name of the superior hemorrhoidal artery. It lies at first in close relation with the left side of the aorta, and then passes as the superior hemorrhoidal in front of the left common iliac artery.

In order to expose the inferior mesenteric artery draw the small intestines and mesentery over to the right side of the abdomen, raise the transverse colon toward the thorax, and divide the peritoneum covering the front of the aorta.

Branches.—Its branches are—the

Left Colic. Superior Hæmorrhoidal. Sigmoid.
The Left Colic Artery (a. colica sinistra) passes behind the peritoneum, in front of the left kidney, to reach the descending colon, and divides into two branches—an ascending branch, which inosculates with the colica media; and a descending branch, which anastomoses with the sigmoid artery. From the arches formed by these inosculations branches are distributed to the descending colon.

The Sigmoid Arteries (aa. sigmoideae).—As a rule there are two of these vessels, but may be three. They run obliquely downward across the Psoas muscle to the sigmoid flexure of the colon, and divide into branches which supply that part of the intestine, anastomosing above with the left colic, and below with the superior hemorrhoidal artery.

The Superior Hemorrhoidal Artery (a. haemorrhoidalis superior) (Figs. 424 and 427), the continuation of the inferior mesenteric, descends into the pelvis between the layers of the mesorectum, crossing, in its course, the ureter and left common iliac vessels. Opposite the middle of the sacrum it divides into two branches, which descend one on each side of the rectum, and about five inches from the anus break up into several small branches, which pierce the muscular coat of the bowel and run downward, as straight vessels, placed at regular intervals from each other in the wall of the gut between its muscular and mucous coat, to the level of the internal sphincter; here they form a series of loops around the lower end of the rectum, and communicate with the middle hemorrhoidal arteries which are branches of the internal iliac and with the inferior hemorrhoidal branches of the internal pudic.

The Suprarenal Artery (a. suprarenalis media) (Fig. 420).—A suprarenal or capsular artery arises, one on each side of the aorta, opposite the superior mesenteric artery. It is a small vessel which passes obliquely upward and outward, over the crura of the Diaphragm, to the under surface of the suprarenal capsule, to which it is distributed, anastomosing with capsular branches from the phrenic and renal arteries. In the adult these arteries are of small size; in the fetus they are as large as the renal arteries.

The Renal Arteries (aa. renales) (Fig. 420).—The renal arteries are two large trunks which arise from the sides of the aorta immediately below the superior mesenteric artery. Each is directed outward across the crus of the Diaphragm, so as to form nearly a right angle with the aorta. The right is longer than the left, on account of the position of the aorta; it passes behind the postcava. The left is somewhat higher than the right. Before reaching the hilum of the kidney, each artery usually divides into four branches. Two of these vessels enter the anterior portion and two the posterior portion of the kidney. There may be but one renal artery; there may be two, three, four, or five branches. The greater number of the branches generally lie between the renal vein and ureter, the vein being in front of the arteries, the ureter behind. The anterior branches supply three-fourths of the kidney, the posterior supply one-fourth. Each vessel gives off a small branch to the suprarenal capsule (a. suprarenalis inferior) and branches to the ureter, ureteral branches, and to the surrounding cellular tissue and muscles, perirenal branches. Hyrtl, in 1870, pointed out that the renal artery gives off a branch which divides and supplies the dorsal or posterior portion of the kidney and its pelvis, and a branch which divides and supplies the ventral or anterior portion of the kidney and its pelvis. The two circulations are distinct and do not anastomose even at the periphery. Between these two sets of vessels is a bloodless zone, the exsanguinated renal zone of Hyrtl, which does not correspond to the median line, but is one-half inch dorsal to the lateral longitudinal renal border. The ventral or anterior segment is much the larger. In very rare instances the bloodless zone corresponds to the median line (Kümmel). An incision of the middle third of the kidney exactly at the junction of the two segments does not divide.
vessels. As the incision approaches either pole there is danger of cutting a branch (Schede). Frequently there is a second renal artery, which is given off from the abdominal aorta either above or below the renal artery proper, the former being the more common position. Instead of entering the kidney at the hilum, an accessory renal artery usually pierces the upper or the lower part of the gland.

The Spermatic Arteries (aa. spermaticae internae) (Fig. 420).—The internal spermatic arteries are distributed to the testes. They are two slender vessels of considerable length, which arise from the front of the aorta a little below the renal arteries. Each artery passes obliquely outward and downward behind the peritoneum, resting on the Psoas muscle, the right spermatic lying in front of the postcava, the left behind the sigmoid flexure of the colon. It then crosses obliquely over the ureter (to which it sends a few branches) and the lower part of the external iliac artery to reach the internal abdominal ring, through which it passes, and accompanies the other constituents of the spermatic cord along the inguinal canal to the scrotum, where it becomes tortuous and is prolonged as the testicular artery (a. testicularis), which accompanies the vas deferens, anastomosing with the artery of the vas deferens and is distributed to the epididymis, the back part of the tunica albuginea, and the substance of the testes. The spermatic artery in the inguinal canal gives off cremasteric branches to supply the Cremaster muscle. In the canal and scrotum the artery lies behind the pampiniform plexus and in front of the vas deferens.

The Ovarian Arteries (aa. ovaricae).—The ovarian arteries (Fig. 428) are the corresponding arteries in the female to the spermatic in the male. They supply the ovaries, are shorter than the spermatic, and do not pass out of the abdominal cavity. The origin and course of the first part of the artery are the same as the spermatic in the male, but on arriving at the margin of the pelvis the ovarian artery passes inward, between the two layers of the broad ligament of the uterus,
to be distributed to the ovary, **ovarian branches**. Branches go to the Fallopian tube, **tubal branches**, the ureter, **ureteral branches**, and the broad ligament, **ligamentous branches**. A branch passes on to the side of the uterus and anastomoses with the uterine arteries, **uterine branch**. Other offsets are continued along the round ligament through the inguinal canal, to the integument of the labium and groin.

At an early period of foetal life, when the testes or ovaries lie by the side of the spine below the kidneys, the spermatic or ovarian arteries are short; but as these organs descend from the abdomen into the scrotum or pelvis, the arteries become gradually lengthened.

**The Inferior Phrenic Arteries (aa. phrenicae inferiores)** (Fig. 420).—The inferior phrenic arteries are two small vessels which present much variety in their origin. They may **arise** separately from the front of the aorta, immediately above the coeliac axis, or by a common trunk, which may spring either from the aorta or from the coeliac axis. Sometimes one is derived from the aorta, and the other from one of the renal arteries. In only one out of thirty-six cases examined did these arteries arise as two separate vessels from the aorta. They diverge from one another across the crura of the Diaphragm, and then pass obliquely upward and outward upon the under surface of the Diaphragm. The **left phrenic** passes behind the esophagus and runs forward on the left side of the esophageal opening. The **right phrenic** passes behind the postcava, and ascends along the right side of the aperture for transmitting that vein. Near the back part of the central tendon each vessel divides into two branches. The **internal branch** runs forward to the front of the thorax, supplying the Diaphragm and anastomosing with its fellow of the opposite side, and with the **musculo-phrenic** and **comes nervi phrenici** branches of the internal mammary. The **external branch** passes toward the side of the thorax and inosulates with the **intercostal arteries**. The internal branch of the right phrenic gives off a few vessels to the postcava, and the left one some branches to the esophagus. Each vessel also sends **capsular branches (rami suprarenales superior)** to the suprarenal capsule of its own side. The spleen on the left side and the liver on the right also receive a few branches from these vessels.

**The Lumbar Arteries (aa. lumbales)**.—The lumbar arteries are analogous to the intercostals. They are usually four in number on each side, and **arise** from the back part of the aorta, nearly at right angles with that vessel. They pass outward and backward, around the sides of the bodies of the lumbar vertebrae, behind the sympathetic nerve and the Psoas magnus muscle, those on the right side being covered by the postcava, and the two upper ones on each side by the crura of the Diaphragm. In the interval between the transverse processes of the vertebra each artery gives off a **dorsal branch**.

After the formation of the dorsal branch the artery passes outward, having a variable relation to the Quadratus lumborum muscle. Most frequently the first lumbar passes in front of the muscle and the others behind it; sometimes the order is reversed and the lowest lumbar passes in front of the muscle. At the outer border of the Quadratus they are continued between the abdominal muscles, anastomose with branches of the epigastric and internal mammary in front, the intercostals above, and branches of the ilio-lumbar and circumflex iliac below. The lumbar arteries are also distributed to the skin of the sides of the abdomen.

The **Dorsal Branch (ramus dorsalis)** gives off, immediately after its origin, a **spinal branch**, which enters the spinal canal. The dorsal branch then continues its course backward between the transverse processes, and is distributed to the muscles and integument of the back, anastomosing with similar branches of the adjacent lumbar arteries and with the posterior branches of the intercostal arteries.
THE COMMON IliAC ARTERIES

The Spinal Branch (ramus spinalis) enters the vertebral canal through the intervertebral foramen, to be distributed to the spinal cord and its membranes and to the bodies of the vertebrae in the same manner as the lateral spinal branches from the vertebral (see page 640).

The Middle Sacral Artery (a. sacralis media) (Fig. 427).—The middle sacral artery is a small vessel, which arises from the back part of the aorta just at its bifurcation. It descends upon the last lumbar vertebra, and along the middle line of the front of the sacrum, to the upper part of the coccyx, where it anastomoses with the lateral sacral arteries, and terminates in a minute branch, which runs down to the situation of the body described as Luschka's gland. It gives off on each side opposite the body of the fifth lumbar vertebra a branch known as the a. lumbalis ima. From the middle sacral artery branches arise which run through the mesorectum to supply the posterior surface of the rectum. Other branches are given off on each side, which anastomose with the lateral sacral arteries, and send off small offsets which enter the anterior sacral foramina.

The artery is the representative of the caudal prolongation of the aorta of animals, and its lateral branches correspond to the intercostal and lumbar arteries in the thoracic and lumbar regions.

THE COMMON IliAC ARTERIES (AA. IliacaE Communes) (Figs. 420, 427).

The abdominal aorta divides into the two common iliac arteries. The bifurcation usually takes place on the left side of the body of the fourth lumbar vertebra. The common iliac arteries are about two inches in length; diverging from the termination of the aorta, they pass downward and outward to the margin of the pelvis, each divides opposite the intervertebral substance, between the last lumbar vertebra and the sacrum, into two branches, the internal and external iliac arteries, the latter supplying the lower extremity; the former, the viscera and parietae of the pelvis.

The right common iliac is somewhat longer than the left, and passes more obliquely across the body of the last lumbar vertebra. In front of it are the peritoneum, the small intestines, branches of the sympathetic nerve, and, at its point of division, the ureter. Behind, it is separated from the fourth and fifth lumbar vertebrae, with the intervening intervertebral disk, by the two common iliac veins. On its outer side, it is in relation with the postcava and the right common iliac vein, above, and the Psoas magnus muscle below.

The left common iliac is in relation, in front, with the peritoneum, branches of the sympathetic nerve, and the superior hemorrhoidal artery; and is crossed at its point of bifurcation by the ureter. It rests on the bodies of the fourth and fifth lumbar vertebrae, with the intervening intervertebral disk. The left common iliac vein lies partly on the inner side, and partly beneath the artery; on its outer side, the artery is in relation with the Psoas magnus muscle.

PLAN OF THE RELATIONS OF THE COMMON ILIAC ARTERIES.

In front. In front.
Peritoneum. Peritoneum.
Small intestines. Sympathetic nerves.
Sympathetic nerves. Superior hemorrhoidal artery.
Ureter. Ureter.

Right Common Iliac. Left common iliac vein. Left Common Iliac.
Vena cava. Right common iliac vein. Psous muscle.
Right Common Iliac.
THE BLOOD-VASCULAR SYSTEM

Fourth and fifth lumbar vertebrae. Right and left common iliac veins. Fourth and fifth lumbar vertebrae. Left common iliac vein.

Branches.—The common iliac arteries give off small branches to the peritoneum, Psoas magnus, ureters, and the surrounding cellular tissue, and occasionally give origin to the iliolumbar or renal arteries.

Peculiarities.—The point of origin varies according to the bifurcation of the aorta. In three-fourths of a large number of cases the aorta bifurcated either upon the fourth lumbar vertebra or upon the intervertebral disk between it and the fifth, the bifurcation being, in one case out of nine below, and in one out of eleven above, this point. In ten out of every thirteen cases the vessel bifurcated within half an inch above or below the level of the crest of the ilium, more frequently below than above.

The point of division is subject to great variety. In two-thirds of a large number of cases it was between the last lumbar vertebra and the upper border of the sacrum, being above that point in one case out of eight and below it in one case out of six. The left common iliac artery divides lower down more frequently than the right.

The relative length, also, of the two common iliac arteries varies. The right common iliac was the longer in sixty-three cases, the left in fifty-two, whilst they were both equal in fifty-three. The length of the arteries varied in five-sevenths of the cases examined from an inch and a half to three inches; in about half of the remaining cases the artery was longer and in the other half shorter, the minimum length being less than half an inch, the maximum four and a half inches. In two instances the right common iliac has been found wanting, the external and internal iliacs arising directly from the aorta.

Surface Marking.—Draw a zone around the body opposite the highest part of the crest of the ilium; in this line take a point half an inch to the left of the middle line. From this draw two lines to points midway between the anterior superior spines of the ilium and the symphysis pubis. These two diverging lines will represent the course of the common and external iliac arteries. Draw a second zone round the body corresponding to the level of the anterior superior spines of the ilium: the portion of the diverging lines between the two zones will represent the course of the common iliac artery; the portion below the lower zone, that of the external iliac artery.

Surgical Anatomy.—The application of a ligature to the common iliac artery may be required on account of aneurism or hemorrhage implicating the external or internal iliacs. Now that the surgeon no longer dreads opening the peritoneal cavity, there can be no question that the easiest and best method of tying the artery is by a transperitoneal route. The abdomen is opened by an incision in either the semilunar line or the linea alba; the intestines are drawn to one side and the peritoneum covering the artery divided. The sheath is then opened, and the needle passed from within outward. On the right side great care must be exercised in passing the needle, since both the common iliac veins lie behind the artery. After the vessel has been tied the incision in the peritoneum over the artery should be sutured. Formerly there were two different methods by which the common iliac artery was tied without opening the peritoneal cavity: 1, an anterior or iliac incision, by which the vessel is approached more directly from the front; and 2, a posterior abdominal or lumbar incision, by which the vessel is reached from behind. If the surgeon select the iliac region, a curved incision, from five to eight inches in length, according to the amount of fat, is made, commencing just outside the middle of Poupart's ligament and a finger's breadth above it, and carried outward toward the anterior superior iliac spine, then upward toward the ribs, and finally curving inward toward the umbilicus. The abdominal muscles and transversalis fascia are divided, and the peritoneum raised upward and inward until the Psoas is reached. The artery will be found on the inner side of this muscle, and is to be cleared with a director, especial care being taken on the right side, as here the common iliac veins lie behind the artery. The aneurism needle is to be passed from within outward. But if the aneurismal tumor should extend high up in the abdomen, along the external iliac, it is better to select the posterior or lumbar route, making an incision partly in the abdomen, partly in the loin. The incision is commenced at the anterior extremity of the last rib, proceeding directly downward to the ilium; it is then curved forward along the crest of the ilium and a little above it to the anterior superior spine of that bone. The abdominal muscles having been cautiously divided in succession, the transversalis fascia must be carefully cut through, and the peritoneum, together with the ureter, separated from the artery and pushed aside; the sacro-iliac articulation must then be felt for, and upon it the vessel will be felt pulsating, and may be fully exposed in close connection with the accompanying vein. On the right side both common iliac veins, as well as the postcava, are in close connection with the artery, and must be carefully avoided. On the left side the vein usually lies on the inner side and behind the artery; but it occasionally happens that the two common iliac veins are joined on
the left instead of the right side, which would add much to the difficulty of an operation in such a case. The common iliac artery may be so short that danger may be apprehended from secondary hemorrhage if a ligature is applied to it. It would be preferable, in such a case, to tie both the external and internal iliacs near their origin.

**Collateral Circulation.**—The principal agents in carrying on the collateral circulation after the application of a ligature to the common iliac are—the anastomoses of the hemorrhoidal branches of the internal iliac with the superior hemorrhoidal from the inferior mesenteric; the anastomoses of the uterine and ovarian arteries and of the vesical arteries of opposite sides; of the lateral sacral with the middle sacral artery; of the epigastric with the internal mammary, inferior intercostal, and lumbar arteries; of the circumflex iliac with the lumbar arteries; of the ilio-lumbar with the last lumbar artery; of the obturator artery, by means of its pubic branch, with the vessel of the opposite side and with the deep epigastric.

**Compression of the Common Iliac Arteries.**—The common iliac arteries may be compressed by Davy’s lever. The instrument consists of a gum-elastic tube about two feet long, in which fits a round wooden “lever” considerably longer than the tube. A small quantity of olive oil having been injected into the rectum, the gum-elastic tube, softened in hot water, is passed into the bowel sufficiently far to permit its pressing upon the common iliac artery as it lies in the groove between the last lumbar vertebra and the Psoas muscle. The wooden lever is then inserted into the tube, and the projecting end carried toward the opposite thigh and raised, when it acts as a lever of the first order, the anus being the fulcrum. In cases where the mesorectum is abnormally short it may be impossible, without unjustifiable force, to compress the artery on the right side. In amputation of the hip-joint the common iliac can be compressed most certainly and safely by opening the abdomen and compressing the vessel by means of the fingers against the Psoas muscle (McBurney’s method).

**The Internal Iliac Artery** (Figs. 420, 427).

The internal iliac or hypogastric artery (a. hypogastrica) supplies the walls and viscera of the pelvis, the generative organs, and inner side of the thigh. It is a short thick vessel, smaller in the adult than the external iliac, and about an inch and a half in length. It arises at the point of bifurcation of the common iliac, and, passing downward to the upper margin of the great sacro-sciatic foramen, divides into two large trunks, an anterior and posterior; from its anterior division a partially obliterated cord, a part of the fetal hypogastric artery, extends forward to the bladder.

**Relations.**—*In front*, with the ureter, which is between the artery and the peritoneum. *Behind*, with the internal iliac vein, the lumbo-sacral cord, and Pyriformis muscle. By its *outer side*, near its origin, with the Psoas magnus muscle.

**Plan of the Relations of the Internal Iliac Artery.**

\[
\text{In front.} \\
\text{Peritoneum.} \\
\text{Ureter.} \\
\]

\[
\begin{array}{c}
\text{Outer side.} \\
\text{Psoas magnus.} \\
\end{array}
\]

\[
\begin{array}{c}
\text{Internal} \\
\text{Iliac.} \\
\end{array}
\]

\[
\text{Behind.} \\
\text{Internal iliac vein.} \\
\text{Lumbo-sacral cord.} \\
\text{Pyriformis muscle.} \\
\]

*In the foetus* the hypogastric artery is twice as large as the external iliac, and appears to be the continuation of the common iliac. Instead of dipping into the pelvis, it passes forward to the bladder, and ascends along the sides of that viscus to its summit, to which it gives branches; it then passes upward along the back part of the anterior wall of the abdomen to the umbilicus, converging toward its fellow of the opposite side. Having passed through the umbilical
opening, the two arteries twine round the umbilical vein in the umbilical cord, and ultimately ramify in the placenta. The portion of the vessel within the abdomen is called the hypogastric artery; the portion external to that cavity, the umbilical artery.

At birth, when the placental circulation ceases, the upper portion of the hypogastric artery, extending from the summit of the bladder to the umbilicus, contracts, and ultimately dwindles to a solid fibrous cord; but the lower portion, extending from its origin (in what is now the internal iliac artery) for about an inch and a half to the wall of the bladder, and thence to the summit of that organ, is not totally impervious, though it becomes considerably reduced in size, and serves to convey blood to the bladder under the name of the superior vesical artery.

Peculiarities as Regards Length.—In two-thirds of a large number of cases the length of the internal iliac varied between an inch and an inch and a half; in the remaining third it was more frequently longer than shorter, the maximum length being three inches, the minimum half an inch.

The lengths of the common and internal iliac arteries bear an inverse proportion to each other, the internal iliac artery being long when the common iliac is short, and vice versa.

As Regards its Place of Division.—The place of division of the internal iliac varies between the upper margin of the sacrum and the upper border of the sacro-sciatic foramen.

The arteries of the two sides in a series of cases often differed in length, but neither seemed constantly to exceed the other.
Surgical Anatomy.—The application of a ligature to the internal iliac artery may be required in cases of aneurism or hemorrhage affecting one of its branches. The vessel may be secured by making an incision through the abdominal parietes in the iliac region in a direction and to an extent similar to that for securing the common iliac; the transversalis fascia having been cautiously divided, and the peritoneum pushed inward from the iliac fossa toward the pelvis, the finger may feel the pulsation of the external iliac at the bottom of the wound, and by tracing this vessel upward the internal iliac is arrived at, opposite the sacro-iliac articulation. It should be remembered that the vein lies behind and on the right side, a little external to the artery, and in close contact with it; the ureter and peritoneum, which lie in front, must also be avoided. The degree of facility in applying a ligature to this vessel will mainly depend upon the length of the vessel. It has been seen that in the great majority of the cases examined the artery was short, varying from an inch to an inch and a half; in these cases the artery is deeply seated in the pelvis; when, on the contrary, the vessel is longer, it is found partly above that cavity. If the artery is very short, as occasionally happens, it would be preferable to apply a ligature to the common iliac or to both the external and internal iliacs at their origin.

A better method of tying the internal iliac artery is by an abdominal section in the median line and reaching the vessel through the peritoneal cavity. This plan has been advocated by Denis, of New York, on the following grounds: (1) It in no way increases the danger of the operation; (2) it prevents a series of accidents which have occurred during ligature of the artery by the older methods; (3) it enables the surgeon to ascertain the exact extent of disease in the main arterial trunk, and select his spot for the application of the ligature; and (4) it occupies much less time.

Collateral Circulation.—In Professor Owen’s dissection of a case in which the internal iliac artery had been tied by Stevens ten years before death for aneurism of the sciatic artery, the internal iliac was found impervious for about an inch above the point where the ligature had been applied, but the obliteration did not extend to the origin of the external iliac, as the ilio-lumbar artery arose just above this point. Below the point of obliteration the artery resumed its natural diameter, and continued so for half an inch, the obturator, lateral sacral, and gluteal arising in succession from the latter portion. The obturator artery was entirely obliterated. The lateral sacral artery was as large as a crow’s quill, and had a very free anastomosis with the artery of the opposite side and with the middle sacral artery. The sciatic artery was entirely obliterated as far as its point of connection with the aneurismal tumor, but on the distal side of the sac it was continued down along the back of the thigh nearly as large in size as the femoral, being pervious about an inch below the sac by receiving an anastomosing vessel from the profunda. The circulation was carried on by the anastomoses of the uterine and ovarian arteries; of the opposite vesical arteries; of the hemorrhoidal branches of the internal iliac with those from the inferior mesenteric; of the obturator artery, by means of its pubic branch, with the vessel of the opposite side and with the epigastric and internal circumflex; of the circumflex and perforating branches of the profunda femoris with the sciatic; of the gluteal with the posterior branches of the sacral arteries; of the ilio-lumbar with the last lumbar; of the lateral sacral with the middle sacral; and of the circumflex iliac with the ilio-lumbar and gluteal.

Branches (Fig. 427).—The branches of the internal iliac are:

**From the Anterior Trunk.**
- Superior Vesical.
- Middle Vesical.
- Inferior Vesical.
- Middle Haemorrhoidal.
- Obturator.
- Internal Pudic.
- Sciatic.

**From the Posterior Trunk.**
- Ilio-lumbar.
- Lateral Sacral.
- Gluteal.

**In female**
- Uterine.
- Vaginal.

The **Superior Vesical** (*a. vesicalis superior*) (Fig. 427), is that part of the foetal hypogastric artery, which remains pervious after birth. It extends to the side of the bladder, distributing numerous branches to the apex and body of the organ. From one of these a slender vessel is derived which accompanies the vas deferens in its course to the testis, where it anastomoses with the spermatic artery. This is the **artery of the vas deferens**. Other branches supply the ureter.

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1 Medico-Chirurgical Transactions, vol. xvi.
The **Middle Vesical** (*a. vesicalis medialis*) (Fig. 427), usually a branch of the superior, is distributed to the base of the bladder and under surface of the vesiculae seminales.

The **Inferior Vesical** (*a. vesicalis inferior*) (Fig. 427) arises from the anterior division of the internal iliac, frequently in common with the middle hemorrhoidal, and is distributed to the base of the bladder, the prostate gland, and vesiculae seminales. The branches distributed to the prostate communicate with the corresponding vessel of the opposite side.

The **Middle Haemorrhoidal Artery** (*a. haemorrhoidalis media*) (Fig. 427) usually arises together with the preceding vessel. It supplies the anus and parts outside the rectum, anastomosing with the other hemorrhoidal arteries.

The **Uterine Artery** (*a. uterina*) (Fig. 428) passes inward from the anterior trunk of the internal iliac to the neck of the uterus. Ascending in a tortuous course on the side of this viscus, between the layers of the broad ligament, it distributes branches to its substance and to the round ligament and the Fallopian tube (*ramus tubarius*), anastomosing, near its termination, with the ovarian artery. It gives a branch to the ovary (*ramus ovarii*), which anastomoses with a branch from the ovarian branches to the cervix uteri (*cervico-uteri*), and a branch which descends on the vagina (*cervico-vaginal*), and, joining with branches from the vaginal arteries, form a median longitudinal vessel both in front and behind; these descend on the anterior and posterior surfaces of the vagina, and are named the **azygos arteries of the vagina**.

The **Vaginal Artery** (*a. vaginalis*) is analogous to the inferior vesical in the male; it descends upon the vagina, supplying its mucous membrane, and sending branches to the neck of the bladder and contiguous part of the rectum. There may be several vaginal arteries. The vaginal artery assists in forming the **azygos arteries** of the vagina, which are anterior and posterior vessels, running longitudinally, and due to anastomoses of the branches of the vaginal from each side and the cervico-vaginal artery.
Luschka, Hyrtl, Waldeyer, Robinson, and others, instead of describing the ovarian and uterine arteries as two distinct vessels, regard them as constituting the chief parts of one vessel, the *arteria uterina ovarica*. What has been called "the circle of Robinson" is composed of a spiral segment (the arteria uterina ovarica), with a portion of the abdominal aorta, common iliacs, and internal iliacs. Robinson¹ has made a careful study of this vascular circle; he shows that it is of great importance in certain surgical procedures, and that its remarkable "capacity for extension" saves it from damage when the uterus is enormously distended by pregnancy, or when it is "drawn through the pudendum with traction forceps for palpation, inspection, or repair."

The author just quoted says further that the utero-ovarian artery has three origins, because it develops from the Wolffian body: The *ovarian segment arises* from the abdominal aorta. The *uterine segment arises* from the anterior branch of the internal iliac artery. The *artery of the round ligament arises* from the deep epigastric. The arteria uterina ovarica artery secures nutrition to the uterus by bringing blood from three sources. It is spiral throughout its entire course, in certain parts is convoluted or looped, and it is accompanied by the pampiniform plexus of veins.

The three origins of this vessel are freely united by anastomoses, and rami laterales are given off, which unite the bilateral vessels in the median line. Robinson describes three bifurcations of the utero-ovarian artery. The *distal bifurcation*, which is "about midway between the uterus and the pelvic wall," and forms an acute angle with the main vessel. This bifurcation indicates the point of division of the external from the internal genitals. The cervico-vaginal artery supplies the external genitals. The *proximal bifurcation* marks the situation of the ovary. The artery bifurcates at an acute angle into two branches to supply the ovary and Fallopian tube. The *middle bifurcation* consists of (1) the division of the uterine segment at the angle formed by the uterus and oviduct ("forming the ramus oviductus and ramus ovarii") and (2) "the bifurcation of the ramus oviductus forming the ramus oviductus and the ramus ligamenti teretis, or the segment of the round ligament."²

**Surgical Anatomy.**—As pointed out by Robinson, the source of bleeding after vaginal hysterectomy is usually the torn and unclamped cervico-vaginal artery.

As previously pointed out, the spiral and convoluted shape of the utero-ovarian artery allows the uterus, ovary, and tube to be drawn into the vagina without injury to the vessels. Robinson points out that in vaginal hysterectomy the genital circle is not divided and only the rami laterales which go to the uterus are cut, the ovaries retaining a normal blood-supply and continuing to functionate.

The *Obturator Artery* (*a. obturatoria*) (Fig. 427) usually arises from the anterior trunk of the internal iliac; frequently from the posterior. It passes forward, below the brim of the pelvis, to the upper part of the obturator foramen, accompanied by the obturator nerve and vein, and, escaping from the pelvic cavity through a short canal formed by a groove on the under surface of the ascending ramus of the os pubis and the arched border of the obturator membrane, it divides into an internal and external branch. In the pelvic cavity this vessel lies upon the pelvic fascia, beneath the peritoneum, and a little below the obturator nerve.

**Branches.**—*Within the pelvis*, the obturator artery gives off an *iliac branch* (*ramus iliacus*) to the iliac fossa, which supplies the bone and the Iliacus muscle, and anastomoses with the ilio-lumbar artery; a *vesical branch* (*ramus vesicalis*), which runs backward to supply the bladder; and a *pubic branch* (*ramus pubicus*), which is given off from the vessel just before it leaves the pelvic cavity. This branch ascends upon the back of the os pubis, communicating with offsets from

¹ Robinson. The Utero-ovarian Artery.
² Ibid.
the deep epigastric artery and with the corresponding vessel of the opposite side. It is placed on the inner side of the femoral ring. External to the pelvis, the obturator artery divides into an internal and an external branch, which are deeply situated beneath the Obturator externus muscle.

The Internal Branch (ramus anterior) curves downward along the inner margin of the obturator foramen, lying beneath the Obturator externus muscle; it distributes branches to the Obturator externus, Pectineus, Adductors, and Gracilis, and anastomoses with the external branch and with the internal circumflex artery.

The External Branch (ramus posterior) curves round the outer margin of the obturator foramen, also lying beneath the Obturator externus muscle, to the space between the Gemellus inferior and Quadratus femoris, where it divides into two branches: one, smaller, courses inward around the lower margin of the foramen and anastomoses with the internal branch and with the internal circumflex; the other inclines outward in the groove below the acetabulum (a. acetabulis), and supplies the muscles attached to the tuberosity of the ischium and anastomoses with the sciatic artery. It sends a branch to the hip-joint through the cotyloid notch, which ramifies on the round ligament as far as the head of the femur.

Peculiarities (Fig. 429).—In two out of every three cases the obturator arises from the internal iliac; in one case in three and a half from the epigastric; and in about one in seventy-two cases by two roots from both vessels. It arises in about the same proportion from the external iliac artery. The origin of the obturator from the epigastric is not commonly found on both sides of the same body.

When the obturator artery arises at the front of the pelvis from the epigastric, it descends almost vertically to the upper part of the obturator foramen. The artery in this course usually lies in contact with the external iliac vein and on the outer side of the femoral ring (Fig. 429, A); in such cases it would not be endangered in the operation for femoral hernia. Occasionally, however, it curves inward along the free margin of Gimbernat’s ligament (Fig. 429, B), and under such circumstances would almost completely encircle the neck of a hernial sac (supposing a hernia to exist in such a case), and would be in great danger of being wounded if an operation was performed.

The Internal Pudic Artery (a. pudenda interna) (Figs. 427, 430, and 431) is the smaller of the two terminal branches of the anterior trunk of the internal iliac, and supplies the external organs of generation. Though the course of the artery is the same in the two sexes, the vessel is much smaller in the female than in the male, and the distribution of its branches somewhat different. The description of its arrangement in the male will first be given, and subsequently the differences which it presents in the female will be mentioned.

The Internal Pudic Artery in the Male passes downward and outward to the lower border of the great sacro-sciatic foramen, and emerges from the pelvis between the Pyriformis and Coecygeus muscles; it then crosses the spine of the ischium and re-enters the pelvis through the lesser sacro-sciatic foramen. The artery now crosses the Obturator internus muscle along the outer wall of the ischio-rectal fossa, being situated about an inch and a half above the lower margin of the ischial tuberosity. It is here contained in a sheath of the obturator fascia, and
gradually approaches the margin of the rami of the ischium, along which it passes forward and upward, pierces the base of the superficial layer of the triangular ligament of the urethra, and runs forward along the inner margin of the rami of the os pubis, and divides into its two terminal branches, the **dorsal artery of the penis** and the **artery of the corpus cavernosum**.

**Relations.**—In the first part of its course, within the pelvis, it lies in front of the Pyriformis muscle and sacral plexus of nerves, and the sciatic artery, and on the outer side of the rectum (on the left side). As it crosses the spine of the ischium it is covered by the Gluteus maximus and overlapped by the great sacro-sciatic ligament. Here the obturator nerve lies to the inner side and the nerve to the Obturator internus to the outer side of the vessel. In the pelvis it lies on the outer side of the ischio-rectal fossa, upon the surface of the Obturator internus muscle, contained in a fibrous canal, the **canal of Alcock**, formed by the splitting of the obturator fascia. It is accompanied by the pudic veins and the pudic nerve.

**Peculiarities.**—The internal pudic is sometimes smaller than usual, or fails to give off one or two of its usual branches; in such cases the deficiency is supplied by branches derived from an additional vessel, the **accessory pudic**, which generally arises from the internal pudic artery before its exit from the great sacro-sciatic foramen. It passes forward along the lower part of the bladder and across the side of the prostate gland to the root of the penis, where it perforates the triangular ligament and gives off the branches usually derived from the pudic artery. The deficiency most frequently met with is that in which the internal pudic ends as the artery of the bulb, the artery of the corpus cavernosum and arteria dorsalis penis being derived from the accessory pudic. Or the pudic may terminate as the superficial perineal, the artery of the bulb being derived, with the other two branches, from the accessory vessel. Occasionally the accessory pudic artery is derived from one of the other branches of the internal iliac, most frequently the inferior vesical or the obturator.

**Surgical Anatomy.**—The relation of the accessory pudic to the prostate gland and urethra is of the greatest interest in a surgical point of view, as this vessel is in danger of being wounded in the operation of lateral lithotomy. The student should also study the position of the internal pudic artery and its branches, when running a normal course with regard to the same operation. The superficial and the transverse perineal arteries are, of necessity, divided in this operation, but the hemorrhage from these vessels is seldom excessive; should a ligature be required, it can readily be applied on account of their superficial position. The artery of the bulb may be divided if the incision be carried too far forward, and injury of this vessel may be attended with serious or even fatal consequences. The main trunk of the internal pudic artery may be wounded if the incision be carried too far outward; but, being bound down by the strong obturator fascia and under cover of the rami of the ischium, the accident is not very likely to occur unless the vessel runs an anomalous course.

**Branches.**—The branches of the internal pudic artery are—the

- **Muscular**.
- **Inferior Haemorrhoidal**.
- **Superficial Perineal**.

**Dorsal Artery of the Penis.**

The **Muscular Branches** consist of two sets—one given off in the pelvis, the other as the vessel crosses the ischial spine. The former are several small offsets which supply the Levator ani, the Obturator internus, the Pyriformis, and the Coccygeus muscles. The branches given off outside the pelvis are distributed to the adjacent part of the Gluteus maximus and External rotator muscles. They Anastomose with branches of the sciatic artery.

The **Inferior Haemorrhoidal Artery** (*a. haemorrhoidalis inferior*) arises from the internal pudic as it passes above the tuberosity of the ischium. Crossing the ischio-rectal fossa it is distributed by two or three terminal branches to the muscles and integument of the anal region. Instead of one inferior hemorrhoidal artery two or three small vessels may arise from the internal pudic.

The **Superficial Perineal Artery** (*a. perinei*) (Fig. 430) supplies the scrotum and the muscles and integument of the perineum. It arises from the internal pudic in front
of the preceding branches, and turns upward, crossing either over or under the Transversus perinei superficialis muscle, and runs forward, parallel to the pubic arch, in the interspace between the Accelerator urinæ and Erector penis muscles, both of which it supplies, and is finally distributed to the skin and dartos of the scrotum. In its passage through the perineum it lies beneath the superficial perineal fascia.

The Transverso Perineal Artery is a small branch which arises either from the internal pudic or from the Transversus perinei superficialis muscle. It runs transversely inward along the cutaneous surface of the Transversus perinei superficialis muscle, which it supplies, as well as the structures between the anus and bulb of the urethra, and anastomoses with the like vessel of the opposite side.

The **Artery of the Bulb** (a. bulbi urethrae) is a large but very short vessel which arises from the internal pudic between the two layers of the triangular ligament, and, passing nearly transversely inward, between the fibres of the Compressor urethrae muscle, it pierces the bulb of the urethra, which it supplies, and continues anteriorly in the corpus spongiosum to the glans and anastomoses with its fellow of the opposite side. It gives off a small branch which descends to supply Cowper's gland.

**Surgical Anatomy.**—This artery is of considerable importance in a surgical point of view, as it is in danger of being wounded in the median or the lateral operation of lithotomy—an accident usually attended in the adult with alarming hemorrhage. The vessel is sometimes very small, occasionally wanting, or even double. It sometimes arises from the internal pudic earlier than usual, and crosses the perineum to reach the back part of the bulb. In such a case the vessel could hardly fail to be wounded in the performance of the lateral operation of lithotomy. If, on the contrary, it should arise from an accessory pudic, it lies more forward than usual and is out of danger in the operation.

The **Artery of the Corpus Cavernosum** (a. profunda penis), one of the terminal branches of the internal pudic, arises from that vessel while it is situated between

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Fig. 430.—The superficial muscles and vessels of the perineum.
the two layers of the triangular ligament; it pierces the superficial layer, and, entering the crus penis obliquely, it runs forward in the centre of the corpus cavernosum, to which its branches are distributed.

The **Dorsal Artery of the Penis** (a. dorsalis penis) ascends between the crus and pubic symphysis, and, piercing the triangular ligament, passes between the two layers of the suspensory ligament of the penis, and runs forward on the dorsum of the penis to the glans, where it divides into two branches which supply the glans and prepuce. On the dorsum of the penis it lies immediately beneath the integument, parallel with the dorsal vein and the corresponding artery of the opposite side. It supplies the integument and fibrous sheath of the corpus cavernosum, sending branches through the sheath to anastomose with the preceding vessel.

The **Internal Pudic Artery in the Female** is smaller than in the male. Its origin and course are similar, and there is considerable analogy in the distribution of its branches. The superficial perineal artery supplies the labia pudendi; the artery of the bulb supplies the bulbi vestibuli and the erectile tissue of the vagina; the artery of the corpus cavernosum (a. profunda clitoridis) supplies the cavernous body of the clitoris; and the arteria dorsalis clitoridis supplies the dorsum of that organ, and terminates in the glans and in the membranous fold corresponding to the prepuce of the male.

The **Sciatic Artery** (a. glutaea inferior) (Fig. 431), the larger of the two terminal branches of the anterior trunk of the internal iliac, is distributed to the muscles at the back of the pelvis. It passes down to the lower part of the great sacro-sciatic foramen behind the internal pudic artery, resting on the sacral plexus of nerves and Pyriformis muscle, and escapes from the pelvis through this foramen between the Pyriformis and Coccygeus. It then descends in the interval between the trochanter major and tuberosity of the ischium, accompanied by the sciatic nerves, and covered by the Gluteus maximus, and is continued down the back of the thigh supplying the skin, and anastomosing with branches of the perforating arteries.
Within the pelvis it distributes branches to the Pyriformis, Coccygeus, and Levator ani muscles; some hemorrhoidal branches, which supply the rectum, and occasionally take the place of the middle hemorrhoidal artery; and vesical branches to the base and neck of the bladder, vesiculæ seminales, and prostate gland. External to the pelvis it gives off the following branches:

- Coccygeal.
- Inferior Gluteal.
- Comes Nervi Ischiadici.

The Coccygeal Branch runs inward, pierces the great sacro-sciatic ligament, and supplies the Gluteus maximus, the integument, and other structures on the back of the coccyx.

The Inferior Gluteal Branches, three or four in number, supply the Gluteus maximus muscle, anastomosing with the gluteal artery in the substance of the muscle.

The Comes Nervi Ischiadici (a. comitans n. ischiadici) is a long, slender vessel which accompanies the great sciatic nerve for a short distance; it then penetrates it and runs in its substance to the lower part of the thigh.

The Muscular Branches supply the Gluteus maximus, anastomosing with the gluteal artery in the substance of the muscle; the external rotators, anastomosing with the internal pudic artery; and the muscles attached to the tuberosity of the ischium, anastomosing with the external branch of the obturator and the internal circumflex arteries.

The Anastomotic Artery is directed downward across the external rotators and assists in forming the so-called crucial anastomosis by anastomosing with the superior perforating and the internal and external circumflex arteries.

The Articular Branch, generally derived from the anastomotic, is distributed to the capsule of the hip-joint.

The Ilio-lumbar Artery (a. ilio lumbalis), given off from the posterior trunk of the internal iliac, turns upward and outward between the obturator nerve and lumbo-sacral cord, to the inner margin of the Psoas muscle, behind which it divides into a lumbar and an iliac branch.

The Lumbar Branch (ramus lumbalis) supplies the Psoas and Quadratus lumborum muscles, anastomosing with the last lumbar artery, and sends a small spinal branch (ramus spinalis) through the intervertebral foramen, between the last lumbar vertebra and the sacrum, into the spinal canal, to supply the cauda equina.

The Iliac Branch (ramus iliacus) descends to supply the Iliacus muscle; some offsets, running between the muscle and the bone, anastomose with the iliac branch of the obturator; one of these enters an oblique canal to supply the diploë, whilst others run along the crest of the ilium, distributing branches to the Gluteal and Abdominal muscles, and anastomose in their course with the gluteal, circumflex iliac, and external circumflex arteries.

The Lateral Sacral Artery (a. sacralis lateralis) (Fig. 427) runs downward. It may be single, but usually there are two on each side, the superior and inferior divisions.

The Superior Division, which is of large size, passes inward, and, after anastomosing with branches from the middle sacral, enters the first or second anterior sacral foramen, gives spinal branches (rami spinalis) to the contents of the sacral canal, and, escaping by the corresponding posterior sacral foramen, supplies the skin and muscles on the dorsum of the sacrum, anastomosing with the gluteal.

The Inferior Division passes obliquely across the front of the Pyriformis muscle and sacral nerves to the inner side of the anterior sacral foramina, descends on the front of the sacrum, and anastomoses over the coccyx with the middle sacral and opposite lateral sacral arteries. In its course it gives off spinal branches which
enter the anterior sacral foramina (*rami spinales*); these, after supplying the contents of the sacral canal, escape by the posterior sacral foramina, and are distributed to the muscles and skin on the dorsal surface of the sacrum, anastomosing with the gluteal.

The **Gluteal Artery** (*a. glutaeæ superior*) (Fig. 431) is the largest branch of the internal iliac, and appears to be the continuation of the posterior division of that vessel. It is a short thick trunk, which passes out of the pelvis above the upper border of the Pyriformis muscle, and immediately divides into a **superficial** and **deep branch**. Within the pelvis it gives off a few muscular branches to the Iliacus, Pyriformis, and Obturator internus, and, just previous to emerging from that cavity, a nutrient artery, which enters the ilium.

The **Superficial Branch** passes beneath the Gluteus maximus and divides into numerous branches, some of which supply that muscle, whilst others perforate its tendinous origin, and supply the integument covering the posterior surface of the sacrum, anastomosing with the posterior branches of the sacral arteries.

The **Deep Branch** runs between the Gluteus medius and minimus, and subdivides into two. Of these, the **superior division** (*ramus superior*), continuing the original course of the vessel, passes along the upper border of the Gluteus minimus to the anterior superior spine of the ilium, anastomosing with the circumflex iliac and ascending branches of the external circumflex artery. The **inferior division** (*ramus inferior*) crosses the Gluteus minimus obliquely to the trochanter major, distributing branches to the Glutei muscles, and inosculates with the external circumflex artery. Some branches piece the Gluteus minimus to supply the hip-joint.

**Surface Marking.**—The position of the three main branches of the internal iliac, the sciatic, internal pudic, and gluteal, which may occasionally be the object of surgical interference, is indicated on the surface in the following way: A line is to be drawn from the posterior superior iliac spine to the posterior superior angle of the great trochanter, with the limb slightly flexed and rotated inward; the point of emergence of the gluteal artery from the upper part of the sciatic notch will correspond with the junction of the upper with the middle third of this line. A second line is to be drawn from the same point to the outer part of the tuberosity of the ischium; the junction of the lower with the middle third marks the point of emergence of the sciatic and pudic arteries from the great sciatic notch.

**Surgical Anatomy.**—Any of these three vessels may require *ligation* for a wound or for aneurism, which is generally traumatic. The gluteal artery is ligated by turning the patient two-thirds over on his face and making an incision from the posterior superior spine of the ilium to the upper and posterior angle of the great trochanter. This must expose the Gluteus maximus muscle, and its fibres are to be separated through the whole thickness of the muscle and pulled apart with retractors. The contiguous margins of the gluteus medius and Pyriformis are now to be separated from each other, and the artery will be exposed emerging from the sciatic notch. In ligation of the sciatic artery, the incision should be made parallel with that for ligation of the gluteal, but one inch and a half lower down. After the fibres of the Gluteus maximus have been separated, the vessel is to be sought for at the lower border of the Pyriformis; the great sciatic nerve, which lies just above it, forming the chief guide to the artery. The internal pudic can be reached through the incision used to reach the sciatic.

**The External Iliac Artery (A. Iliaca Externa)** (Fig. 427).

The external iliac artery is larger in the adult than is the internal iliac. It passes obliquely downward and outward along the inner border of the Psoas muscle, from the bifurcation of the common iliac to Poupart's ligament, where it enters the thigh and becomes the femoral artery.

**Relations.**—*In front*, with the peritoneum, subperitoneal areolar tissue or *Abernethy's fascia*, the termination of the ileum on the right side, and the sigmoid flexure on the left, and a thin layer of fascia derived from the iliac fascia, which surrounds the artery and vein. At its origin it is occasionally crossed by the ureter. The spermatic vessels descend for some distance upon it near its termination, and it is
crossed in this situation by the genital branch of the genito-femoral nerve and the deep circumflex iliac vein; the vas deferens curves down along its inner side. Behind, it is in relation with the external iliac vein, which, at Poupart's ligament, lies at its inner side; on the left side the vein is altogether internal to the artery. Externally, it rests against the Psoas muscle, from which it is separated by the iliac fascia. The artery rests upon this muscle, near Poupart's ligament. Numerous lymphatic vessels and glands are found lying on the front and inner side of the vessel.

**Plan of the Relations of the External Iliac Artery.**

*In front.*

- Peritoneum, intestines, and fascia.
- Lymphatic vessels and glands.
- Spermatic vessels.
- Genito-femoral nerve (genital branch).
- Deep circumflex iliac vein.

*Outer side.*

- Psoas magnus.
- Iliac fascia.

*Inner side.*

- External iliac vein and vas deferens near Poupart's ligament.

*Behind.*

- External iliac vein.
- Psoas magnus.

**Surface Marking.**—The surface line indicating the course of the external iliac artery has been already given (see page 684).

**Surgical Anatomy.**—The application of a ligature to the external iliac may be required in cases of aneurism of the femoral artery or for a wound of the artery. This vessel may be secured in any part of its course, excepting near its upper end, which is to be avoided on account of the proximity of the great stream of blood in the internal iliac, and near its lower end, which should also be avoided, on account of the proximity of the deep epigastric and circumflex iliac vessels. The patient having been placed in the supine position, an incision should be made, commencing below at a point about three-quarters of an inch above Poupart's ligament, and a little external to its middle, and running upward and outward, parallel to Poupart's ligament, to a point one inch internal and one inch above the anterior superior spine of the ilium. When the artery is deeply seated more room will be required, and may be obtained by curving the incision from the point last named inward toward the umbilicus for a short distance. Another mode of ligating the vessel is the plan advocated by Sir Astley Cooper, by making an incision close to Poupart's ligament from about half an inch outside of the external abdominal ring to one inch internal to the anterior superior spine of the ilium. This incision, being made in the course of the fibres of the aponeurosis of the external oblique, is less likely to be followed by a ventral hernia, but there is danger of wounding the epigastric artery, and only the lower end of the vessel can be ligated. Abernethy, who first tied this artery, made his incision in the course of the vessel. The abdominal muscles and transversalis fascia having been cautiously divided, the peritoneum should be separated from the iliac fossa and raised toward the pelvis; and on introducing the finger to the bottom of the wound, the artery may be felt pulsating along the inner border of the Psoas muscle. The external iliac vein is generally found on the inner side of the artery, and must be cautiously separated from it by the finger-nail or handle of the knife, and the aneurism needle should be introduced on the inner side, between the artery and the vein.

Ligation of the external iliac artery has recently been performed by a transperitoneal method. An incision four inches in length is made in the semilunar line, commencing about an inch below the umbilicus and carried through the abdominal wall into the peritoneal cavity. The intestines are then pushed upward and held out of the way by a broad abdominal retractor, and an incision is made through the peritoneum at the margin of the pelvis in the course of the artery, and the vessel is secured in any part of its course which may seem desirable to the operator. The advantages of this operation appear to be that if it is found necessary, the common iliac artery can be ligated instead of the external iliac without extension or modification of the incision; and secondly, that the vessel can be ligated without in any way interfering with the coverings of the sac of an aneurism. Possibly a disadvantage may exist in the greater risk of hernia after this method.
Collateral Circulation.—The principal anastomoses in carrying on the collateral circulation, after the application of a ligature to the external iliac, are—the iliolumbar with the circumflex iliac; the glutal with the external circumflex; the obturator with the internal circumflex; the sciatic with the superior perforating and circumflex branches of the profunda artery; and the internal pudic with the external pudic. When the obturator arises from the epigastric it is supplied with blood by branches, either from the internal iliac, the lateral sacral, or the internal pudic. The epigastric receives its supply from the internal mammary and inferior intercostal arteries, and from the internal iliac by the anastomoses of its branches with the obturator.

In the dissection of a limb eighteen years after the successful ligature of the external iliac artery by Sir A. Cooper, the report of which is to be found in Guy’s Hospital Reports, vol. i. p. 50, the anastomosing branches are described in three sets: An anterior set.—1. A very large branch from the iliolumbar artery to the circumflex iliac; 2. another branch from the iliolumbar, joined by one from the obturator, and breaking up into numerous tortuous branches to anastomose with the external circumflex; 3. two other branches from the obturator, which passed over the brim of the pelvis, communicated with the epigastric, and then broke up into a plexus to anastomose with the internal circumflex. An internal set.—Branches given off from the obturator, after quitting the pelvic, which ramified among the adductor muscles on the inner side of the hip-joint, and joined most freely with branches of the internal circumflex. A posterior set.—1. three large branches from the glutal to the external circumflex; 2. several branches from the sciatic around the great sciatic notch to the internal and external circumflex, and the perforating branches of the profunda.

Branches.—Besides several small branches to the Psoas muscle and the neighboring lymphatic glands, the external iliac gives off two branches of considerable size—the deep epigastric and deep circumflex iliac arteries.

The Internal or Deep Epigastric Artery (a. epigastrica inferior) (Fig. 427) arises from the external iliac a few lines above Poupart’s ligament. It at first descends to reach this ligament, and then ascends obliquely along the inner margin of the internal abdominal ring, lying between the transversalis fascia and peritoneum, and, continuing its course upward, it pierces the transversalis fascia, and passing over the semilunar fold of Douglas, enters the sheath of the Rectus muscle. It then ascends on the posterior surface of the muscle, and finally divides into numerous branches which anastomose, above the umbilicus, with the superior epigastric branch of the internal mammary and with the inferior intercostal arteries (Fig. 413). The deep epigastric artery bears a very important relation to the internal abdominal ring as it passes obliquely upward and inward from its origin from the external iliac. In this part of its course it lies along the lower and inner margin of the ring and beneath the commencement of the spermatic cord. As it passes to the inner side of the internal abdominal ring it is crossed by the vas deferens in the male and the round ligament in the female.

Branches.—The branches of this vessel are the following: The cremasteric (a. spermatica externa in the male, a. ligamenti teretis uteri in the female), which accompanies the spermatic cord, and supplies the Cremaster muscle and other coverings of the cord, anastomosing with the spermatic artery in the male, and which accompanies the round ligament in the female; a pubic branch (ramus pubicus), which runs along Poupart’s ligament, and then descends behind the os pubis to the inner side of the femoral ring, and anastomoses with offsets from the obturator artery; muscular branches, some of which are distributed to the abdominal muscles and peritoneum, anastomosing with the lumbar and circumflex iliac arteries; cutaneous branches perforate the tendon of the External oblique, and supply the integument, anastomosing with branches of the superficial epigastric.

Peculiarities.—The origin of the deep epigastric may take place from any part of the external iliac between Poupart’s ligament and two inches and a half above it, or it may arise below this ligament, from the common femoral or from the deep femoral.

Union with Branches.—It frequently arises from the external iliac by a common trunk with the obturator. Sometimes the epigastric arises from the obturator, the latter vessel being furnished by the internal iliac, or the epigastric may be formed by two branches, one derived from the external iliac, the other from the internal iliac.
Surgical Anatomy.—The deep epigastric artery follows a line drawn from the middle of Poupart's ligament toward the umbilicus; but shortly after this line crosses the linea semilunaris the direction changes, and the course of the vessel is directly upward in the line of junction of the inner third with the outer two-thirds of the Rectus muscle. It has important surgical relations, in addition to the fact that it is one of the principal means, through its anastomosis with the internal mammary, in establishing the collateral circulation after ligature of either the common or external iliac arteries. It lies close to the internal abdominal ring, and is therefore internal to an oblique inguinal hernia, but external to a direct inguinal hernia, as the hernia emerges from the abdomen. It forms the outer boundary of Hesselbach's triangle. It is in close relationship with the spermatic cord, which lies in front of it in the inguinal canal, separated only by the transversalis fascia. The vas deferens hooks round its outer side.

The Deep Circumflex Iliac Artery (\(a. \text{circumflexa ilium profunda}\)) (Fig. 427) arises from the outer side of the external iliac nearly opposite the epigastric artery. It ascends obliquely outward behind Poupart's ligament, contained in a fibrous sheath formed by the junction of the transversalis and iliac fasciae, to the anterior superior spinous process of the ilium. It then runs along the inner surface of the crest of the ilium to about its middle, where it pierces the Transversalis, and runs backward between that muscle and the Internal oblique, to anastomose with the ilio-lumbar and gluteal arteries. Opposite the anterior superior spine of the ilium it gives off a large branch which ascends between the Internal oblique and Transversalis muscles, supplying them, and anastomosing with the lumbar and epigastric arteries. It also gives off cutaneous branches.

**ARTERIES OF THE LOWER EXTREMITY.**

The artery which supplies the greater part of the lower extremity is the direct continuation of the external iliac. It continues as a single trunk from Poupart's ligament to the lower border of the Popliteus muscle, and here divides into two branches, the anterior and posterior tibial, an arrangement exactly similar to what occurs in the upper limb. For convenience of description, the upper part of the main trunk is named femoral, the lower part, popliteal.

**THE FEMORAL ARTERY (\(a. \text{femoralis}\)) (Figs. 432 and 433).**

The femoral artery commences immediately behind Poupart's ligament, midway between the anterior superior spine of the ilium and the symphysis pubis, and, passing down the forepart and inner side of the thigh, terminates at the opening in the Adductor magnus, at the junction of the middle with the lower third of the thigh, where it becomes the popliteal artery. The vessel, at the upper part of the thigh, lies in front of the hip-joint, just on a line with the innermost part of the head of the femur; in the lower part of its course it is in close relation with the inner side of the shaft of the bone, and between these two parts the vessel is some distance from the bone. In the upper third of the thigh it is contained in a triangular space called Scarpa's triangle. In the middle third of the thigh it is contained in an aponeurotic canal called Hunter's canal.

**Scarpa's Triangle (\( \text{trigonum femorale} \)).**—Scarpa's triangle corresponds to the depression seen immediately below the fold of the groin. It is a triangular space, the apex of which is directed downward, and the sides formed externally by the Sartorius, internally by the inner margin of the Adductor longus, and above by Poupart's ligament. The floor of the space is formed from without inward by the Iliacus, Psoas, Pectineus (in some cases a small part of the Adductor brevis), and the Adductor longus muscles; and it is divided into two nearly equal parts by the femoral vessels, which extend from the middle of its base to its apex, the artery
giving off in this situation its superficial and profunda branches, the vein receiving the deep femoral and internal saphenous. On the outer side of the femoral artery is the femoral nerve dividing into its branches. In the outer corner of the space is the external cutaneous nerve. Within the sheath of the artery, and lying upon the outer side of the vessel, is the crural branch of the genito-femoral nerve. At the base of the triangle the vein is to the inner side of the artery; at the apex of the triangle it is passing behind the artery. Besides the vessels and nerves, this space contains some fat and lymphatics.

Hunter's Canal or the Adductor Canal (canalis adductorius [Hunteri].) — This is the aponeurotic space in the middle third of the thigh, extending from the apex of Scarpa's triangle to the femoral opening in the Adductor magnus muscle. It is bounded, externally, by the Vastus internus; internally by the Adductors longus and magnus muscles; and is covered in by a strong aponeurosis which extends transversely from the Vastus internus across the femoral
vessels to the Adductor longus and magnus; lying on which aponeurosis is the Sartorius muscle. It contains the femoral artery and vein enclosed in their own sheath of areolar tissue, the vein being behind and on the outer side of the artery, and the internal or long saphenous nerve lying at first on the outer side and then in front of the vessels.

For convenience of description, and also in reference to its surgical anatomy, the femoral artery is divided into a short trunk, about an inch and a half or two inches long, which is known as the common femoral artery, while the remainder of the vessel is termed the superficial femoral artery, to distinguish it from the deep femoral (profunda femoris), a large branch given off from the common femoral at its termination, and which, by its derivation, from the parent trunk, marks the commencement of the superficial femoral artery.

The Common Femoral Artery (Figs. 432 and 433).

The common femoral artery is very superficial, being covered by the skin and superficial fascia, superficial inguinal lymphatic glands, the iliac portion of the fascia lata, and the prolongation downward of the transversalis fascia, which forms the anterior part of the sheath of the vessels. It has in front of it filaments from the crural branch of the genitofemoral nerve, the superficial circumflex iliac vein, and occasionally the superficial epigastric vein. It rests on the inner margin of the Psoas muscle, which separates it from the capsular ligament of the hip-joint, and a little lower on the Pectineus muscle; and crossing behind it is the branch to the Pectineus from the femoral nerve. Separating the artery from the Pectineus muscles is the pubic portion of the fascia lata and the prolongation from the fascia covering the Iliacus muscle, which forms the posterior layer of the sheath of the vessels. The femoral nerve lies about half an inch to the outer side of the common femoral artery, being separated from the artery by a small part of the Psoas muscle. To the inner side of the artery is the femoral vein, between the margins of the Pectineus and Psoas muscles. The two vessels are
en closed in a strong fibrous sheath formed by the proper sheath of the vessels, strengthened by fascia (see page 511); the artery and vein are separated, however, from one another by a thin fibrous partition.

**Plan of the Relations of the Common Femoral Artery.**

*In front.*
- Skin and superficial fascia.
- Superficial inguinal glands.
- Iliac portion of fascia lata.
- Prolongation of transversalis fascia.
- Crural branch of genito-femoral nerve.
- Superficial circumflex iliac vein.
- Superficial epigastric vein.

*Inner side.*
- Femoral vein.

*Behind.*
- Prolongation of fascia covering the Iliacus muscle.
- Pubic portion of fascia lata.
- Nerve to Pectineus.
- Psoas muscle.
- Pectineus muscle.
- Capsule of hip-joint.

*Outer side.*
- Small part of Psoas muscle, separating the artery from the femoral nerve.

**The Superficial Femoral Artery** (Figs. 432 and 433).

The superficial femoral artery is only superficial where it lies in Scarpa's triangle. Here it is covered by the skin, superficial and deep fascia, and crossed by the internal cutaneous branch of the femoral nerve. In Hunter's canal it is more deeply seated, being covered by the integument, the superficial and deep fascia, the Sartorius and the aponeurotic covering of Hunter's canal. The internal saphenous nerve crosses the artery from without inward. Behind, the artery lies at its upper part on the femoral vein and the profunda artery and vein, which separate it from the Pectineus muscle, and lower down on the Adductor longus and Adductor magnus muscles. To the outer side is the long saphenous nerve and the nerve to the Vastus internus, the Vastus internus muscle, and, at its lower part, the femoral vein. To the inner side is the Adductor longus above and the Adductor magnus and Sartorius below.

**Plan of the Relations of the Superficial Femoral Artery.**

*In front.*
- Skin, superficial and deep fascie.
- Internal cutaneous nerve.
- Sartorius.
- Aponeurotic covering of Hunter's canal.
- Internal saphenous nerve.

*Inner side.*
- Adductor longus.
- Adductor magnus.
- Sartorius.

*Behind.*
- Femoral vein.
- Profunda artery and vein.
- Pectineus muscle.
- Adductor longus.
- Adductor magnus.

*Outer side.*
- Long saphenous nerve.
- Nerve to vastus internus.
- Vastus internus.
- Femoral vein (below).
The femoral vein, at Poupart’s ligament, lies close to the inner side of the artery, separated from it by a thin fibrous partition; but lower down it is behind it, and then to its outer side.

The internal saphenous nerve is situated on the outer side of the artery, in the middle third of the thigh, beneath the aponeurotic covering of Hunter’s canal, but not usually within the sheath of the vessels. The internal cutaneous nerve passes obliquely across the upper part of the sheath of the femoral artery.

Peculiarities. Double Femoral Reunited.—Several cases are recorded in which the femoral artery divided into two trunks below the origin of the profunda, and became reunited near the opening of the Adductor magnus so as to form a single popliteal artery. One of them occurred in a patient operated upon for popliteal aneurism.

Change of Position.—A few cases have been recorded in which the femoral artery was situated at the back of the thigh, the vessel being continuous above with the internal iliac, escaping from the pelvis through the great sacro-sciatic foramen, and accompanying the great sciatic nerve to the popliteal space, where its division occurred in the usual manner. The external iliac in these cases was small, and terminated in the profunda.

Position of the Vein.—The femoral vein is occasionally placed along the inner side of the artery, throughout the entire extent of Scarpa’s triangle, or it may be slit so that a large vein is placed on each side of the artery for a greater or less extent.

Origin of the Profunda.—This vessel occasionally arises from the inner side, and, more rarely, from the back of the common trunk; but the more important peculiarity, in a surgical point of view, is that which relates to the height at which the vessel arises from the femoral. In three-fourths of a large number of cases it arose between one or two inches below Poupart’s ligament; in a few cases the distance was less than an inch; more rarely, opposite the ligament; and in one case, above Poupart’s ligament, from the external iliac. Occasionally, the distance between the origin of the vessel and Poupart’s ligament exceeds two inches, and in one case it was found to be as much as four inches.

Surface Marking.—The upper two-thirds of a line drawn from a point midway between the anterior superior spine of the ilium and the symphysis pubis to the adductor tubercle on the inner condyle of the femur, with the thigh abducted and rotated outward, will indicate the course of the femoral artery.

Surgical Anatomy.—Compression of the femoral artery, which is constantly requisite in amputations and other operations on the lower limbs, and also for the cure of popliteal aneurisms, is most effectually made immediately below Poupart’s ligament. In this situation the artery is very superficial, and is merely separated from the ascending ramus of the os pubis by the Psoas muscle; so that the surgeon, by means of his thumb or a compressor, may effectually control the circulation through it. This vessel may also be compressed in the middle third of the thigh by placing a compress over the artery, beneath the tourniquet, and directing the pressure from without inward, so as to compress the vessel against the inner side of the shaft of the femur.

The application of a ligature to the femoral artery may be required in the cases of wound or aneurism of the arteries of the leg, of the popliteal or femoral; and the vessel may be exposed and tied in any part of its course. The great depth of this vessel at its lower part, its close connection with important structures, and the density of its sheath render the operation in this situation one of much greater difficulty than the application of a ligature at its upper part, where it is more superficial.

Ligature of the common femoral artery is usually considered unsafe, on account of the connection of large branches with it—viz., the deep epigastric and the deep circumflex iliac arising just above Poupart’s ligament; on account of the number of small branches which arise from it in its short course; and on account of the uncertainty of the origin of the profunda femoris, which, if it arise high up, would be too close to the ligature for the formation of a firm coagulum. The profunda sometimes arises higher than the point above mentioned, and rarely between two or three inches (in one case four) below Poupart’s ligament. It would appear, then, that the most favorable situation for the application of a ligature to the femoral is on the superficial femoral at the apex of Scarpa’s triangle. In order to expose the artery in this situation, an incision between three and four inches long should be made in the course of the vessel, the patient lying in the recumbent position, with the limb slightly flexed and abducted, and rotated outward. A large vein is frequently met with, passing in the course of the artery to the internal saphenous vein; this must be avoided, and the fascia lata having been cautiously divided and the Sartorius exposed, that muscle must be drawn outward in order to expose fully the sheath of the vessels. The finger being introduced into the wound and the pulsation of the artery felt, the sheath should be opened on the outer side of the vessel to a sufficient extent to allow of the

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1  Ligature of the femoral artery has been also recommended and performed for elephantiasis of the leg and acute inflammation of the knee-joint (Maunder, Clin. Soc. Trans., vol. ii. p. 37).—Ed. of 15th English edition.
introduction of the ligature, but no farther; otherwise the nutrition of the coats of the vessel may be interfered with, or muscular branches which arise from the vessel at irregular intervals may be divided. In this part of the operation the long saphenous nerve and the nerve to the Vastus internus, which is in close relation with the sheath, should be avoided. The aneurism needle must be carefully introduced and kept close to the artery, to avoid the femoral vein, which lies behind the vessel in this part of its course.

To expose the artery in Hunter's canal, an incision should be made between three and four inches in length, a finger's breadth internal to the line of the artery, in the middle of the thigh—i.e., midway between the groin and the knee. The integument is first divided. The fascia lata having been divided, and the outer border of the Sartorius muscle exposed, it should be drawn inward, when the strong fascia which is stretched across from the Adductors to the Vastus internus will be exposed, and must be freely divided; the sheath of the vessels is now seen, and must be opened, and the artery secured by passing the aneurism needle between the vein and artery in the direction from without inward. The femoral vein in this situation lies on the outer side of the artery and the long saphenous nerve on the anterior and outer side of the artery.

It has been seen that the femoral artery occasionally divides into two trunks below the origin of the profunda. If in the operation for tying the femoral two vessels are met with, the surgeon should alternately compress each, in order to ascertain which vessel is connected with the aneurismal tumor or with the bleeding from the wound, and that one only should be tied which controls the pulsation or hemorrhage. If, however, it is necessary to compress both vessels before the circulation in the tumor is controlled, both should be tied, as it would be probable that they became reunited, as in the instances referred to above.

In wounds of the femoral artery the question of the mode of treatment is of considerable importance. If the wound in the superficial structures is a large one, the injured vessel must be exposed and tied; but if the wound is a punctured one and the bleeding has ceased, the question will arise whether to cut down upon the artery or to trust to pressure. Mr. Cripps advises that if the wound is in the "upper part of the thigh—that is to say, in a position where the femoral artery is comparatively superficial—the surgeon may enlarge the opening with a good prospect of finding the wounded vessel without an extensive or prolonged operation. If the wound be in the lower half of the thigh, owing to the greater depth of the artery and the possibility of its being the popliteal that is wounded, the search is rendered a far more severe and hazardous operation, and it should not be undertaken until a thorough trial of pressure has proved ineffectual."

Great care and attention are necessary for the successful application of pressure. The limb should be carefully bandaged from the foot upward to the wound, which is not covered, and then onward to the groin. The wound is then dusted with iodoform or boracic powder and a conical pad applied over the wound. Rollers the thickness of the index finger are then placed along the course of the vessel above and below the wound, and the whole carefully bandaged to a back splint with a foot-piece.

Collateral Circulation.—When the common femoral is tied the main channels for carrying on the circulation are the anastomoses of the gluteal and circumflex iliac arteries above with the external circumflex below; of the obturator and sciatic above with the internal circumflex below; and of the comes nervi ischiadici with the arteries in the ham.

The principal agents in carrying on the collateral circulation after ligature of the superficial femoral artery are, according to Sir A. Cooper, as follows:

"The arteria profunda formed the new channel for the blood. The first artery sent off passed down close to the back of the thigh-bone, and entered the two superior articular branches of the popliteal artery.

"The second new large vessel, arising from the profunda at the same part with the former, passed down by the inner side of the Biceps muscle to a branch of the popliteal which was distributed to the Gastrocnemius muscle; whilst a third artery, dividing into several branches, passed down with the sciatic nerve behind the knee-joint, and some of its branches united themselves with the inferior articular arteries of the popliteal, with some recurrent branches of those arteries, with arteries passing to the Gastrocnemii, and, lastly, with the origin of the anterior and posterior tibial arteries.

"It appears, then, that it is those branches of the profunda which accompany the sciatic nerve that are the principal supporters of the new circulation.""

In Porta's work (tab. xii., xiii.) is a good representation of the collateral circulation after the ligature of the femoral artery. The patient had survived the operation three years. The lower part of the artery is at least as large as the upper: about two inches of the vessel appear to have been obliterated. The external and internal circumflex arteries are seen anastomosing by a great number of branches with the lower branches of the femoral (muscular and anasto-

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3 Alterazioni patologiche delle Arterie.
motica magna) and with the articular branches of the popliteal. The branches from the external circumflex are extremely large and numerous. One very distinct anastomosis can be traced between this artery on the outside and the anastomotica magna on the inside through the intervention of the superior external articular artery, with which they both anastomose; and blood reaches even the anterior tibial recurrent from the external circumflex by means of anastomosis with the same external articular artery. The perforating branches of the profunda are also seen bringing blood round the obliterated portion of the artery into long branches (muscular) which have been given off just below that portion. The termination of the profunda itself anastomoses most freely with the superior external articular. A long branch of anastomosis is also traced down from the internal iliac by means of the comites nervi ischiadici of the sciatic, which anastomoses on the popliteal nerves with branches from the popliteal and posterior tibial arteries. In this case the anastomosis had been too free, since the pulsation and growth of the aneurism recurred, and the patient died after ligature of the external iliac.

There is an interesting preparation in the Museum of the Royal College of Surgeons of a limb on which John Hunter had tied the femoral artery fifty years before the patient's death. The whole of the superficial femoral and popliteal artery seems to have been obliterated. The anastomosis by means of the comites nervi ischiadici, which is shown in Porta's plate, is distinctly seen: the external circumflex and the termination of the profunda artery seem to have been the chief channels of anastomoses; but the injection has not been a very successful one.

Branches (Figs. 432 and 433).—The branches of the femoral artery are—the

<table>
<thead>
<tr>
<th>Superficial Epigastric.</th>
<th>Profunda Femoris</th>
<th>Anastomotica Magna.</th>
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<tbody>
<tr>
<td>Superficial Circumflex Iliac.</td>
<td>Internal Circumflex.</td>
<td></td>
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<tr>
<td>Superficial External Pudic.</td>
<td>Three Perforating.</td>
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The **Superficial Epigastric (a. epigastrica superficialis)** arises from the femoral about half an inch below Poupart's ligament, and, passing through the saphenous opening in the fascia lata, ascends on the abdomen, in the superficial fascia covering the External oblique muscle, nearly as high as the umbilicus. It distributes branches to the superficial inguinal glands, the superficial fascia, and the integument, anastomosing with branches of the deep epigastric.

The **Superficial Circumflex Iliac (a. circumflexa ilium superficialis)**, the smallest of the cutaneous branches, arises close to the preceding, and, piercing the fascia lata, runs outward, parallel with Poupart's ligament, as far as the crest of the ilium, dividing into branches which supply the integument of the groin, the superficial fascia, and the superficial inguinal lymphatic glands, anastomosing with the deep circumflex iliac and with the gluteal and external circumflex arteries.

The **Superficial External Pudic** or the **Superior Superior External Pudic (a. pudenda externa superficialis)** arises from the inner side of the femoral artery, close to the preceding vessels, and, after passing through the saphenous opening, courses inward, across the spermatic cord or round ligament, to be distributed to the integument on the lower part of the abdomen, the penis and scrotum in the male, and the labium in the female, anastomosing with branches of the internal pudic.

The **Deep External Pudic** or the **Deep Superior External Pudic (a. pudenda externa profunda)**, more deeply seated than the preceding, passes inward across the Pectineus and Adductor longus muscles, covered by the fascia lata, which it pierces at the inner border of the thigh, its branches being distributed, in the male, to the integument of the scrotum and perineum; and in the female to the labium, anastomosing with branches of the superficial perineal artery.

The **Deep Femoral** or the **Profunda Femoris (a. profunda femoris)** (Figs. 432 and 433) nearly equals the size of the superficial femoral. It arises from the outer and back part of the femoral artery, from one to two inches below Poupart's
ligament. It at first lies on the outer side of the superficial femoral, and then passes behind it and the femoral vein to the inner side of the femur, and, passing downward beneath the Adductor longus, terminates at the lower third of the thigh in a small branch which pierces the Adductor magnus (and from this circumstance is sometimes called the **fourth perforating artery**), and is distributed to the flexor muscles on the back of the thigh, anastomosing with branches of the popliteal and inferior perforating arteries.

**Relations.**—*Behind*, it lies first upon the Iliacus, and then on the Pectineus, Adductor brevis, and Adductor magnus muscles. *In front*, it is separated from the superficial femoral artery, above by the femoral and profunda veins, and below by the Adductor longus. On its **outer side** the origin of the Vastus internus separates it from the femur.

**Plan of the Relations of the Profunda Artery.**

*In front.*
- Superficial femoral artery.
- Femoral and profunda veins.
- Adductor longus.

*Outer side.*
- Vastus internus.

*Profunda Femoris.*

*Behind.*
- Iliacus.
- Pectineus.
- Adductor brevis.
- Adductor magnus.

**Branches.**—The profunda gives off the following named branches:

- **Muscular.**
- **External circumflex.**
- **Internal circumflex.**
- **Four perforating.**

**Muscular Branches** are given off in Scarpa's triangle, and also from the vessel as it lies between the Adductor muscles.

The **External Circumflex Artery** (*a. circumflexa femoris lateralis*) supplies the muscles on the front of the thigh. It *arises* from the outer side of the profunda, passes horizontally outward, between the divisions of the femoral nerve and behind the Sartorius and Rectus muscles, and divides into three sets of branches—**ascending, transverse, and descending.**

The **ascending branch** (*ramus ascendens*) passes upward, beneath the Tensor fasciae femoris muscle, to the outer side of the hip, anastomosing with the terminal branches of the gluteal and deep circumflex iliac arteries. It sends out muscular branches. The **descending branch** (*ramus descendens*) passes downward, behind the Rectus, upon the Vasti muscles, to which its branches are distributed, one or two passing beneath the Vastus externus as far as the knee, anastomosing with the superior articular branches of the popliteal artery. These are accompanied by the branch of the femoral nerve to the Vastus externus. The **transverse branch**, the smallest, passes outward over the Crureus, pierces the Vastus externus, and winds round the femur to its back part, just below the great trochanter, anastomosing at the back of the thigh with the internal circumflex, sciatic, and superior perforating arteries.

The **Internal Circumflex Artery** (*a. circumflexa femoris medialis*), smaller than the external, *arises* from the inner and back part of the profunda, and winds round the inner side of the femur, between the Pectineus and Psoas muscles. On
reaching the upper border of the Adductor brevis it gives off two muscular branches, one of which passes inward to be distributed to the Adductor muscles, the Gracilis, and Obturator externus, anastomosing with the obturator artery; the other descends, and passes beneath the Adductor brevis, to supply it and the great Adductor; while the continuation of the vessel passes backward and divides into an ascending and a transverse branch (Fig. 348). The ascending branch (ramus profundus) passes obliquely upward upon the tendon of the Obturator externus and under cover of the Quadratus femoris toward the digital fossa, where it anastomoses with twigs from the gluteal and sciatic arteries. The transverse branch (ramus superficialis), larger than the ascending, appears between the Quadratus femoris and upper border of the Adductor magnus, anastomosing with the sciatic, external circumflex, and superior perforating arteries, the crucial anastomosis. Opposite the hip-joint the artery gives off an articular vessel (ramus acetabuli), which enters the joint beneath the transverse ligament; and, after supplying the adipose tissue, passes along the round ligament to the head of the bone.

The Perforating Arteries (Figs. 431, 432, and 433), usually three in number, are so called from their perforating the tendon of the Adductor magnus muscle to reach the back of the thigh. They pass backward close to the linea aspera of the femur, under cover of small tendinous arches in the Adductor magnus. The first is given off above the Adductor brevis, the second in front of that muscle, and the third immediately below it.

The first perforating artery (a. perforans prima) passes backward between the Pectineus and Adductor brevis (sometimes perforates the latter); it then pierces the Adductor magnus close to the linea aspera. It gives off branches which supply the Adductor brevis, the Adductor magnus, the Biceps, and Gluteus maximus muscles, and anastomoses with the sciatic, internal and external circumflex, and middle perforating arteries. The second perforating artery (a. perforans secunda), larger than the first, pierces the tendons of the Adductor brevis and Adductor magnus muscles, and divides into ascending and descending branches, which supply the flexor muscles of the thigh, anastomosing with the first and third perforating arteries. The second artery frequently arises in common with the first. The nutrient artery of the femur is usually given off from this branch. The third perforating artery (a. perforans tertia) is given off below the Adductor brevis; it pierces the Adductor magnus, and divides into branches which supply the flexor muscles of the thigh; anastomosing above with the higher perforating arteries, and below with the terminal branches of the profunda and the muscular branches of the popliteal. A fourth perforating artery is represented by the termination of the profunda femoris artery.

The nutritive artery of the femur (a. nutricia femoris), if single, comes from the second perforating artery; if double, from the first and third perforating arteries. If double, one vessel is called superior and the other inferior.

Muscular Branches (rami musculares) are given off from the superficial femoral throughout its entire course. They vary from two to seven in number, and supply chiefly the Sartorius and Vastus internus.

The Anastomotica Magna (a. genu suprema) (Figs. 432 and 433) arises from the femoral artery just before it passes through the tendinous opening in the Adductor magnus muscle, and immediately divides into a superficial and deep branch.

The Superficial Branch (ramus saphenus) pierces the aponeurotic covering of Hunter's canal, and accompanies the long saphenous nerve to the inner side of the thigh. It passes between the Sartorius and Gracilis muscles, and, piercing the fascia lata, is distributed to the integument of the upper and inner part of the leg, anastomosing with the inferior internal articular artery.

The Deep Branch (ramus musculoarticularis) descends in the substance of the Vastus internus, lying in front of the tendon of the Adductor magnus, to the inner side of the knee, where it anastomoses with the superior internal articular artery.
and the anterior recurrent branch of the anterior tibial. A branch from this vessel crosses outward above the articular surface of the femur, forming an anastomotic arch with the superior external articular artery, and supplies branches to the knee-joint.

THE POPLITEAL ARTERY (A. POPLITEA) (Figs. 431 and 432).

The popliteal artery commences at the termination of the femoral at the opening in the Adductor magnus, and, passing obliquely downward and outward behind the knee-joint to the lower border of the Popliteus muscle divides into the anterior and posterior tibial arteries. A portion of the artery lies in the popliteal space; but above and below, to a considerable extent, it is covered by the muscles which form the boundaries of the space, and is therefore beyond the confines of the hollow.

The Popliteal Space (Fig. 434).

Dissection.—A vertical incision about eight inches in length should be made along the back part of the knee-joint, connected above and below by a transverse incision from the inner to the outer side of the limb. The flaps of integument included between these incisions should be reflected in the direction shown in Fig. 345, page 525.

Boundaries.—The popliteal space, or the ham, is a lozenge-shaped space, widest at the back part of the knee-joint, and deepest above the articular end of the femur. It is bounded externally, above the joint, by the Biceps, and below by the joint by the Plantaris and external head of the Gastrocnemius. Internally, above the joint, by the Semimembranosus, Semiten- dinosus, Gracilis, and Sartorius; below the joint, by the inner head of the Gastrocnemius.

Above, it is limited by the apposition of the inner and outer hamstring muscles; below, by the junction of the two heads of the Gastrocnemius. The floor is formed by the lower part of the posterior surface of the shaft of the femur, the posterior ligament of the knee-joint, the upper end of the tibia, and the fascia covering the Popliteus muscle, and the space is covered in by the fascia lata.

Contents.—It contains the popliteal vessels and their branches, together with the termination of the external saphenous vein, the internal and external popliteal nerves and some of their branches, the lower extremity of the small sciatic nerve, the articular branch from the obturator nerve, a few small lymphatic glands, and a considerable quantity of loose adipose tissue.
Position of Contained Parts.—The internal popliteal nerve descends in the middle line of the space lying superficial and crossing the artery from without inward. The external popliteal nerve descends on the outer side of the upper part of the space, lying close to the tendon of the Biceps muscle. More deeply at the bottom of the space are the popliteal vessels, the vein lying superficial to the artery, to which it is closely united by dense areolar tissue; it is a thick-walled vessel, and lies at first to the outer side of the artery, and then crosses it to gain the inner side below; sometimes the vein is double, the artery lying between the two venae comitantes, which are usually connected by short transverse branches. More deeply and, at its upper part, close to the surface of the bone is the popliteal artery, and passing off from it at right angles are its articular branches. The articular branch from the obturator nerve descends upon the popliteal artery to supply the knee, and occasionally there is found deep in the space an articular filament from the great sciatic nerve.

The popliteal lymphatic glands, four or five in number, are found surrounding the artery; one usually lies superficial to the vessel; another is situated between it and the bone, and the rest are placed on either side of it.

The Popliteal Artery, in its course downward from the aperture in the Adductor magnus to the lower border of the Popliteus muscle, rests first on the inner surface of the femur, and is then separated by a little fat from the hollowed popliteal surface of the bone; in the middle of its course it rests on the posterior ligament of the knee-joint, and below on the fascia covering the Popliteus muscle. Superficially, it is covered above by the Semimembranosus; in the middle of its course, by a quantity of fat, which separates it from the deep fascia and integument; and below it is overlapped by the Gastrocnemius, Plantaris, and Soleus muscles, the popliteal vein, and the internal popliteal nerve. The popliteal vein, which is intimately attached to the artery, lies superficial and external to it above; it then crosses it and lies to its inner side. The internal popliteal nerve is still more superficial and external above, but below the joint it crosses the artery and lies on its inner side. Laterally, the artery is bounded by the muscles which are situated on either side of the popliteal space.

Plan of the Relations of the Popliteal Artery.

In front.
Femur.
Ligamentum posticum.
Popliteus.

Inner side
Semimembranosus.
Internal condyle.
Gastrocnemius (inner head).

Popliteal Artery.

Outer side
Biceps.
Outer condyle.
Gastrocnemius (outer head).
Plantaris.

Behind.
Semimembranosus.
Fascia.
Popliteal vein.
Internal popliteal nerve.
Gastrocnemius.
Plantaris.
Soleus.

Peculiarities in Point of Division.—Occasionally the popliteal artery divides prematurely into its terminal branches; this unusual division occurs most frequently opposite the knee-joint. The anterior tibial under these circumstances may pass in front of the Popliteus muscle.

Unusual Branches.—The artery sometimes divides into the anterior tibial and peroneal, the posterior tibial being wanting or very small. Occasionally the popliteal is found to divide into three branches, the anterior and posterior tibial and peroneal.
THE POPLITEAL SPACE

Surface Marking.—The course of the upper part of the popliteal artery is indicated by a line drawn from the outer border of the Semimembranosus muscle at the junction of the middle and lower third of the thigh obliquely downward to the middle of the popliteal space, exactly behind the knee-joint. From this point it passes vertically downward to the level of a line drawn through the lower part of the tubercle of the tibia.

Surgical Anatomy.—The popliteal artery is not infrequently the seat of injury. It may be torn by direct violence, as by the passage of a cart-wheel over the knee or by hyper-extension of the knee, and in the dead body, at all events, the middle and internal coats may be ruptured by extreme flexion. It may also be lacerated by fracture of the lower part of the shaft of the femur or by antero-posterior dislocation of the knee-joint. It has been torn in breaking down adhesions in cases of fibrous ankylosis of the knee, and is in danger of being wounded, and in fact has been wounded, in performing Maceneew’s operation of osteotomy of the lower end of the femur for genu valgum. In addition, Spencer records a case in which the popliteal artery was wounded from in front by a stab just below the knee, the knife passing through the intersosseous space. The popliteal artery is more frequently the seat of aneurism than is any other artery in the body, with the exception of the thoracic aorta. This is due no doubt, in a great measure, to the amount of movement to which it is subjected, and to the fact that it is supported by loose and lax tissue only, and not by muscles, as is the case with most arteries.

Ligature of the popliteal artery is required in cases of wound of that vessel, but for aneurism of the posterior tibial it is preferable to tie the superficial femoral. The popliteal may be tied in the upper or lower part of its course; but in the middle of the ham the operation is attended with considerable difficulty, from the great depth of the artery and from the extreme degree of tension of the lateral boundaries of the space.

In order to expose the vessel in the upper part of its course, the patient should be placed in the supine position, with the knee flexed and the thigh rotated outward, so that it rests on its outer surface; an incision three inches in length, beginning at the junction of the middle and lower third of the thigh, is to be made parallel to and immediately behind the tendon of the Adductor magnus, and the skin, superficial and deep fascia divided. The tendon of the muscle is thus exposed, and is to be drawn forward and the hamstring tendons backward. A quantity of fatty tissue will now be opened up, in which the artery will be felt pulsating. This is to be separated with the point of a director until the artery is exposed. The vein and nerve will not be seen, as they lie to the outer side of the artery. The sheath is to be opened and the aneurism needle passed from before backward, keeping its point close to the artery for fear of injuring the vein. The only structure to avoid is the long saphenous vein in the superficial incision. The upper part of the popliteal artery may also be tied by an incision on the back of the limb, along the outer margin of the Semimembranosus, but the operation is a more difficult one, as the internal popliteal nerve and the popliteal vein are first exposed, and great care has to be exercised in separating them from the artery.

To expose the vessel in the lower part of its course, where the artery lies between the two heads of the Gastrocnemius, the patient should be placed in the prone position with the limb extended. An incision should then be made through the integument in the middle line, commencing opposite the bend of the knee-joint, care being taken to avoid the external saphenous vein and nerve. After dividing the deep fascia and separating some dense cellular membrane, the artery, vein, and nerve will be exposed, descending between the two heads of the Gastrocnemius. Some muscular branches of the popliteal should be avoided if possible, or, if divided, tied immediately. The leg being now flexed, in order the more effectually to separate the two heads of the Gastrocnemius, the nerve should be drawn inward and the vein outward, and the aneurism needle passed between the artery and vein from without inward.

Branches.—The branches of the popliteal artery are—

Muscular

Superior or Sural

Superior External Articular.

Azygos Articular.

Inferior Internal Articular.

Inferior External Articular.

The Superior Muscular Branches, two or three in number, arise from the upper part of the popliteal artery, and are distributed to the lower part of the Adductor magnus and flexor muscles of the thigh, anastomosing with the fourth perforating branch of the profunda.

The Inferior Muscular (aa. surales) are two large branches which are distributed to the two heads of the Gastrocnemius and to the Plantaris muscle. They arise from the popliteal artery opposite the knee-joint.
The Cutaneous Branches arise separately from the popliteal artery or from some of its branches; they descend between the two heads of the Gastrocnemius muscle, and, piercing the deep fascia, are distributed to the integument of the calf. One branch usually accompanies the short, or external, saphenous vein, the superficial sural artery.

The Superior Articular Arteries, two in number, arise one on each side of the popliteal, and wind round the femur immediately above its condyles to the front of the knee-joint. The internal branch (a. genu superior medialis) winds inward beneath the hamstring muscles, to which it supplies branches, above the inner head of the Gastrocnemius, and, passing beneath the tendon of the Adductor magnus, divides into two branches, one of which supplies the Vastus internus, inosculating with the anastomotica magna and inferior internal articular; the other ramifies close to the surface of the femur, supplying it and the knee-joint, and anastomosing with the superior external articular artery. This branch is frequently of small size, a condition which is associated with an increase in the size of the anastomotica magna. The external branch (a. genu superior lateralis) passes above the outer condyle, beneath the tendon of the Biceps, and divides into a superficial and deep branch: the superficial branch supplies the Vastus externus, and anastomoses with the descending branch of the external circumflex and the inferior external articular arteries; the deep branch supplies the lower part of the femur and knee-joint, and forms an anastomotic arch across the bone with the anastomotica magna and the inferior internal articular arteries.

The Azygos Articular (a. genu media) is a small branch arising from the popliteal artery opposite the bend of the knee-joint. It pierces the posterior ligament, and supplies the ligaments and synovial membrane in the interior of the articulation.

The Inferior Articular Arteries, two in number, arise from the popliteal beneath the Gastrocnemius, and wind round the head of the tibia below the joint. The internal branch (a. genu inferior medialis) first descends along the upper margin of the Popliteus muscle, to which it gives branches; it then passes below the inner tuberosity, beneath the interial lateral ligament, at the anterior border of which it ascends to the front and inner side of the joint, to supply the head of the tibia and the articulation of the knee, anastomosing with the inferior external articular and superior internal articular arteries. The external branch (a. genu inferior lateralis) passes outward above the head of the fibula, to the front of the knee-joint, passing in its course beneath the outer head of the Gastrocnemius, the external lateral ligament, and the tendon of the Biceps muscle, and divides into branches which anastomose with the inferior internal articular artery, the superior external articular artery, and the anterior recurrent branch of the anterior tibial.

Circumpatellar Anastomosis.—Around and above the patella, and on the contiguous ends of the femur and tibia, is a large network of vessels, forming a superficial and a deep plexus. The superficial plexus is situated between the fascia and skin round about the patella; the deep plexus, which forms a close network of vessels, lies on the surface of the lower end of the femur and upper end of the tibia around their articular surfaces, and sends numerous offsets into the interior of the joint. The arteries from which this plexus is formed are the two internal and two external articular branches of the popliteal, the anastomotica magna, the terminal branch of the profunda, the descending branch from the external circumflex and the anterior recurrent branch of the anterior tibial.

The Anterior Tibial Artery (A. Tibialis Anterior) (Fig. 435).

The anterior tibial artery commences at the bifurcation of the popliteal at the lower border of the Popliteus muscle, passes forward between the two
heads of the Tibialis posticus, and through the large oval aperture above the upper border of the interosseous membrane to the deep part of the front of the leg; it here lies close to the inner side of the neck of the fibula; it then descends on the anterior surface of the interosseous membrane, gradually approaching the tibia; and at the lower part of the leg lies on this bone, and then on the anterior ligament of the ankle to the bend of the ankle-joint, where it lies more superficially, and becomes the dorsalis pedis.

**Relations.**—In the upper two-thirds of its extent it rests upon the interosseous membrane, to which it is connected by delicate fibrous arches thrown across it; in the lower third, upon the front of the tibia and the anterior ligament of the ankle-joint. In the upper third of its course it lies between the Tibialis anticus and Extensor longus digitorum; in the middle third, between the Tibialis anticus and Extensor proprius hallucis. At the bend of the ankle it is crossed by the tendon of the Extensor proprius hallucis, and lies between it and the innermost tendon of the Extensor longus digitorum. It is covered, in the upper two-thirds of its course, by the muscles which lie on either side of it and by the deep fascia; in the lower third, by the integument, anterior annular ligament, and fascia.

The anterior tibial artery is accompanied by two veins, venae comites, which lie one on each side of the artery; the anterior tibial nerve, coursing round the outer side of the neck of the fibula, comes into relation with the outer side of the artery shortly after it has passed through the opening in the interosseous membrane; about the middle of the leg it is placed superficial to it; at the lower part of the artery the nerve is generally again on the outer side.

**Plan of the Relations of the Anterior Tibial Artery.**

*In front.*

Integument, superficial and deep fasciae.
Anterior tibial nerve.
Tibialis anticus (overlaps it in the upper part of the leg).
Extensor longus digitorum.
Extensor proprius hallucis (overlap it slightly).
Anterior annular ligament.

*Inner side.*

Tibialis anticus.
Extensor proprius hallucis (crosses it at its lower part).

*Outer side.*

Anterior tibial nerve.
Extensor longus digitorum.
Extensor proprius hallucis.

*Behind.*

Interosseous membrane.
Tibia.
Anterior ligament of ankle-joint.

**Peculiarities in Size.**—This vessel may be very small, may be deficient to a greater or less extent, or may be entirely wanting, its place being supplied by perforating branches from the posterior tibial or by the anterior division of the peroneal artery.

**Course.**—The artery occasionally deviates in its course toward the fibular side of the leg, regaining its usual position beneath the annular ligament at the front of the ankle. In two instances the vessel has been found to approach the surface in the middle of the leg, being covered merely by the integument and fascia below that point.

**Surface Marking.**—Draw a line from the inner side of the head of the fibula to midway between the two malleoli. In this line take a point one inch and a quarter below the head of the fibula, and the portion of the line below this point will mark the course of the artery.

**Surgical Anatomy.**—The anterior tibial artery may be tied in the upper or lower part of the leg. In the upper part the operation is attended with great difficulty, on account of the depth of the vessel from the surface. An incision, about four inches in length, should be made
through the integument, midway between the spine of the tibia and the outer margin of the fibula, and the deep fascia exposed. The wound must now be carefully dried, its edges retracted, and the white line separating the Tibialis anticus from the Extensor longus digitorum sought for. When this has been clearly defined, the deep fascia is to be divided in this line, and the Tibialis anticus separated from adjacent muscles with the handle of the scalpel or a director until the interosseous membrane is reached. The foot is to be flexed in order to relax the muscles, and upon drawing them apart the artery will be found lying on the interosseous membrane with the nerve on its outer side or on the top of the artery. The nerve should be drawn outward, and the vena comites separated from the artery and the needle passed round it.

To tie the vessel in the lower third of the leg above the ankle-joint an incision about three inches in length should be made through the integument between the tendons of the Tibialis anticus and Extensor proprius hallucis muscles, the deep fascia being divided to the same extent. The tendon on either side should be held aside, when the vessel will be seen lying upon the tibia, with the nerve on the outer side and one of the vena comites on either side.

Branches.—The branches of the anterior tibial artery are—

Posterior Recurrent Tibial.
Superior Fibular.
Anterior Recurrent Tibial.
Muscular.
Internal Malleolar.
External Malleolar.

The Posterior Recurrent Tibial (a. recurrens tibialis posterior) is not a constant branch, and is given off from the anterior tibial before that vessel passes through the interosseous space. It ascends beneath the Popliteus muscle, which it supplies, and anastomoses with the lower articular branches of the popliteal artery, giving off an offset to the superior tibio-fibular joint.

The Superior Fibular is sometimes given off from the anterior tibial, sometimes from the posterior tibial. It passes outward, round the neck of the fibula, through the Soleus, which it supplies, and ends in the substance of the Peroneus longus muscle.
The Anterior Recurrent Tibial (a. recurrens tibialis anterior) arises from the anterior tibial as soon as that vessel has passed through the interosseous space; it ascends in the Tibialis anticus muscle, and ramifies on the front and sides of the knee-joint, Anastomosing with the articular branches of the popliteal, with the anastomotica magna, and the external articular branches of the popliteal, assisting in the formation of the circumarticularplexus.

The Muscular Branches are numerous; they are distributed to the muscles which lie on each side of the vessel, some cutaneous branches piercing the deep fascia to supply the integument, others passing through the interosseous membrane, and anastomosing with branches of the posterior tibial and peroneal arteries.

The Malleolar Arteries supply the ankle-joint. The internal branch (a. malleolaris anterior medialis) arises about two inches above the articulation, and passes beneath the tendons of the Extensor proprius hallucis and Tibialis anticus to the inner ankle, upon which it ramifies, anastomosing with branches of the posterior tibial and internal plantar arteries and with the internal calcanean from the posterior tibial. The external branch (a. malleolaris anterior lateralis) passes beneath the tendons of the Extensor longus digitorum and Peroneous tertius, and supplies the outer ankle, anastomosing with the anterior peroneal artery and with ascending branches from the tarsal branch of the dorsalis pedis.

The Dorsalis Pedis Artery (A. Dorsalis Pedis) (Figs. 435, 436).

The dorsalis pedis, the continuation of the anterior tibial, passes forward from the bend of the ankle along the tibial side of the foot to the back part of the first intermetatarsal space, where it divides into two branches, the dorsalis hallucis and communicating.

Relations.—This vessel, in its course forward, rests upon the astragalus, navicular, and middle cuneiform bones and the ligaments connecting them, being covered by the integument and fascia, anterior annular ligament, and crossed near its termination by the innermost tendon of the Extensor brevis digitorum. On its tibial side is the tendon of the Extensor proprius hallucis; on its fibular side, the innermost tendon of the Extensor longus digitorum, and the termination of the anterior tibial nerve. It is accompanied by two veins.

Plan of the Relations of the Dorsalis Pedis Artery.

In front.
Integument and fascia.
Anterior annular ligament.
Innermost tendon of Extensor brevis digitorum.

Tibial side.
Extensor proprius hallucis.

Fibular side.
Extensor longus digitorum.
Anterior tibial nerve.

Behind.
Astragalus.
Navicular.
Middle cuneiform.
And their ligaments.

Peculiarities in Size.—The dorsal artery of the foot may be larger than usual, to compensate for a deficient plantar artery; or it may be deficient in its terminal branches to the toes, which are then derived from the internal plantar; or its place may be supplied altogether by a large anterior peroneal artery.
Position.—This artery frequently curves outward, lying external to the line between the middle of the ankle and the back part of the first interosseous space.

Surface Marking.—The dorsalis pedis artery is indicated on the surface of the dorsum of the foot by a line drawn from the centre of the space between the two malleoli to the back of the first intermetatarsal space.

Surgical Anatomy.—This artery may be tied, by making an incision through the integument between two and three inches in length, on the fibular side of the tendon of the Extensor proprius hallucis, in the interval between it and the inner border of the short Extensor muscle. The incision should not extend farther forward than the back part of the first intermetatarsal space; as the artery divides in that situation. The deep fascia being divided to the same extent, the artery will be exposed, the nerve lying upon its outer side.

Branches.—The branches of the dorsalis pedis are—the

Cutaneous. 
Tarsal. 
Metatarsal—Interosseous. 
Dorsalis Hallucis. 
Communicating.

Cutaneous Branches go to the skin of the dorsum and inner surface of the foot.

The Tarsal Artery (a. tarsae lateralis) arises from the dorsalis pedis, as that vessel crosses the navicular bone; it passes in an arched direction outward, lying upon the tarsal bones, and covered by the Extensor brevis digitorum; it supplies that muscle and the articulations of the tarsus, and anastomoses with branches from the metatarsal, external malleolar, peroneal, and external plantar arteries.
The Metatarsal (a. arcuata) arises a little anterior to the preceding; it passes outward to the outer part of the foot, over the bases of the metatarsal bones, beneath the tendons of the short Extensor, its direction being influenced by its point of origin; and it anastomoses with the tarsal and external plantar arteries. This vessel gives off three branches, the dorsal interosseous arteries (aa. metatarsae dorsales), which pass forward upon the three outer Dorsal interossei muscles, and, in the clefts between the toes, divide into two dorsal collateral branches for the adjoining toes (aa. digitales dorsales). At the back part of each interosseous space these vessels receive the posterior perforating branches from the plantar arch, and at the forepart of each interosseous space they are joined by the anterior perforating branches from the digital arteries. The outermost interosseous artery gives off a branch which supplies the outer side of the little toe.

The Dorsalis Hallucis or the First Dorsal Interosseous (a. dorsalis hallucis) is one of the terminal branches of the dorsalis pedis. It runs forward along the outer border of the first metatarsal bone, and at the cleft between the first and second toes divides into two branches, one of which passes inward, beneath the tendon of the Extensor proprius hallucis, and is distributed to the inner border of the great toe; the outer branch bifurcates, to supply the adjoining sides of the great and second toes.

The Communicating Artery (ramus plantaris profundus), the other terminal branch of the dorsalis pedis, dips down into the sole of the foot, between the two heads of the First dorsal interosseous muscle, and inosculates with the termination of the external plantar artery, to complete the plantar arch. It here gives off its plantar digital branch, which is named the arteria magna hallucis, or the princeps hallucis. This artery passes forward along the first interosseous space, and, after sending a branch along the inner side of the great toe, bifurcates for the supply of the adjacent sides of the great and second toes.

The Posterior Tibial Artery (A. Tibialis Posterior) (Fig. 434).

The posterior tibial is an artery of large size, which extends obliquely downward from the lower border of the Popliteus muscle, along the tibial side of the leg, to the fossa between the inner ankle and the heel, where it divides beneath the origin of the Abductor hallucis, on a level with a line drawn from the point of the internal malleolus to the centre of the convexity of the heel, into the internal and external plantar arteries. At its origin it lies opposite the interval between the tibia and fibula; as it descends, it approaches the inner side of the leg, lying behind the tibia, and, in the lower part of its course, is situated midway between the inner malleolus and the tuberosity of the os calcis.

Relations.—It lies successively upon the Tibialis posticus, the Flexor longus digitorum, the tibia, and the back part of the ankle-joint. It is covered by the deep transverse fascia, which separates it above from the Gastrocnemius and Soleus muscles; at its termination it is covered by the Abductor hallucis muscle. In the lower third, where it is more superficial, it is covered only by the integument and fascia, and runs parallel with the inner border of the tendon Achillis. It is accompanied by two veins and by the posterior tibial nerve, which lies at first to the inner side of the artery, but soon crosses it, and is, in the greater part of its course, on its outer side.

Plan of the Relations of the Posterior Tibial Artery.

In front.
Tibialis posticus.
Flexor longus digitorum.
Tibia.
Ankle-joint.
Behind the inner ankle the tendons and blood-vessels are arranged, under cover of the internal annular ligament, in the following order, from within outward: First, the tendons of the Tibialis posticus and Flexor longus digitorum, lying in the same groove, behind the inner malleolus, the former being the most internal. External to these is the posterior tibial artery, having a vein on either side: and, still more externally, the posterior tibial nerve. About half an inch nearer the heel is the tendon of the Flexor longus hallucis.

Peculiarities in Size.—The posterior tibial is not unfrequently smaller than usual, or absent, its place being supplied by a large peroneal artery which passes inward at the lower end of the tibia, and either joins the small tibial artery or continues alone to the sole of the foot.

Surface Marking.—The course of the posterior tibial artery is indicated by a line drawn from a point one inch below the centre of the popliteal space to midway between the tip of the internal malleolus and the centre of the convexity of the heel.

Surgical Anatomy.—The application of a ligature to the posterior tibial may be required in cases of wound of the sole of the foot attended with great hemorrhage, when the vessel should be tied at the inner ankle. In cases of wound of the posterior tibial it will be necessary to enlarge the opening so as to expose the vessel at the wounded point, excepting where the vessel is injured by a punctured wound from the front of the leg. In cases of aneurism from wound of the artery low down, the vessel should be tied in the middle of the leg. But in aneurism of the posterior tibial high up it would be better to tie the femoral artery.

To tie the posterior tibial artery at the ankle, a semilunar incision, convex backward, should be made through the integument, about two inches and a half in length, midway between the heel and the inner ankle or a little nearer the latter. The subcutaneous cellular tissue having been divided, a strong and dense fascia, the internal annular ligament, is exposed. This ligament is continuous above with the deep fascia of the leg, covers the vessels and nerves, and is intimately adherent to the sheaths of the tendons. This having been cautiously divided upon a director, the sheath of the vessels is exposed, and, being opened, the artery is seen with one of the venous comites on each side. The aneurism needle should be passed round the vessel from the heel toward the ankle, in order to avoid the posterior tibial nerve, care being at the same time taken not to include the venous comites.

The vessel may also be tied in the lower third of the leg by making an incision, about three inches in length, parallel with the inner margin of the tendon Achilles. The internal saphenous vein being carefully avoided, the two layers of fascia must be divided upon a director, when the artery is exposed along the outer margin of the Flexor longus digitorum, with one of its venous comites on either side and the nerve lying external to it.

To tie the posterior tibial in the middle of the leg is a very difficult operation, on account of the great depth of the vessel from the surface. The patient being placed in the recumbent position, the injured limb should rest on its outer side, the knee being partially bent and the foot extended, so as to relax the muscles of the calf. An incision about four inches in length should then be made through the integument a finger’s breadth behind the inner margin of the tibia, taking care to avoid the internal saphenous vein. The deep fascia having been divided, the margin of the Gastrocnemius is exposed, and must be drawn aside, and the tibial attachment of the Soleus divided, a director being previously passed beneath it. The artery may now be felt pulsating beneath the deep fascia about an inch from the margin of the tibia. The fascia having been divided, and the limb placed in such a position as to relax the muscles of the calf as much as possible, the veins should be separated from the artery, and the aneurism needle passed round the vessel from without inward, so as to avoid wounding the posterior tibial nerve.

Branches.—The branches of the posterior tibial artery are—the

- Peroneal.
- Nutrient.
- Muscular.
- Cutaneous.
- Communicating.
- Internal Calcanean.
- Malleolar cutaneous.
The Peroneal Artery (a. peronaea) (Fig. 434) lies, deeply seated, along the back part of the fibular side of the leg. It arises from the posterior tibial about an inch below the lower border of the Popliteus muscle, passes obliquely outward to the fibula, and then descends along the inner border of that bone, contained in a fibrous canal between the Tibialis posticus and the Flexor longus hallucis, or in the substance of the latter muscle to the lower third of the leg, where it gives off the anterior peroneal. It then passes across the articulation between the tibia and fibula to the outer side of the os calcis, where it gives off its terminal branches, the external calcanean.

Relations.—This vessel rests at first upon the Tibialis posticus, and then, for the greater part of its course, in a fibrous canal between the origins of the Flexor longus hallucis and Tibialis posticus, covered or surrounded by the fibres of the Flexor longus hallucis. It is covered, in the upper part of its course, by the Soleus and deep transverse fascia; below, by the Flexor longus hallucis.

**Plan of the Relations of the Peroneal Artery.**

**In front.**

Tibialis posticus.
Flexor longus hallucis.

**Outer side.**

Fibula.
Flexor longus hallucis.

**Inner side.**

Peroneal Artery.
Flexor longus hallucis.

**Behind.**

Soleus.
Deep transverse fascia.
Flexor longus hallucis.

**Peculiarities in Origin.**—The peroneal artery may arise three inches below the Popliteus, or from the posterior tibial high up, or even from the popliteal.

Its size is more frequently increased than diminished; and then it either reinforces the posterior tibial by its junction with it, or altogether takes the place of the posterior tibial in the lower part of the leg and foot, the latter vessel only existing as a short muscular branch. In those rare cases where the peroneal artery is smaller than usual a branch from the posterior tibial supplies its place, and a branch from the anterior tibial compensates for the diminished anterior peroneal artery. In one case the peroneal artery has been found entirely wanting.

The anterior peroneal is sometimes enlarged, and takes the place of the dorsal artery of the foot.

**Branches.**—The branches of the peroneal are—the

Muscular.
Nutrient.
Anterior Peroneal.

**Communicating.**

Posterior Peroneal.
External Calcanean.

**Muscular Branches.**—The peroneal artery in its course gives off branches to the Soleus, Tibialis posticus, Flexor longus hallucis, and Peronei muscles.

The Nutrient Artery (a. nutritia fibulae) supplies the fibula.

The Anterior Peroneal (ramus perforans) (Fig. 436) pierces the interosseous membrane, about two inches above the outer malleolus, to reach the forepart of the leg, and, passing down beneath the Peroneus tertius to the outer ankle, ramifies on the front and outer side of the tarsus, anastomosing with the external malleolar and tarsal arteries.

The Communicating (ramus communicans) is given off from the peroneal about an inch from its lower end, and, passing inward, join the communicating branch of the posterior tibial.
The **Posterior Peroneal** passes down behind the outer ankle to the back of the external malleolus, to terminate in branches which ramify on the outer surface and back of the os calcis.

**External Calcanean** (*ramus calcaneus lateralis*) are the terminal branches of the peroneal artery; they pass to the outer side of the heel, and communicate with the external malleolar, and, on the back of the heel, with the internal calcanean arteries.

**Cutaneous Branches** come from the posterior tibial and supply the skin of the inner side and back of the leg.

The **Nutrient Artery** of the tibia (*a. nutricia tibiae*) arises from the posterior tibial near its origin, and, after supplying a few muscular branches, enters the nutrient canal of that bone, which it traverses obliquely from above downward. This is the largest nutrient artery of bone in the body.

The **Muscular Branches** of the posterior tibial are distributed to the Soleus and deep muscles along the back of the leg.

The **Communicating Branch** (*ramus communicans*), to join a similar branch of the peroneal, runs transversely across the back of the tibia, about two inches above its lower end, passing beneath the Flexor longus hallucis.

The **Malleolar** or **Internal Malleolar** (*a. malleolaris posterior medialis*) lies upon the tibia, sends branches over the inner ankle, and anastomoses with the inner malleolar branch of the anterior tibial.

The **Internal Calcanean** (*rami calcanei mediales*) are several large arteries which arise from the posterior tibial just before its division: they are distributed to the fat and integument behind the tendo Achillis and about the heel, and to the muscles on the inner side of the sole, anastomosing with the peroneal and internal malleolar, and, on the back of the heel, with the external calcanean arteries.

The **Internal Plantar Artery** (*a. plantaris medialis*) (Figs. 437 and 438), much smaller than the external, passes forward along the inner side of the foot. It is
at first situated above⁠¹ the Abductor hallucis, and then between it and the Flexor brevis digitorum, both of which it supplies. At the base of the first metatarsal bone, where it has become much diminished in size, it passes along the inner border of the great toe, inosculating with its digital branch. Small superficial digital branches (ramus superficialis) accompany the digital branches of the medial plantar nerve and join the plantar digital arteries of the three inner spaces. In addition, this vessel gives off numerous cutaneous branches.

The External Plantar Artery (a. plantaris lateralis) (Figs. 437 and 438), much larger than the internal, passes obliquely outward and forward to the base of the fifth metatarsal bone. It then turns obliquely inward to the interval between the bases of the first and second metatarsal bones, where it anastomoses with the communicating branch from the dorsalis pedis artery, thus completing the plantar arch (arcus plantaris) (Fig. 438). As this artery passes outward, it is first placed between the os calcis and Abductor hallucis, and then between the Flexor brevis digitorum and Flexor accessorius, and as it passes forward to the base of the little toe it lies more superficially between the Flexor brevis digitorum and Abductor minimi digitii, covered by the deep fascia and integument. The remaining portion of the vessel is deeply situated: it extends from the base of the metatarsal bone of the little toe to the back part of the first interosseous space, and forms the plantar arch; it is convex forward, lies upon the Interossei muscles opposite the tarsal ends of the metatarsal bones, and is covered by the Adductor obliquus hallucis, the flexor tendons of the toes, and the Lumbricales.

Surface Marking.—The course of the internal plantar artery is represented by a line drawn from the midpoint of the tip of the internal malleolus and the centre of the convexity of the heel to the middle of the under surface of the great toe; the external plantar by a line from the same point to within a finger's breadth of the tuberosity of the fifth metatarsal bone. The plantar arch is indicated by a line drawn from this point—i.e., a finger's breadth internal to the tuberosity of the fifth metatarsal bone transversely across the foot to the back of the first interosseous space.

Surgical Anatomy.—Wounds of the plantar arch are always serious, on account of the depth of the vessel and the important structures which must be interfered with in an attempt to ligate it. They must be treated on similar lines to those of wounds of the palmar arches (see page 667). Delorme has shown that the plantar arch may be ligated from the dorsum of the foot in almost any part of its course by removing a portion of one of the three middle metatarsal bones.

Branches.—The plantar arch, besides distributing numerous branches to the muscles, integument, and fasciae in the sole, gives off the following branches:

Posterior Perforating. Digital.

The Posterior Perforating (rami perforantes posteriores) are three small branches which ascend through the back part of the three outer interosseous spaces, between the heads of the Dorsal interossei muscles, and anastomoses with the interosseous branches from the metatarsal artery.

The Digital Branches (aa. metatarsae plantares) are four in number, and supply the three outer toes and half the second toe. It will be remembered that the arteria princeps hallucis is the plantar digital branch of the communicating arms in the first interosseous space and supplies the adjacent sides of the great and little toes. The first digital branch of the plantar arch passes outward from the outer side of the plantar arch, and is distributed to the outer side of the little toe, passing in its course beneath the Abductor and short Flexor muscles. The second, third, and fourth run forward along the interosseous spaces, and on arriving at the clefts between the toes divides into collateral digital branches (aa: digitales plantares), which supply the adjacent sides of the three outer toes and

¹ This refers to the erect position of the body. In the ordinary position for dissection the artery is deeper than the muscle.
the outer side of the second. At the bifurcation of the toes each digital artery sends upward, through the forepart of the corresponding interosseous space, a small branch which inosculates with the interosseous branches of the metatarsal artery. These are the **anterior perforating branches** (*rami perforantes anteriores*).

From the arrangement already described of the distribution of the vessels to the toes it will be seen that both sides of the three outer toes and the outer side of the second toe are supplied by branches from the plantar arch; both sides of the great toe and the inner side of the second are supplied by the communicating branch of the dorsalis pedis.
THE VEINS.

The Veins are the vessels which serve to return the blood from the capillaries of the different parts of the body to the heart. They consist of two distinct sets of vessels, the pulmonary and systemic veins, and an appendage to the systemic, the portal system.

The Pulmonary Veins are concerned in the circulation in the lungs. Unlike other vessels of this kind, they contain arterial blood, which they return from the lungs to the left auricle of the heart. The pulmonary veins are four in number.

The Systemic Veins are concerned in the general circulation; they return the venous blood from the body generally to the right auricle of the heart. The systemic veins are the precava or superior vena cava, the postcava or inferior vena cava, and the coronary sinus.

The Portal Vein and its radicles constitute the portal system. The portal system is in reality an appendage to the systemic venous system. It is confined to the abdominal cavity, returning the venous blood from the viscera of digestion, and carrying it to the liver by a single trunk of large size, the portal vein or vena portae. This vessel ramifies in the substance of the liver and breaks up into a minute
network of capillaries. These capillaries then re-collect to form the hepatic veins, by which the blood is conveyed to the postcava.

The veins, like the arteries, are found in nearly every tissue of the body. They commence by minute plexuses which receive the blood from the capillaries. The branches which have their commencement in these plexuses unite together into trunks, and these, in their passage toward the heart, constantly increase in size as they receive tributaries or join other veins. The veins are larger and altogether more numerous than the arteries; hence the entire capacity of the venous system is much greater than that of the arterial, the pulmonary veins excepted, which only slightly exceed in capacity the pulmonary arteries. From the combined area of the smaller venous branches being greater than the main trunks, it results that the venous system represents a cone, the summit of which corresponds to the heart, its base to the circumference of the body. In form the veins are perfectly cylindrical, like the arteries, their walls being collapsed when empty, and the uniformity of their surface being interrupted at intervals by slight constrictions, which indicate the existence of valves in their interior (Fig. 439). They usually retain, however, about the same calibre as long as they receive no branches, but not so uniformly as do the arteries.

The veins communicate very freely with one another (Fig. 441), especially in certain regions of the body, and this communication exists between the larger trunks as well as between the smaller branches. Thus, in the cavity of the cranium and between the veins of the neck, where obstruction would be attended with imminent danger to the cerebral-venous system, we find that the sinuses and larger veins have large and very frequent anastomoses (Fig. 440). The same free communication exists between the veins throughout the whole extent of the spinal canal, and between the veins composing the various venous plexuses in the abdomen and pelvis, as the spermatic, uterine, vesical, and prostatic.

Veins have thinner walls than arteries, the difference in thickness being due to the small amount of elastic and muscular tissues which the veins contain. The superficial veins usually have thicker coats than the deep veins, and the veins of the lower limb are thicker than those of the upper.

**Histology of the Veins.**—As previously stated, capillaries enter into venules or precapillary veins. The venules empty into larger veins. Vein walls are much thinner than arterial walls. A vein has a much thinner media and much less elastic tissue than an artery, and a very strongly developed adventitia. The intima is a connective-tissue layer containing a small number of elastic fibres and lined with endothelium. The media contains some circular muscle fibres and some fine elastic fibres. In some veins the media is thoroughly well developed (veins of the lower extremities), in others it is practically absent (veins of the retina, of the pia, of bone, the precava). The adventitia is dense and strong, and is composed of connective-tissue elastic fibres and non-striated muscle fibres placed longitudinally. Fig. 442 shows a transverse section of part of the wall of a vein. The vein valves (Fig. 439) are composed of intima and contain elastic fibres. The large veins and the veins of medium size possess vasa vaso-
THE PULMONARY VEINS

723
titia and to some extent in the media. The walls of veins contain vasomotor nerves. "Small blood-vessels are often surrounded by lymph capillaries and sometimes by endothelium-lined spaces which are in communication with the lymphatic system. These are called perivascular lymph spaces."1

The systemic veins are subdivided into three sets: superficial, deep, and sinuses. The Superficial or Cutaneous Veins are found between the layers of the superficial fascia, immediately beneath the integument; they return the blood from these structures, and communicate with the deep veins by perforating the deep fascia.

![Transverse section of part of the wall of one of the posterior tibial veins](image)

The Deep Veins accompany the arteries, and are usually enclosed in the same sheath with those vessels. With the smaller arteries—as the radial, ulnar, brachial, tibial, and peroneal—they exist generally in pairs, one lying on each side of the vessel, and are called venæ comites. The larger arteries—as the axillary, subclavian, popliteal, and femoral—have usually only one accompanying vein. In certain organs of the body, however, the deep veins do not accompany the arteries; for instance, the veins in the skull and spinal canal, the hepatic veins in the liver, and the larger veins returning blood from the osseous tissue.

Sinuses are venous channels which, in their structure and mode of distribution, differ altogether from the veins. They are found only in the interior of the skull, and consist of channels formed by a separation of the two layers of the dura, their outer coat consisting of fibrous tissue, their inner of an endothelial layer continuous with the lining membrane of the veins.

THE PULMONARY VEINS (V. PULMONALES) (Fig. 443).

The pulmonary veins return the arterial blood from the lungs to the left auricle of the heart. They are four in number, two for each lung. The pulmonary veins differ from other veins in several respects: 1. They carry arterial instead of venous blood. 2. They are destitute of valves. 3. They are only slightly larger than the arteries they accompany. 4. They accompany those vessels singly. They commence in a capillary network upon the walls of the air-cells, where they are continuous with the capillary ramifications of the pulmonary artery, and, uniting together, form one vessel for each lobe. These vessels, uniting successively, form a single trunk for each lobe, three for the right and two for the left lung. The vein from the middle lobe of the right lung generally unites with that from the upper lobe, forming two trunks on each side, which open separately into the left auricle. Occasionally they remain separate; there are then three

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1 Histology and Microscopic Anatomy. By Szymonowicz and MacCallum.
veins on the right side. Not unfrequently the two left pulmonary veins terminate by a common opening.

Within the lung, the branches of the pulmonary artery are in front, the veins behind, and the bronchi between the two.

At the root of the lung, the veins are in front, the artery in the middle, and the bronchus behind.

Within the pericardium, their anterior surface is invested by the serous layer of this membrane. The right pulmonary veins pass behind the right auricle and ascending aorta and precava; the left pass in front of the thoracic aorta with the left pulmonary artery.

THE SYSTEMIC VEINS.

The systemic veins may be arranged into three groups: 1. Those of the head and neck, upper extremity, and thorax, which terminate in the precava. 2. Those of the lower extremity, abdomen, and pelvis, which terminate in the postcava. 3. The cardiac veins, which open directly into the right auricle of the heart.

VEINS OF THE HEAD AND NECK.

The veins of the head and neck may be subdivided into three groups: 1. The veins of the exterior of the head and face. 2. The veins of the neck. 3. The veins of the diploë and interior of the cranium.
Veins of the Exterior of the Head and Face (Fig. 444).

The veins of the exterior of the head and face are—the

Frontal.                     Temporal.
Supraorbital.                Internal Maxillary.
Angular.                     Temporo-maxillary.
Facial.                      Posterior Auricular.
Occipital.

The **Frontal Vein** (*v. frontalis*) commences on the anterior part of the skull by a venous plexus which communicates with the anterior tributaries of the temporal vein. The veins converge to form a single trunk, which runs downward near the middle line of the forehead parallel with the vein of the opposite side, and unites with it at the root of the nose by a transverse branch called the **nasal arch** (*v. naso-frontalis*). Occasionally the frontal veins join to form a single trunk, which
bifurcates at the root of the nose into the two angular veins. At the root of
the nose the veins diverge and join the supraorbital vein, at the inner angle of
the orbit, to form the angular vein.

The Supraorbital Vein (v. supraorbitalis) commences on the forehead, com-
municating with the anterior temporal vein, and runs downward and inward,
superficial to the Occipito-frontalis muscle, receiving tributaries from the neigh-
boring structures, and from the frontal vein of the diploë, and joins the frontal
vein at the inner angle of the orbit to form the angular vein.

The Angular Vein (v. angularis), formed by the junction of the frontal and
supraorbital veins, runs obliquely downward and outward on the side of the root
of the nose, and receives the veins of the ala nasi on its inner side and the superior
corneal veins on its outer side; it moreover communicates with the ophthalmic
vein, thus establishing an important anastomosis between this vessel and the
cavernous sinus. Some small veins from the dorsum of the nose terminate in the
nasal arch.

The Anterior Facial Vein (v. facialis anterior) commences at the side of the
root of the nose, being a direct continuation of the angular vein, which is itself
formed by the union of the frontal vein and the supraorbital vein. It lies behind
and follows a less tortuous course than the facial artery. It passes obliquely
downward and outward, beneath the Zygomaticus major and minor muscles,
descends along the anterior border of the Masseter, crosses over the body of the
lower jaw, with the facial artery to beneath the angle, and unites with the anterior
division of the temporo-maxillary vein (v. facialis posterior) to form the common
facial vein.

The Common Facial Vein (v. facialis communis) is formed by the union of the
anterior facial and the anterior division of the temporo-maxillary vein, just beneath
the angle of the mandible. The vein is covered by the Platysma myoid muscle,
runs downward and backward beneath the Sterno-cleido-mastoid muscle, crosses
the external carotid artery, and empties into the internal jugular vein at the level
of the hyoid line. It receives a large branch at the anterior border of the Sterno-
cleido-mastoid muscle, which comes from the anterior jugular vein in the supra-
sternal fossa.

Tributaries of the Anterior and Common Facial Veins.—The anterior facial vein
receives, near the angle of the mouth, communicating tributaries of considerable
size, the deep facial or anterior internal maxillary vein, from the pterygoid
plexus. It is also joined by the inferior palpebral, the superior and inferior
labial veins, the buccal veins from the cheek, and the masseteric veins. The
common facial vein receives the submental; the inferior palatine, which returns
the blood from the plexus round the tonsil and soft palate; the submaxillary
vein, which commences in the submaxillary gland; and, generally, the ranine
vein.

Surgical Anatomy.—There are some points about the facial vein which render it of great
importance in surgery. It is not so flaccid as are most superficial veins, and, in consequence of
this, remains more patent when divided. It has, moreover, no valves. It communicates freely
with the intra-cranial circulation, not only at its commencement by its tributaries, the angular
and supraorbital veins, communicating with the ophthalmic vein, a tributary of the cavernous
sinus, but also by its deep branch, which communicates through the pterygoid plexus with the
cavernous sinus by branches which pass through the foramen ovale and foramen lacerum
medium. These facts have an important bearing upon the surgery of some diseases of the
face, for on account of its patency the facial vein favors septic absorption, and therefore any
phlegmonous inflammation of the face following a poisoned wound is liable to set up thrombosis
in the facial vein, and detached portions of the clot may give rise to purulent foci in other
parts of the body. And on account of its communications with the cerebral sinuses these
thrombi are apt to extend upward into them and so induce a fatal issue.
The Superficial Temporal Vein (vv. temporales superficiales) commences by a minute plexus on the side and vertex of the skull, which communicates with the frontal and supraorbital veins in front, the corresponding vein of the opposite side, and the posterior auricular and occipital veins behind. From this network anterior and posterior branches are formed which unite above the zygoma, forming the trunk of the vein. The trunk is joined in this situation by a large vein, the middle temporal (v. temporalis media), which receives blood from the substance of the Temporal muscle and pierces the fascia at the upper border of the zygoma. The junction of the superficial temporal and the middle temporal veins forms the common temporal vein (v. temporalis communis), which descends between the external auditory meatus and the condyle of the jaw, enters the substance of the parotid gland, and unites with the internal maxillary vein to form the temporo-massillay vein.

Tributaries.—The common temporal vein receives in its course some parotid veins, an articular branch from the articulation of the jaw, anterior auricular veins from the external ear, and a vein of large size, the transverse facial (v. transversa faciei), from the side of the face. The middle temporal vein, previous to its junction with the temporal vein, receives a branch, the orbital vein (v. orbitalis), which is formed by some external palpebral branches, and passes backward between the layers of the temporal fascia.

The Pterygoid Plexus (plexus pterygoideus) and the Internal Maxillary Vein.—The internal maxillary vein is a vessel of considerable size, receiving branches which correspond with those of the internal maxillary artery. Thus it receives the two mediulral or middle meningeal veins, the deep temporal, the pterygoid, masseteric, buccal, and alveolar veins, some palatine veins, the sphenopalatine and the inferior dental veins. The deep temporal veins (vv. temporales profundae) come to the pterygoid plexus from the temporal muscle. These branches form a large plexus, the pterygoid plexus, which is placed between the Temporal and External pterygoid and partly between the Pterygoid muscles. This plexus is a tributary of the internal maxillary vein, and communicates very freely with the facial vein and with the cavernous sinus by branches through the foramen Vesali, foramen ovale, and foramen lacerum medium, at the base of the skull. The trunk of the internal maxillary vein comes from the plexus, then passes backward behind the neck of the lower jaw, and unites with the temporal vein, forming the temporo-massillay vein.

The Temporo-massillay Vein (v. facialis posterior), formed by the union of the superficial temporal and internal maxillary veins, descends in the substance of the parotid gland on the outer surface of the external carotid artery, between the ramus of the jaw and the Sterno-mastoid muscle, and divides into two branches, an anterior, which passes inward to join the facial vein, and a posterior, which is joined by the posterior auricular vein and becomes the external jugular.

The Posterior Auricular Vein (v. auricularis posterior) commences upon the side of the head by a plexus which communicates with the tributaries of the temporal and occipital veins. The vein descends behind the external ear and joins the posterior division of the temporo-massillay vein, forming the external jugular. This vessel receives the stylo-mastoid vein and some tributaries from the back part of the external ear.

The Occipital Vein (v. occipitalis) commences at the back part of the vertex of the skull by a plexus in a similar manner to the other veins. From the plexus comes one or two veins, which follow the course of the occipital artery, passing deeply beneath the muscles of the back part of the neck, and terminating in the suboccipital triangle by becoming continuous with the posterior vertebral vein. Sometimes they are more superficial, and in this case they are tributaries of the
external jugular vein. As the outermost occipital vein passes across the mastoid portion of the temporal bone, it receives the mastoid vein, which thus establishes a communication with the lateral sinus.

**The Veins of the Neck (Fig. 444).**

The veins of the neck, which return the blood from the head and face, are—the

- **External Jugular.**
- **Posterior External Jugular.**
- **Vertebral.**
- **Anterior Jugular.**
- **Internal Jugular.**

The **External Jugular Vein** (*v. jugularis externa*) receives the greater part of the blood from the exterior of the cranium and deep parts of the face, being formed by the junction of the posterior division of the temporo-maxillary and the posterior auricular veins. It commences in the substance of the parotid gland, on a level with the angle of the lower jaw, and runs perpendicularly down the neck in the direction of a line drawn from the angle of the jaw to the middle of the clavicle. In its course it crosses the Sterno-mastoid muscle, and runs parallel with its posterior border as far as its attachment to the clavicle, where it perforates the deep fascia, and terminates in the subclavian vein, on the outer side of, or in front of, the Scalemus anticus muscle. In the neck it is separated from the Sterno-mastoid by the investing layer of the deep cervical fascia, and is covered by the Platysma, the superficial fascia, and the integument. This vein is crossed about its middle by the superficialis colli nerve, and throughout the upper half of its course is accompanied by the auricularis magnus nerve. The external jugular vein varies in size, bearing an inverse proportion to that of the other veins of the neck; it is occasionally double. It is provided with two pairs of valves, the lower pair being placed at its entrance into the subclavian vein, the upper pair in most cases about an inch and a half above the clavicle. The portion of vein between the two sets of valves is often dilated, and is termed the **sinus**. These valves do not prevent the regurgitation of the blood or the passage of injection from below upward.¹

**Tributaries.**—This vein receives the occipital occasionally, the posterior external jugular, and, near its termination, the suprascapular and transverse cervical veins. It communicates with the anterior jugular, and, in the substance of the parotid, receives a large branch of communication from the internal jugular.

The **Posterior External Jugular Vein** (*v. jugularis posterior*) commences in the occipital region, and returns the blood from the integument and superficial muscles in the upper and back part of the neck, lying between the Splenius and Trapezius muscles. It runs down the back part of the neck, and opens into the external jugular just below the middle of its course.

The **Anterior Jugular Vein** (*v. jugularis anterior*) commences near the hyoid bone from the convergence of the inferior coronary, the submental and the mental veins, and communicating branches. It passes down between the median line and the anterior border of the Sterno-mastoid, and at the lower part of the neck passes beneath that muscle to open into the termination of the external jugular or into the subclavian vein (Fig. 465). This vein varies considerably in size, bearing almost always an inverse proportion to the external jugular. Most frequently there are two anterior jugulars, a right and left, but occasionally only one. This vein receives some laryngeal veins, and occasionally a small thyroid vein. Just above the sternum the two anterior jugular veins communicate by a

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¹ The student may refer to an interesting paper by Dr. Struthers, "On Jugular Venesection in Asphyxia, Anatomically and Experimentally Considered, including the Demonstration of Valves in the Veins of the Neck," in the Edinburgh Medical Journal for November, 1856.—Ed. of 15th English edition.
transverse trunk, which receives tributaries from the inferior thyroid veins. It also communicates with the internal jugular. There are no valves in this vein.

The **Internal Jugular Vein** (*v. jugularis interna*) collects the blood from the interior of the cranium, from the superficial parts of the face, and from the neck. It *commences* just external to the jugular foramen, at the base of the skull, being formed by the coalescence of the lateral and inferior petrosal sinuses (Fig. 458). At its origin it is somewhat dilated, and this dilatation is called the *sinus* or *gulf of the internal jugular vein* (*bulbus v. jugularis superior*). It runs down the side of the neck in a vertical direction, lying at first on the outer side of the internal carotid artery, and then on the outer side of the common carotid artery, and at the root of the neck unites with the subclavian vein to form the innominate vein. Just before its termination it is distinctly dilated (*bulbus v. jugularis inferior*). The internal jugular vein, at its *commencement*, lies upon the Rectus capitis lateralis, and behind the internal carotid artery and the nerves passing through the jugular foramen; lower down, the vein and artery lie upon the same plane, the glossopharyngeal and hypoglossal nerves passing forward between them; the vagus descends between and behind them in the same sheath, and the accessory passes obliquely outward, behind or in front of the vein. At the root of the neck the vein of the right side is placed at a little distance from the artery; on the left side it usually lies over the artery at its lower part. The right internal jugular vein crosses the first part of the subclavian artery. The internal jugular vein is of considerable size, but varies in different individuals, the left one being usually the smaller. It is provided with a pair of valves, which are placed at its point of termination or from one-half to three-quarters of an inch above it.

**Tributaries.**—This vein receives in its course the facial, lingual, pharyngeal, superior, and middle thyroid veins. A branch from the cochlea opens into the sinus of the internal jugular vein. A venous plexus from the lateral sinus (*plexus venosus caroticus internus*) surrounds the internal carotid artery in the carotid canal and empties into the internal jugular vein. At its point of junction with the common facial vein it becomes increased in size. (See Facial Veins, p. 726.)

The **Lingual Veins** (*vv. linguale*) (Fig. 445) *commence* on the dorsum, sides, and under surface of the tongue, and, passing backward, following the course of the lingual artery and its branches, terminate in the internal jugular. Sometimes the **ranine vein**, which is a branch of considerable size commencing below the tip of the

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**Fig. 445.**—Veins of the tongue. (Testut, modified from Hirschfeld.)
tongue, joins the lingual. Generally, however, it passes backward, crosses the Hyo-glossus muscle in company with the hypoglossal nerve, and joins the internal jugular. The lingual vein receives the sublingual vein and the dorsalis lingue veins.

The Pharyngeal Veins (vv. pharyngeae) vary in number. They commence in a minute plexus, the pharyngeal plexus (plexus pharyngeus), at the back part and sides of the pharynx, and, after receiving meningeal tributaries, the dural or meningeal veins (vv. meningeae), the Vidian veins (vv. canalis pterygoidei [Vidiī]), and the sphenopalatine veins, terminate in the internal jugular. They occasionally open into the facial, lingual, or superior thyroid vein.

The Superior Thyroid Vein (v. thyreoida superioris) (Fig. 446) commences in the substance and on the surface of the thyroid gland by tributaries corresponding with the branches of the superior thyroid artery, and terminates in the upper part of the internal jugular vein. It receives the superior laryngeal and cricothyroid veins. Some anatomists teach that there are two superior thyroid veins on each side, the upper vein being the one just considered, the lower vein being the one usually pointed out as the middle thyroid.

The Middle Thyroid Vein (Fig. 448) collects the blood from the lower part of the lateral lobe of the thyroid gland, and, being joined by some veins from the larynx and trachea, terminates in the lower part of the internal jugular vein. Often in
place of the middle thyroid vein there are two veins, the superior and inferior accessory thyroid. These veins pass into the internal jugular.

Veins of the Thyroid Gland\(^1\) (Fig. 447).—On the surface of the thyroid glands the veins form a plexus between the capsule and the gland. A number of veins

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\(^1\) See Kocher's description in Langenbeck's Arch. f. klin. Chir., vol. xxix., and James Berry's description in his treatise on Diseases of the Thyroid Gland.
penetrate the capsule and pass into adjacent trunks. The most important veins coming from the gland are the superior, middle, and inferior thyroids (or instead of the middle thyroid the superior and inferior accessory thyroid) and the thyreoidea ima.

The superior thyroid vein emerges from the summit of the superior horn of the gland, runs along by the superior thyroid artery, and terminates in the internal jugular vein. A large branch which passes along the inner margin of the upper horn and across the upper surface of the isthmus joins the superior thyroid veins of each side. The middle thyroid vein when present emerges from the side of the gland and empties into the internal jugular. This single vein may be replaced by two veins, the superior and inferior accessory thyroid veins. The superior vein emerges from the outer surface of the upper horn somewhat below the apex. The inferior vein comes from the posterior and inferior portion of the gland. Both empty into the internal jugular. The lower surface of the isthmus and the inner side of each inferior horn is drained by two veins. Each vein is called the thyreoidea ima (Kocher). The left vein empties into the left innominate vein. The right vein empties into either the right or left innominate vein. These veins may be very small, may be absent, or may join and form one vein which empties into the left innominate. An inferior thyroid is often also present. It comes from the outer portion of the inferior horn of the gland and empties into the innominate vein.

The facial and occipital veins have been described on pages 726 and 727.

Surgical Anatomy.—The internal jugular vein occasionally requires ligature in cases of septic thrombosis of the lateral sinus from suppuration in the middle ear. This is done in order to prevent septic emboli being carried into the general circulation. This operation has been performed in a number of cases, with satisfactory results. The cases are generally those of chronic disease of the middle ear, with discharge of pus which perhaps has existed for many years. The patient is seized with acute septic inflammation, spreading to the mastoid cells, and, consequent on this, septic thrombosis of the lateral sinus extending to the internal jugular vein. Such cases are always extremely grave, for there is danger that a portion of the septic clot will be detached and cause septic embolism in the thoracic visceræ. If thrombo-phlebitis of the sinus is suspected the mastoid should be opened and cleansed and the sinus should be at once exposed and explored. If the sinus is found to be thrombosed the surgeon should at once proceed to ligate the internal jugular vein, by an incision along the anterior border of the sternomastoid, the centre of which is on a level with the greater cornu of the hyoid bone. The vein should be ligated in two places and divided between. After the vessel has been secured and divided the lateral sinus is to be thoroughly cleared out, and, by removing the ligature from the upper end of the divided vein, all septic clots may be removed by syringing from the sinus through the vein. If hemorrhage occurs from the distal end of the sinus, it can be arrested by careful plugging with antiseptic gauze.

The thyroid veins are small vessels when the gland is of normal size, but become enormous when the gland is much enlarged.

In the operation of thyroidectomy the veins as well as the arteries are ligated before the gland, or rather before one lobe of it is extirpated.

The Vertebral Vein (v. vertebrai) (Fig. 449) commences by numerous small veins from the intraspinal venous plexuses (plexus venosi vertebrales); these pass outward and enter the foramen in the transverse process of the atlas, and descend, forming a dense plexus around the vertebral artery in the canal formed by the foramina in the transverse processes of the cervical vertebrae. The vessels of this plexus unite at the lower part of the neck into two main trunks, one of which emerges from the foramen in the transverse process of the sixth cervical vertebra, and the other through that of the seventh. Uniting, these two trunks form a single vessel which terminates at the root of the neck in the back part of the innominate vein near its origin, its mouth being guarded by a pair of valves. On the right side it crosses the first part of the subclavian artery.

Tributaries.—The vertebral vein receives in its course a vein from the inside of the skull through the posterior condylloid foramen. It anastomoses with the
THE VEINS OF THE DIPLOÈ

...occipital vein and receives muscular veins from the muscles in the prevertebral region; dorsi-spinal veins, from the back part of the cervical portion of the spine; meningo-rachidian veins, from the interior of the spinal canal; the anterior and posterior vertebral veins; and close to its termination it is joined by a small vein from the first intercostal space which accompanies the superior intercostal artery.

The Anterior Vertebral or Anterior Deep Cervical Vein commences in a plexus around the transverse processes of the upper cervical vertebrae, descends in company with the ascending cervical artery between the Scalenus anticus and Rectus capitis anticus major muscles, and opens into the vertebral vein just before its termination.

The Posterior Vertebral or Posterior Deep Cervical Vein (v. cervicalis profunda) (Fig. 449) accompanies the profunda cervicis artery, lying between the Complexus and Semispinalis colli. It commences in the suboccipital region by communicating branches from the occipital vein and tributaries from the deep muscles at the back of the neck. It receives tributaries from the plexuses around the spinous processes of the cervical vertebrae, and terminates in the lower end of the vertebral vein.

The Veins of the Diploë (Venae Diploicae) (Fig. 450).

The diploë of the cranial bones is channelled in the adult by a number of tortuous canals, the diploic canals or canals of Breschet (canales diploici [Brescheti]), which are lined by a more or less complete layer of compact tissue. The veins they contain are large and capacious, their walls being thin, and formed only of endothelium resting upon a layer of elastic tissue, and they present at irregular intervals pouch-like dilatations, or culs-de-sac, which serve as reservoirs for the blood. These are the veins of the diploë; they can only be displayed by removing the outer table of the skull.

In adult life, as long as the cranial bones are distinct and separable, these veins are confined to the particular bones; but in old age, when the sutures are...
united, they communicate with each other and increase in size. These vessels communicate, in the interior of the cranium, with the dural veins and with the sinuses of the dura, and on the exterior of the skull with the veins of the pericranium. They are divided into the frontal diploic vein (v. diploica frontalis), which opens into the supraorbital vein by an aperture in the supraorbital notch and into the superior longitudinal sinus; the anterior temporal diploic vein (v. diploica temporalis anterior), which is confined chiefly to the frontal bone, communicates with the sphenoparietal sinus and, after escaping by an aperture in the great wing of the sphenoid, opens into one of the deep temporal veins; the posterior temporal, or external parietal diploic vein (v. diploica temporalis posterior), is between the emissarium parietale and the emissarium mastoideum; and the occipital diploic vein (v. diploica occipitalis), the largest of the four, which is confined to the occipital bone, and opens into the emissarium occipitale.

Fig. 450.—Veins of the diploë as displayed by the removal of the outer table of the skull.

The Emissary Veins are considered on page 743.

The Dural or Meningeal Veins (vv. meningeae).—They are numerous in the dura, are without valves, anastomose freely with each other, do not increase in size as they reach the sinus which receives them, and bear no regular relation to the dural arteries. The medidural artery has two vena comites. The other dural arteries usually have two apiece, but may have but one. The medidural or middle meningeal veins (vv. mediduralis, vv. meningeae mediae) accompany the medidural artery, are united to the sphenoparietal sinus, pass through the foramen spinosum, and join the pterygoid plexus. The other dural veins empty into the longitudinal sinus and communicate with the plexus of the foramen ovale.

The Cerebral Veins (Venae Cerebri).

The cerebral veins are remarkable for the absence of valves and for the extreme thinness of their coats. The coats are thin because they contain no muscular tissue. The cerebral veins may be divided into two sets: the superficial veins, which are placed on the surface, and the deep veins, which occupy the interior of the organ. The veins of the brain do not accompany associated arteries.
The **Superficial** or **Cortical Cerebral Veins** (*venae cerebri externae*) ramify upon the surface of the brain, being lodged in the fissures between the convolutions, a few running across the convolutions. They receive branches from the substance of the brain and terminate in the sinuses. They are named, from the position they occupy, **super cerebra**l or **superior, medici** cerebral or **median**, and **sub cerebra**l or **in**ferior cerebra**l** veins.

The **Super cerebra**l or **Superior Cerebral Veins** (*vv. super cerebrales, vv. cerebri superiores*), eight to twelve in number on each side, return the blood from the convolutions on the superior surface of the hemisphere; they pass forward and inward toward the intercerebral fissure, where they receive the medicerebral veins; near their termination they become invested with a tubular sheath of the arachnoid, and open into the longitudinal sinus in the opposite direction to the course of the current of the blood.

The **Medi cerebra**l or **Median Cerebral Veins** (*v. medici cerebrales, v. cerebri media*) return the blood from the convolutions of the mesial surface of the corresponding hemisphere; they open into the supercerebral veins, or occasionally into the falcial sinus.

The **Sub cerebra**l or **Inferior Cerebral Veins** (*vv. sub cerebrales, vv. cerebri inferiores*) ramify on the lower part of the outer surface and on the under surface of the cerebral hemisphere. Some, collecting tributaries from the under surface of the frontal lobes of the brain, terminate in the cavernous sinus. One vein of large size, the **medi cerebra**l or **superficial sylvian vein**, commences on the under surface of the temporal lobe, and, running along a portion of the sylvian fissure, opens into the cavernous sinus. The **great anastomotic vein of Trolard or the superficial communicating vein** establishes a union between the sinuses of the vertex and those of the base of the brain. It comes from one of the supercerebral veins, passes downward into the sylvian fissure, and, by means of the medicerebral vein, effects a communication with the cavernous sinus. The **posterior anastomotic vein** connects the medicerebral vein with the lateral sinus. Other veins commence on the under surface of the base of the brain, and unite to form from three to five veins, which open into the superpetrosal and lateral sinuses from before backward.

The **Velar, Deep Cerebral, Central, or Ventricular Veins, Veins of Galen** (*vv. velares, venae Galeni, vv. cerebri internae*) (Fig. 647), are two in number. Each is formed by the union of two veins, the **vena corporis striati**, and the **choroid vein**, on either side. The velar veins run backward, parallel with one another, between the layers of the velum, and in the region of the epiphysis unite to form one vein, the **vena magna Galeni** (*v. cerebri magna*), which passes out of the brain at the great transverse fissure, between the posterior extremity, or splenium, of the callosum and the quadrigemina, to enter the tentorial sinus. The two velar veins receive tributaries from the callosal region, from a portion of the occipital lobe, and just before their union each vein receives the basilar vein. The vena magna Galeni receives the **vermian vein** from the superficial cerebellar veins.

The **Vena Corporis Striati** on each side **commences** in the groove between the corpus striatum and optic thalamus, receives numerous veins from both of these parts, and unites behind the fornix column with the choroid vein to form one of the velar veins.

The **Choroid Vein** (*v. choroidae*) originates in the extreme end of the mediusern of the lateral ventricle and runs along the whole length of the outer border of the parapleura, receiving veins from the hippocampus, the fornix, and callosum, and unites, at the anterior extremity of the parapleura, with the vein of the corpus striatum to form the velar vein of that side.

The **Basilar Vein** (*v. basalis*) **commences** at the preperforatum at the base of the brain by the union of a small precerebral vein, which courses backward between the frontal lobes of the cerebrum, with the deep sylvian vein, which
descends through the lower part of the sylvian fissure and receives veins from the insula. It passes backward over the crus, receiving the inferior striate vein from the corpus striatum, intercural veins from the interceral space, ventricular veins from the medullary of the lateral ventricles, and tributaries from the uncinate gyre, and enters the vein of Galen just before its junction with the vein of the opposite side.

The Superficial Cerebellar Veins (Fig. 645) occupy the surface of the cerebellum, and are disposed in two sets, supercerebellar or superior, and subcerebellar or inferior.

The Superficial or Superior Superficial Cerebellar Veins (vv. supercerebellares, vv. cerebelli superiores) pass partly forward and inward, across the superior vermis (prevermis), to terminate in lateral branches which pass partly to the tentorial sinus and partly outward to the lateral and superpetrosal sinuses.

The Subcerebellar or Inferior Superficial Cerebellar Veins (vv. subcerebellares, vv. cerebelli inferiores), of large size, terminate in the lateral, subpetrosal, and occipital sinuses.

The Deep Cerebellar Veins bring blood from the interior of the cerebellum to the superficial veins.

Veins of the Pons.—Veins come from the depth of the pons, the deep veins, and empty into a plexus of superficial veins. From this superficial venous plexus a superior vein passes to the basilar vein, and an inferior vein either into a cerebellar vein or into the superpetrosal sinus.

Veins of the Oblongata.—Veins pass from the depth of the oblongata and end in a plexus on the surface. From this plexus comes a ventro-median vein, which is a prolongation of a like vein of the spinal cord—a dorso-median vein corresponding to a like vein of the cord—and small branches which pass with the roots of the glosso-pharyngeal, vagus, accessory, and hypoglossal nerves, and empty into the occipital and the subpetrosal sinuses.

The perivascular lymph-spaces are especially found in connection with the vessels of the brain. These vessels are enclosed in a sheath, which acts as a lymphatic channel, through which the lymph is carried to the subarachnoid and subdural spaces, from which it is returned into the general circulation.

The Sinuses of the Dura (Sinus Durae Matris) (Figs. 451, 452, 453, 456, 457)

Ophthalmic Veins and Emissary Veins.

The sinuses of the dura are venous channels formed by a separation of the two layers of this membrane, the outer coat consisting of fibrous tissue, the inner coat of an endothelial layer continuous with the lining membrane of the veins. The thick walls of a sinus resist intracranial pressure. They are divided into two sets: (1) those situated at the upper and back part of the skull; (2) those at the base of the skull. The former are—the

Longitudinal or Superior Longitudinal Sinus. Tentorial or Straight Sinus.

Falcial or Inferior Longitudinal Sinus. Lateral Sinuses.

Occipital Sinus.

The Longitudinal or Superior Longitudinal Sinus (sinus longitudinalis, sinus sagittalis superior) (Figs. 451, 452, and 453) occupies the attached margin of the falx. Commencing at the foramen cæcum, through which, in the child, it constantly communicates by a small branch with the veins of the nasal fossa, it runs from before backward, grooving the inner surface of the frontal, the adjacent margins of the two parietal, and the superior division of the crucial ridge of the occipital bone, and terminates by opening into the torcular. The sinus is triangular on transverse section, is narrow in front, and gradually increases in size as it passes backward. On examining its inner surface it presents the internal openings of the supercerebral veins, which run, for the most part, from behind forward, and open

1 A. W. Hughes.
chiefly at the back part of the sinus, their orifices being concealed by fibrous folds; numerous fibrous bands, chordae Willisii (Fig. 453), are also seen extending transversely across the inferior angle of the sinus; and some small, white, projecting bodies, the glandulae Pacchioni (granulationes arachnoidales). This sinus communicates by numerous small apertures with spaces in the dura

known as lacunae laterales or parasinoidal spaces (Fig. 453). The arachnoid villi project into these spaces. This sinus receives the supercerebral veins, numerous veins from the diploë and dura, the outlets of the parasinoidal spaces, and, at the posterior extremity of the sagittal suture, veins from the pericranium, which pass through the parietal foramina. In children the longitudinal sinus receives a twig from the nose which passes through the foramen cæcum.

The Torcular or the Confluence of the Sinuses (Figs. 452 and 456) is the dilated extremity of the longitudinal sinus. It is of irregular form, and is lodged on one
side (generally the right) of the internal occipital protuberance. From it the lateral sinus of the side to which it is deflected is derived. It receives also the blood from the occipital sinus.

The Falcial or Inferior Longitudinal Sinus (sinus falcialis, sinus sagittalis inferior) (Fig. 452), more correctly described as the inferior longitudinal vein, is contained in the posterior part of the free margin of the falx. It is of a cylindrical form, increases in size as it passes backward, and terminates in the tentorial sinus. It receives several veins from the falx, and occasionally a few from the mesal surface of the hemispheres.

The Tentorial or Straight Sinus (sinus tentorii, sinus rectus) (Figs. 451 and 452) is situated at the line of junction of the falx with the tentorium. It is triangular in form, increases in size as it proceeds backward, and runs obliquely downward and backward from the termination of the falcial sinus to the lateral sinus of the opposite side to that into which the longitudinal sinus is prolonged. It communicates by a cross-branch with the torcular. Besides the falcial sinus, it receives the vena magna Galeni and the supereerebellar veins. A few transverse bands cross its interior. This sinus is usually considered to be formed by the union of the great vein of Galen and the falcial sinus.

The Lateral Sinus (sinus lateralis, sinus transversus) (Figs. 451, 452, 456, and 457) is of large size. There are two lateral sinuses situated in the attached margin of the tentorium throughout most of its extent. They commence at the internal occipital protuberance, one, generally the right, being the direct continuation of the
longitudinal sinus, the other of the tentorial sinus. Each passes outward and forward, describing a slight curve with its convexity upward, to the base of the petrous portion of the temporal bone, then, leaving the tentorium, curves downward and inward to reach the jugular foramen, where it terminates in the internal jugular vein. It rests, in its course, upon the inner surface of the occipital, the posterior inferior angle of the parietal, and the mastoid portion of the temporal bone, and on the occipital again, at the jugular process, just before its termination. The portion of the sinus resting on the mastoid process of the temporal and the jugular process of the occipital bone is not covered by the tentorium and is often called the sigmoid sinus because of its shape, which resembles the letter S. These sinuses are frequently of unequal size, that formed by the longitudinal sinus being the larger, and they increase in size as they proceed from behind forward. The horizontal portion is of a triangular form, the curved portion semicylindrical. Their inner surface is smooth, and not crossed by the fibrous bands found in the other sinuses. The lateral sinuses receive the blood from the superpetrosal sinuses at the base of the petrous portion of the temporal bone, and they unite with the subpetrosal sinus, just external to the jugular foramen, to form the internal jugular vein (Fig. 457). They communicate with the veins of the pericranium by means of the mastoid and posterior condyloid veins, and they receive some of the subcerebral and subcerebellar veins, some veins from the diploë, and often veins from the internal ear (\textit{v. auditivae internae}), which come out of the internal auditory meatus. The petro-squamous sinus, when present, runs backward along the junction of the petrous and squamous portions of the temporal bone, and opens into the lateral sinus.

**Surgical Anatomy.**—The lateral sinus may, as a result of middle-ear disease, be attacked by supplicative inflammation, which leads to blocking (\textit{septic thrombo-phlebitis}). In such a case the surgeon will be obliged to open the sinus to remove infected clot and tie the internal jugular vein to intercept thrombi. The line overlying the sinus is as follows: Draw a line horizontally outward from the occipital protuberance to a point one inch posterior to a vertical line drawn through the external auditory meatus and from this point drop a second line to the mastoid process.

The \textbf{Occipital Sinus} (\textit{sinus occipitalis}) (Fig. 452) is the smallest of the cranial sinuses. There is often but a single occipital sinus, but occasionally there are two. It is situated in the attached margin of the falx. It commences by several small veins around the margin of the foramen magnum, one of which joins the termination of the lateral sinus; it communicates with the posterior spinal veins and terminates in the torcular.

The sinuses at the base of the skull are—the

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<thead>
<tr>
<th>Cavernous Sinuses.</th>
<th>Superpetrosal Sinuses or Superior Petrosal Sinuses.</th>
</tr>
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<tbody>
<tr>
<td>Sphenoparietal Sinuses.</td>
<td>Subpetrosal Sinuses or Inferior Petrosal Sinuses.</td>
</tr>
<tr>
<td>Circular Sinus.</td>
<td>Transverse Sinus.</td>
</tr>
</tbody>
</table>

The \textbf{Cavernous Sinus} (\textit{sinus cavernosus}) (Figs. 456 and 457) is named from presenting a reticulated structure, due to being traversed by numerous interlacing filaments (Fig. 454). There are two cavernous sinuses, of irregular form, larger behind than in front, and placed one on each side of the sella turcica, extending from the sphenoidal fissure to the apex of the petrous portion of the temporal bone. Each receives anteriorly the ophthalmic vein through the sphenoidal fissure, and opens behind into the petrosal sinuses. On the inner wall of each sinus is found the internal carotid artery, accompanied by filaments of the carotid plexus and by the abducent nerve; and on its outer wall, the oculomotor, trochlear, and ophthalmic division of the trigeminal nerve (Fig. 454). These parts are separated
from the blood flowing along the sinus by the lining membrane, which is continuous with the inner coat of the veins. The cavernous sinuses receive some of the cerebral veins, and also the sphenoparietal sinuses. They communicate with the lateral sinuses by means of the super- and subpetrosal sinuses, and with the facial veins through the ophthalmic veins. They also communicate with each other by means of the circular sinus.

**Surgical Anatomy.**—An arterio-venous communication may be established between the cavernous sinus and the carotid artery, as it lies in it, giving rise to a pulsating tumor in the orbit. Such a communication may be the result of injury, such as a bullet wound, a stab, or a blow or fall sufficiently severe to cause a fracture of the base of the skull in this situation, or it may occur from the rupture of an aneurism or a diseased condition of the internal carotid artery. The disease begins with sudden noise and pain in the head, followed by exophthalmos, swelling and congestion of the lids and conjunctive. A pulsating tumor develops at the margin of the orbit, with thrill and the characteristic bruit; accompanying these symptoms there may be impairment of sight, paralysis of the iris and orbital muscles, and pain of varying intensity. In some cases the opposite orbit becomes affected by the passage of the arterial blood into the opposite sinus by means of the circular sinus. Or the arterial blood may find its way through the emissary veins into the pterygoid plexus, and thence into the veins of the face. Pulsating tumors of the orbit may also be due to traumatic aneurism of one of the orbital arteries, and symptoms resembling those of pulsating tumor may be produced by pressure on the ophthalmic vein, as it enters the sinus, by an aneurism of the internal carotid artery.

The Sphenoparietal Sinus or Sinus Alae Parvae (sinus sphenoparietalis).—Each of these sinuses is lodged in the dura on the under surface of the lesser wing of the sphenoid bone. It takes origin from one of the medullar veins, usually receives blood from the diploë of the skull, passes inward, and ends in the anterior part of the cavernous sinus.

The Ophthalmic Veins are two in number, superior and inferior.

The superior ophthalmic vein (v. ophthalmica superior) (Fig. 455) begins as the naso-frontal vein (v. nasofrontalis), at the inner angle of the orbit, which communicates with the angular vein. It joins the angular vein with the cavernous sinus; it pursues the same course as the ophthalmic artery, and receives tributaries corresponding to the branches derived from that vessel. Forming a short single trunk, it passes through the inner extremity of the sphenoidal fissure, and terminates in the cavernous sinus. It anastomoses with the inferior ophthalmic vein and receives lachrymal, anterior, and posterior ethmoidal and muscular branches, and veins of the eyelids and of the bulbus oculi.
The inferior ophthamlic vein (*v. ophthalmica inferior*) (Fig. 455) arises in the veins of the eyelids and lachrymal sac, receives the veins from the floor of the orbit, and from the portion of the nasal fossa supplied by the anterior and posterior ethmoidal arteries. It either passes out of the orbit through the spheno-maxillary fissure to join the pterygoid plexus of veins, or else, passing backward through the sphenoidal fissure, it enters the cavernous sinus, either by a separate opening, or, more frequently, in common with the superior ophthalmic vein. It receives muscular
The blood-vascular system

tributaries and veins of the bulbus oculi, and anastomoses with the superior ophthalmic vein.

The **Circular Sinus** (*sinus circularis*) (Figs. 454 and 456) is formed by two transverse vessels, the **anterior** and **posterior intercavernous sinuses** (*sinus intercavernous anterior* and *sinus intercavernous posterior*), which connect together the two cavernous sinuses; the one passing in front and the other behind the hypophysis, and thus forming with the cavernous sinuses a venous circle around that body. The anterior one is usually the larger of the two, and one or other is occasionally found to be absent.

The **Superpetrosal** or **Superior Petrosal Sinus** (*sinus superpetrosus, sinus petrosus superior*) (Figs. 452 and 456) is situated along the superior border of the petrous portion of the temporal bone, in the front part of the attached margin of the tentorium. It is small and narrow, and connects together the cavernous and lateral sinuses at each side. It receives some cerebellar and subcerebral veins, and usually veins from the tympanic cavity.

The **Subpetrosal** or **Inferior Petrosal Sinus** (*sinus subpetrosus, sinus petrosus inferior*) (Figs. 452 and 456) is situated in the groove formed by the junction of the posterior border of the petrous portion of the temporal with the basilar process of the occipital bone. It *commences* in front at the termination of the cavernous sinus, and behind joins the lateral sinus after it has passed through the jugular foramen; the junction of these two sinuses forming the commencement of the internal jugular vein. The subpetrosal sinus receives a vein from the internal ear and also veins from the medulla, pons, and under surface of the cerebellum.

The junction of the two sinuses takes place at the lower border of, or just external to, the jugular foramen. The exact relation of the parts to one another in the
foramen is as follows: The subpetrosal sinus is in front, with the dural branch of the ascending pharyngeal artery, and is directed obliquely downward and backward; the lateral sinus is situated at the back part of the foramen with a dural branch of the occipital artery, and between the two are the glossopharyngeal, vagus, and accessory nerves (Fig. 457). These three sets of structures are divided from each other by two processes of fibrous tissue. The junction of the sinuses takes place superficial to the nerves, so that these latter lie a little internal to the venous channels in the foramen (Fig. 457). These sinuses are semicylindrical in form.

The Transverse or Basilar Sinus (plexus basilaris) (Figs. 456 and 457) consists of several interlacing veins between the layers of the dura over the basilar process of the occipital bone, which serve to connect the two subpetrosal sinuses. With them the anterior spinal veins communicate.

Emissary Veins (emissaria).—The emissary veins are vessels which pass through apertures in the cranial wall and establish communications between the sinuses inside the skull and the diploic veins in the diploë, and the veins external to the skull. Some of these are always present, others only occasionally so. They vary much in size in different individuals. The principal emissary veins are the following: 1. A vein, almost always present, which passes through the mastoid foramen (emissarium mastoideum) and connects the lateral sinus with the posterior auricular or with an occipital vein. 2. A constant vein which passes through the parietal foramen (emissarium parietale) and connects the longitudinal sinus with the veins of the scalp. 3. A plexus of minute veins which pass through the anterior condyloid foramen (emissarium condyloideum) and connect the occipital sinus with the vertebral vein and deep veins of the neck. 4. An inconstant vein which passes through the posterior condyloid foramen and connects the lateral sinus with the deep veins of the neck. 5. One or two veins of considerable size which pass through the foramen ovale and connect the cavernous sinus with the pterygoid and pharyngeal plexuses. 6. Two or three small veins which pass through the foramen lacerum medium and connect the cavernous sinus with the pterygoid and pharyngeal plexuses. 7. There is sometimes a small vein connecting the same parts and passing through the inconstant foramen of Vesalius at the root of the pterygoid process of the sphenoid bone. 8. A plexus of veins passing through the carotid canal and connecting the cavernous sinus with the internal jugular vein. 9. A small vein (emissarium occipitale) usually connects the occipital vein with the lateral sinus or the torcular and the occipital diploic vein.

Surgical Anatomy.—These emissary veins are of great importance in surgery. In addition to them there are, however, other communications between the intra- and extra-cranial circulation, as, for instance, the communication of the angular and supra-orbital veins with the ophthalmic vein at the inner angle of the orbit, and the communication of the veins of the scalp with the diploic veins. Through these communications inflammatory processes commencing on the outside of the skull may travel inward, leading to osteo-phlebitis of the diploë and inflammation of the membranes of the brain. To this in former days was to be attributed one of the principal dangers of scalp wounds and other injuries of the scalp.

By means of these emissary veins blood may be abstracted almost directly from the intracranial circulation. For instance, leeches applied behind the ear abstract blood almost directly from the lateral sinus by means of the vein passing through the mastoid foramen. Again, epistaxis in children will frequently relieve severe headache, the blood which flows from the nose being derived from the longitudinal sinus by means of the vein which passes through the foramen cecum, which is another communication between the intracranial and extracranial circulation constantly found in children.
THE BLOOD-VASCULAR SYSTEM

VEINS OF THE UPPER EXTREMITY AND THORAX.

The veins of the Upper Extremity are divided into two sets, superficial and deep.

The Superficial Veins are placed immediately beneath the integument between the layers of superficial fascia.

The Deep Veins accompany the arteries, and constitute the venae comites of those vessels.

Both sets of vessels are provided with valves, which are more numerous in the deep than in the superficial veins.
The Superficial Veins of the Upper Extremity (Fig. 459).

The superficial veins of the upper extremity are—the

Superficial Veins of the Hand.  
Anterior Ulnar.  
Posterior Ulnar.  
Common Ulnar.  
Radial.  
Median.  
Median Cephalic.  
Median Basilic.  
Basilic.  
Cephalic.

The **Superficial Veins of the Hand and Fingers** (Figs. 458 and 459) are principally situated on the dorsal surface. These dorsal veins begin in each finger as a venous plexus, in which are distinct veins running in a longitudinal direction, and called **dorsal digital veins** (vv. digitales dorsales propriae). The dorsal digital veins terminate over the first phalanges, in the **venous arches of the fingers** (areus venosi digitales). From these arches take origin the four **dorsal interosseous** or the **interdigital veins** (vv. metacarpeae dorsales). These veins form the **dorsal venous plexus of the hand** (rete venosum dorsale manus). This plexus lies in a line with the lower ends of the shafts of the metacarpal bones. It receives the dorsal interosseous veins, the radial digital vein of the index finger, and numerous superficial veins from the back of the hand. It gives origin to the superficial radial vein and the posterior ulnar vein. The superficial veins of the palmar surface are of less diameter than the dorsal veins. They arise from each of the phalanges by a plexus (vv. digitales volares propriae). Vessels at the edges of the fingers take most of the blood to the dorsal veins. There are also veins in the finger webs (vv. intercapitulares), which take blood from the palm to the dorsum. A superficial plexus, the **palmar plexus**, lies upon the palmar fascia, the fascia of the thenar eminence, and the fascia of the hypothenar eminence.

The **Anterior Ulnar Vein** (v. ulnaris anterior) (Fig. 459) commences on the anterior surface of the ulnar side of the hand and wrist, and ascends along the anterior surface of the ulnar side of the forearm to the bend of the elbow, where it joins with the posterior ulnar vein to form the common ulnar. Occasionally it opens separately into the median basilic vein. It communicates with branches of the median vein in front and with the posterior ulnar behind.

The **Posterior or Dorsal Ulnar Vein** (v. ulnaris posterior) (Fig. 458) commences on the posterior surface of the ulnar side of the wrist. It runs on the posterior surface of the ulnar side of the forearm, and just below the elbow unites with the anterior ulnar vein to form the common ulnar, or else joins the median basilic and helps to form the basilic. It communicates with the deep veins of the palm by a branch which emerges from beneath the Abductor minimi digitii muscle.

The **Common Ulnar Vein** (v. ulnaris communis) (Fig. 459) is a short trunk which is not constant. When it exists it is formed by the junction of the two preceding veins, and, passing upward and outward, joins the median basilic to form the basilic vein. When it does not exist the anterior and posterior ulnar veins open separately into the median basilic vein.

The **Radial Vein** (v. radialis) (Figs. 459 and 460) commences upon the dorsal surface of the wrist, communicating with the deep veins of the palm by a branch which passes through the first interosseous space. The radial vein soon forms a large vessel, which ascends along the radial side of the forearm and receives numerous veins from both its surfaces. At the bend of the elbow it unites with the median cephalic to form the cephalic vein. Spalteholz considers the ulnar vein as a portion of the basilic and the radial vein a portion of the cephalic.

The **Median Vein** (v. mediana cubiti) (Fig. 459) ascends on the front of the forearm, and communicates with the anterior ulnar and radial veins. At the bend
of the elbow it receives a branch of communication from the deep veins, the **deep median vein**, and divides into two branches, the **median cephalic** and **median basilic**, which diverge from each other as they ascend.

The **Median Cephalic** (v. mediana cephalica) (Fig. 459), usually the smaller of the two, passes outward in the groove between the Supinator longus and Biceps muscles, and joins with the radial to form the cephalic vein. The branches of the external cutaneous nerve pass beneath this vessel.

The **Median Basilic Vein** (v. mediana basilica) (Fig. 459) passes obliquely inward, in the groove between the Biceps and Pronator radii teres muscles, and joins the common ulnar to form the basilic. This vein passes in front of the brachial artery, from which it is separated by a fibrous expansion, the **bicipital fascia**, which is given off from the tendon of the Biceps to the fascia covering the Flexor muscles of the forearm. Filaments of the internal cutaneous nerve pass in front as well as behind this vessel.¹

**Venesection** is usually performed at the bend of the elbow, and as a matter of practice the largest vein in this situation is commonly selected. This is usually the median basilic, and there are anatomical advantages and disadvantages in selecting this vein. The advantages are, that in addition to its being the largest, and therefore yielding a greater supply of blood, it is the least movable and can be easily steadied on the bicipital fascia on which it rests. The disadvantages are, that it is in close relationship with the brachial artery, separated only by the bicipital fascia; and formerly, when venesection was frequently practised, arterio-venous aneurism was no uncommon result of this practice. Another disadvantage is, that the median basilic is crossed by some of the branches of the internal cutaneous nerve, and these may be divided in the operation, giving rise to “traumatic neuralgia of extreme intensity” (Tillaux).

The **Basilic Vein** (v. basilica) (Figs. 460 and 462) is of considerable size and is formed by the coalescence of the common ulnar vein with the median

¹ Cruveilhier says: “Numerous varieties are observed in the disposition of the veins of the elbow; sometimes the common median vein is wanting; but in those cases its two branches are furnished by the radial vein, and the cephalic is almost always in a rudimentary condition. In other cases only two veins are found at the bend of the elbow, the radial and ulnar, which are continuous, without any demarcation, with the cephalic and basilic.”—Ed. of 15th English edition.
It passes upward along the inner side of the Biceps muscle and pierces the deep fascia a little below the middle of the arm. The opening in the fascia is known as the semilunar hiatus (hiatus semilunaris). The vein ascends in the course of the brachial artery to the lower border of the tendons of the Latissimus dorsi and Teres major muscles, and is continued onward as the axillary vein.

The Cephalic Vein (v. cephalica) (Fig. 459) is formed by the union of the median cephalic and the radial veins. It courses along the outer border of the Biceps muscle, lying in the same groove with the upper external cutaneous branch of the musculo-spiral nerve, to the upper third of the arm; it then passes in the interval between the Pectoralis major and Deltoid muscles, lying in the same groove with the descending or humeral branch of the acromial-thoracic artery. It pierces the costo-coracoid membrane, and, crossing the axillary artery, terminates in the axillary vein just below the clavicle. This vein is occasionally connected with the external jugular or subclavian by a branch which passes from it upward in front of the clavicle.

The Deep Veins of the Upper Extremity (Fig. 460).

The deep veins of the upper extremity follow the course of the arteries, forming their venæ comites or companion veins. Usually there is one vein lying on each side of the corresponding artery, and they are connected at intervals by short transverse branches.

There are two digital veins accompanying each artery along the sides of the fingers: these, uniting at their base, pass along the interosseous spaces in the palm, and terminate in the two venæ comites which accompany the superficial palmar arch. Branches from these vessels on the radial side of the hand accompany the superficialis volae, and on the ulnar side terminate in the deep ulnar veins (Fig. 460). The deep ulnar veins, as they pass in front of the wrist, communicate with the interosseous and superficial veins, and at the elbow unite with the deep radial veins to form the venæ comites of the brachial artery. The venæ comites of the brachial communicate by numerous transverse branches, which cross over or under the artery.

The Interosseous Veins (Fig. 460) accompany the anterior and posterior interosseous arteries. The anterior interosseous veins commence in front of the wrist, where they communicate with the deep radial and ulnar veins; at the upper part of the forearm they receive the posterior interosseous veins, and terminate in the venæ comites of the ulnar artery.

The Deep Palmar Veins accompany the deep palmar arch, being formed by tributaries which accompany the ramifications of that vessel. At the wrist they receive a dorsal and a palmar tributary from the thumb. The deep palmar veins communicate with the deep ulnar veins at the inner side of the hand, and on the outer side terminate in the deep radial veins (Fig. 460), which are the venæ comites of the radial artery. Accompanying the radial artery the deep radial veins terminate in the venæ comites of the brachial artery.

The Brachial Veins (vv. brachiales) (Fig. 460) are placed one on each side of the brachial artery, receiving tributaries corresponding with the branches given off from that vessel; at the lower margin of the Subscapularis muscle they join the axillary vein.

These deep veins have numerous anastomoses, not only with each other, but also with the superficial veins. One of the brachial veins empties into the axillary, the other, usually the smaller, generally unites with the basilic.

The Axillary Vein (v. axillaris) (Fig. 461) is of large size, and may be regarded as the continuation upward of the basilic vein, or as formed by the fusion of a brachial vein with the basilic vein. If the first view is accepted a brachial vein is described as one of the tributaries of the axillary vein. The axillary vein com-
mences at the lower border of the tendons of the Teres major and Latissimus dorsi muscles, increases in size as it ascends, by receiving tributaries corresponding with the branches of the axillary artery, and terminates immediately beneath the clavicle at the outer border of the first rib, where it becomes the subclavian vein. This vessel is covered in front by the Pectoral muscles and costocoracoid membrane, and lies on the thoracic side of the axillary artery, which it partially overlaps. It receives the brachial veins, the venae comites of the axillary artery except the circumflex veins; and near its termination the cephalic vein. This vein is provided with a pair of valves opposite the lower border of the Subscapularis muscle; valves are also found at the termination of the cephalic and subscapular veins. The circumflex veins end in the subscapular or one of the brachial veins.

The **Long Thoracic Branch** (*v. thoracalis lateralis*) (Fig. 462) receives the **thoracoepigastric vein** (*v. thoracoepigastrica*), which comes all the way from the superficial epigastric or from the femoral vein.

The **Costo-axillary Veins** (*vv. costoaxillares*) (Fig. 462) come from the first six intercostal spaces and bring blood from the intercostal veins to the axillary.

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**Surgical Anatomy.**—There are several points of surgical interest in connection with the axillary vein. Being more superficial, larger, and slightly overlapping the axillary artery, it is more liable to be wounded in the operation of extirpation of the axillary glands, especially as these glands, when diseased, are apt to become adherent to the vessel. When wounded there is always danger of air being drawn into its interior, and death resulting. This is due not only to the fact that it is near the thorax, and therefore liable to be influenced by the respiratory movements, but also because it is adherent by its anterior surface to the costo-coracoid membrane, and therefore if wounded is likely to remain patulous and favor the chance of air being sucked in. This adhesion of the vein to the fascia prevents its collapsing, and therefore favors the furious bleeding which takes place in these cases.
To avoid wounding the axillary vein in the extirpation of glands from the axilla no undue force should be used in isolating the glands. If the vein is found to be so embedded in the malignant deposit that the latter cannot be removed without taking away a part of the vein, this must be done, the vessel having been first ligated above and below.

The Subclavian Vein (*v. subclavia*) (Figs. 424 and 446), the continuation of the axillary, extends from the outer border of the first rib to the inner end of the clavicle, where it unites with the internal jugular to form the innominate vein. It is in relation, in front, with the clavicle and Subclavius muscle; behind and above, with the subclavian artery, from which it is separated internally by the Scalenus anticus muscle and phrenic nerve. Below, it rests in a depression on the first rib and upon the pleura. Above, it is covered by the cervical fascia and integument.

An expansion of the aponeurosis of the Subclavius muscle lies upon the vein (Fig. 462).

The subclavian vein occasionally rises in the neck to a level with the third part of the subclavian artery, and in two instances has been seen passing with this vessel behind the Scalenus anticus. This vessel is usually provided with valves about an inch from its termination in the innominate, just external to the entrance of the external jugular vein.

**Tributaries.**—It receives the external and anterior jugular veins and a small branch from the cephalic, outside the Scalenus, and on the inner side of that muscle the internal jugular vein. At the angle of junction with the internal...
jugular the left subclavian vein receives the thoracic duct (Fig. 463), while the right subclavian vein receives the right lymphatic duct.

The **Innominate** or **Brachio-cephalic Veins** (*vv. anonymae*) (Fig. 464) are two large trunks, placed one on each side of the root of the neck, and formed by the union of the internal jugular and subclavian veins of the corresponding side.

The **Right Innominate Vein** (*v. anonyma dextra*) is a short vessel, an inch in length, which commences at the inner end of the clavicle, and, passing almost vertically downward, joins with the left innominate vein just below the cartilage of the first rib, close to the right border of the sternum, to form the precava, or **superior vena cava**. It lies superficial and external to the innominate artery; on its right side is the phrenic nerve, and the pleura is here interposed between it and the apex of the lung. This vein, at the angle of junction of the internal jugular with the subclavian, receives the right vertebral vein, and, lower down, the right internal mammary, right inferior thyroid, and sometimes the right thyroidea ima and the right superior intercostal veins.

The **Left Innominate Vein** (*v. anonyma sinistra*), about two and a half inches in length, and larger than the right, passes from left to right across the upper and front part of the chest, at the same time inclining downward, and unites with

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![Diagram of the thoracic duct and its termination in the subclavian vein.](image)

**Fig. 463.**—The bend of the thoracic duct at its termination in the subclavian vein. (Poirier and Charpy.)

the right innominate vein to form the precava. It is in relation, in *front*, with the first piece of the sternum, from which it is separated by the Sterno-hyoid and Sterno-thyroid muscles, the thymus gland or its remains, and some loose areolar tissue. *Behind*, it lies across the roots of the three large arteries arising from the arch of the aorta. This vessel is joined by the left vertebral, left internal mammary, left inferior thyroid, left thyroidea ima, and the left superior intercostal veins, and occasionally some thymic and pericardiac veins, and the right thyroidea ima. There are no valves in the innominate veins.

**Peculiarities.**—Sometimes the innominate veins open *separately* into the right auricle; in such cases the right vein takes the ordinary course of the precava; but the left vein—the left precava, or left superior vena cava, as it is termed—after communicating by a small branch with the right one, passes in front of the root of the left lung, and, turning to the back of the heart, receives the cardiac veins, and terminates in the back of the right auricle. This occasional condition in the adult is due to the persistence of the early foetal condition, and is the normal state of things in birds and some mammals.

The **Internal Mammary Vein** (*v. mammaria interna*) corresponds to the internal mammary artery, follows the course of that vessel, and receives branches corresponding with those derived from it. There are two internal mammary veins in the region of the Triangularis sterni muscle, but above this point the vein is single. The double vein is formed by the union of the venae comites of the superior epigastric
artery (vv. epigastricae superiores) and the vena comites of the musculo-phrenic artery (vv. musculophrenicae). It receives the twelve anterior intercostal veins from the upper six intercostal spaces of the corresponding side—six anterior perforating veins (rami perforantes)—veins from the surface of the sternum (rami sternalis) —muscular veins, and vessels from the mediastinum and pleura. The two veins of each side unite into a single trunk, at the upper margin of the triangularis sterni muscle, which terminates in the innominate vein.  

The Vertebral Vein (see p. 732).

The Inferior Thyroid Veins (vv. thyreoideae inferiores) (Fig. 464), two, frequently three or four, in number, arise in the venous plexus on the thyroid body (plexus thyreoideus impar), communicating with the middle and superior thyroid veins. (See Kocher’s views, pages 731 and 732.) Kocher states that two thyroid ima veins are present, and that inferior thyroid veins may also be present. The veins from the lower portion of the gland form a plexus in front of the trachea, behind the Sterno-thyroid muscles. From this plexus a left vein descends and joins the left innominate trunk, and a right vein passes obliquely downward and outward across the innominate artery to open into the right innominate vein, just at its junction with the precava. The thyreoidea ima vein (v. thyreoidea ima) passes downward in front of the trachea and terminates in the left innominate vein. These veins receive tributaries from the tracheal veins (vv. tracheales), from the oesophageal veins (vv. oesophageae), from the inferior laryngeal vein (v. laryngea inferior).
The Intercostal Veins (vv. intercostales) are divided into anterior and posterior intercostals.

The Anterior Intercostal Veins are tributaries of the internal mammary or the musculo-phrenic veins (p. 750).

The Posterior Intercostal Veins (Fig. 464) number eleven on each side, there being one vein in each intercostal space. Each vein lies in the groove at the lower margin of the rib above the corresponding intercostal artery. On the right side the first posterior intercostal vein crosses the neck of the first rib anteriorly and opens into the vertebral vein or the innominate vein. The first posterior intercostal of the left side follows a like course, and empties into the vertebral or innominate vein. The posterior intercostals of the right side, from the fifth to the eleventh, inclusive, open individually into the vena azygos major. The left upper azygos vein receives the fifth, sixth, seventh, and eighth posterior intercostals of the left side. The left lower azygos vein receives the ninth, tenth, and eleventh left posterior intercostals.

The Right Superior Intercostal Vein (v. intercostalis suprema dextra) is formed by the union of the second, third, and fourth right posterior intercostals. It passes downward and inward and opens into the vena azygos major.

The Left Superior Intercostal Vein (v. intercostalis suprema sinister) runs across the transverse aorta and opens into the left innominate vein. It usually receives the bronchial and left superior phrenic vein, and communicates below with the vena azygos minor superior. Each posterior intercostal vein obtains branches from the ribs and muscles and also a dorsal branch, which receives blood from the muscles of the back, from in front of the vertebral bodies, from back of the vertebral arches, and from the spinal canal by way of a vein which passes through the intervertebral foramen.

The Precava or Superior Vena Cava (v. cava superior) (Fig. 464) receives the blood which is conveyed to the heart from the whole of the upper half of the body. It is a short trunk, varying from two inches and a half to three inches in length, formed by the junction of the two innominate veins. It commences immediately below the cartilage of the first rib close to the sternum on the right side, and, descending vertically, enters the pericardium about an inch and a half above the heart, and terminates in the upper part of the right auricle opposite the upper border of the third right costal cartilage. In its course it describes a slight curve, the convexity of which is turned to the right side.

Relations.—In front, with the pericardium and process of cervical fascia which is continuous with it; this separates it from the thymus gland and from the sternum; behind, with the root of the right lung; on its right side, with the phrenic nerve and right pleura; on its left side, with the commencement of the innominate artery and ascending part of the aorta. The portion contained within the pericardium is covered by the serous layer of that membrane in its anterior three-fourths. It receives the vena azygos major just before it enters the pericardium, and several small veins from the pericardium and parts in the mediastinum. The precava has no valves.

The Azygos Veins connect together the precava and postcava, taking the place of those vessels in that part of the chest occupied by the heart.

The Larger or Right Azygos Vein or the Vena Azygos Major (v. azygos) (Fig. 464) commences opposite the first or second lumbar vertebra by a branch from the right lumbar veins, called the right ascending lumbar vein (v. lumbalis ascendens dextra); sometimes by a branch from the right renal vein or from the postcava. It enters the thorax through the aortic opening in the Diaphragm, and passes along the right side of the vertebral column to the fourth thoracic vertebra, where it arches forward over the root of the right lung, and terminates in the precava just before that vessel enters the pericardium. Whilst passing through the aortic opening
of the Diaphragm it lies with the thoracic duct on the right side of the aorta, and in the thorax it lies upon the intercostal arteries on the right side of the aorta and thoracic duct, and is partly covered by pleura.

**Tributaries.**—It receives the lower ten posterior intercostal veins of the right side, the upper two or three of these opening, first of all, into the right superior intercostal vein. It receives the azygos minor veins, several esophageal, mediastinal, and pericardial veins; near its termination, the right bronchial vein; and generally the right superior intercostal vein. A few imperfect valves are found in this vein; but its tributaries are provided with complete valves.

The intercostal veins on the left side, below the three upper intercostal spaces, usually form two trunks, named the **left lower and the left upper azygos veins.**

The **Left Lower or Smaller Azygos Vein** or the **Vena Azygos Minor** (v. hemiazygos) (Fig. 464) commences in the lumbar region by a branch from one of the lumbar veins, **ascending lumbar** (v. lumbalis ascendens), or from the left renal. It passes into the thorax through the left crus of the Diaphragm, and, ascending on the left side of the spine as high as the ninth thoracic vertebra, passes across the column, behind the aorta and thoracic duct, to terminate in the right azygos vein. It receives the four or five lower intercostal veins of the left side, and some esophageal and mediastinal veins.

The **Left Upper Azygos Vein** (v. hemiazygos accessoria) varies inversely with the size of the left superior intercostal. It receives veins from the intercostal spaces between the left superior intercostal vein and highest tributary of the left lower azygos. They are usually three or four in number, usually the fourth, fifth, sixth, and seventh left posterior intercostal veins. They join to form a trunk which ends in the right azygos vein or in the left lower azygos. It sometimes receives the left bronchial vein. When this vein is small or altogether wanting, the left superior intercostal vein will extend as low as the fifth or sixth intercostal space.

**Surgical Anatomy.**—In obstruction of the postcava the azygos veins are one of the principal means by which the venous circulation is carried on, connecting as they do the precava and postcava, and communicating with the common iliac veins by the ascending lumbar veins, and with many of the tributaries of the postcava.

The **Bronchial Veins** (vv. bronchiales) return the blood from the substance of the lungs, except from the smaller bronchial tubes and alveola. The blood from them is received by the pulmonary veins. The bronchial vein of the right side opens into the vena azygos major near its termination. The bronchial vein of the left side opens into the left superior intercostal vein or the left upper azygos vein. The bronchial veins are joined by veins from the trachea and mediastinum.

**The Spinal Veins.**

The numerous venous plexuses placed upon and within the spine may be arranged into four sets:

1. Those placed on the exterior of the spinal column, the **dorsi-scapal veins.**
2. Those situated in the interior of the spinal canal, between the vertebrae and the theca vertebralis, **meningo-rachidian veins.**
3. The veins of the bodies of the vertebrae, **venæ basis vertebrae.**
4. The veins of the spinal cord, **medulli-scapal veins.**

1. The **Dorsal-scapal Veins** (plexus venosi vertebralis externi) commence by small branches which receive their blood from the integument of the back of the spine and from the muscles in the vertebral grooves. They constitute two plexuses: one anterior plexus (plexus venosi vertebralis anteriores) upon the vertebral bodies and a **posterior plexus** (plexus venosi vertebralis posteriores), which surrounds the spinous processes, the laminae, and the transverse and articular processes of
all the vertebrae. At the bases of the transverse processes they communicate, by means of ascending and descending branches, with the veins surrounding the contiguous vertebrae, and they join with the veins in the spinal canal by branches which perforate the ligamenta subflava. Other branches pass obliquely forward, between the transverse processes, and communicate with the intraspinal veins through the intervertebral foramina (vv. intervertebrales). The dorsi-spinal veins terminate by joining the vertebral veins in the neck, the intercostal veins in the thorax, and the lumbar and sacral veins in the loins and pelvis.

![Diagram of the Blood-Vascular System](image)

**Fig. 465.**—Transverse section of a thoracic vertebra, showing the spinal veins.

2. The **Meningo-rachidian Veins** (*plexus venosi vertebrales interni*).—The principal veins contained in the spinal canal are situated between the theca vertebralis and the vertebrae. They consist of two longitudinal plexuses, one of which runs along the posterior surface of the bodies of the vertebrae, **anterior longitudinal spinal veins**. The other plexus, **posterior longitudinal spinal veins**, is placed on the inner or anterior surface of the laminae of the vertebrae.

![Diagram of the Blood-Vascular System](image)

**Fig. 466.**—Vertical section of two thoracic vertebrae, showing the spinal veins.

The **Anterior Longitudinal Spinal Veins** (*sinus vertebrales longitudinales*) consist of two large, tortuous veins which extend along the whole length of the vertebral column, from the foramen magnum, where they communicate by a venous ring around that opening, to the base of the coccyx, being placed one on each side of the posterior surface of the bodies of the vertebrae along the margin of the posterior common ligament. These veins communicate together opposite each vertebra by
VEINS OF LOWER EXTREMITY, ABDOMEN AND PELVIS 755

transverse trunks which pass beneath the ligament. Each transverse trunk receives the large vena basis vertebrae (v. basivertebralis) from the interior of the body of the vertebra. The anterior longitudinal spinal veins are least developed in the cervical and sacral regions. They are not of uniform size throughout, being alternately enlarged and constricted. At the intervertebral foramina they communicate with the dorsi-spinal veins, and with the vertebral veins in the neck, with the intercostal veins in the thoracic region, and with the lumbar and sacral veins in the corresponding regions.

The Posterior Longitudinal Spinal Veins, smaller than the anterior, are situated one on each side, between the inner surface of the laminae and the theca vertebralis. They communicate (like the anterior) opposite each vertebra by transverse trunks, and with the anterior longitudinal veins by lateral transverse branches which pass from behind forward. The posterior longitudinal veins, by branches which perforate the ligamenta subflava, join with the dorsi-spinal veins. From them branches are given off which pass through the intervertebral foramina and join the vertebral, intercostal, lumbar, and sacral veins. The anterior and posterior longitudinal spinal veins join by numerous branches and really constitute one plexus, the plexus venosi vertebrales interni.

The Intervertebral Veins (vv. intervertebrales) accompany the spinal nerves in the intervertebral foramina, receive veins from the spinal cord, and join the meningo-rachidian and the dorsi-spinal veins.

3. The Veins of the Bodies of the Vertebrae or the Venæ Basis Vertebrae (vv. basivertebræ) emerge from the foramen on the posterior surface of each vertebra and join the transverse trunk connecting the anterior longitudinal spinal veins. They are contained in large, tortuous channels in the substance of the bones, similar in every respect to those found in the diploe of the cranial bones. These canals lie parallel to the upper and lower surface of the bones. They commence by small openings on the front and sides of the bodies of the vertebrae, through which communicating branches from the veins external to the bone pass into its substance, and converge to the principal canal, which is sometimes double toward its posterior part. They open into the corresponding transverse branch uniting the anterior longitudinal veins. They become greatly developed in advanced age.

4. The Veins of the Spinal Cord or the Medulli-spinal Veins (vv. spinalæ) emerge from the cord substance and enter the pia plexus. The pia plexus is a minute, tortuous, venous plexus which covers the entire surface of the cord, being situated between the pia and arachnoid. “In this plexus there are six longitudinal channels—one antero-median, along the anterior fissure—two antero-lateral, immediately behind the anterior nerve roots—two postero-lateral, immediately behind the posterior nerve roots—and one postero-median, over the postero-septum” (Cunningham). These vessels are largest in the lumbar region. Near the base of the skull they unite and form two or three small trunks, which communicate with the vertebral veins, and terminate in the subcerebellar veins or in the subpetrosal sinuses. Each of the spinal nerves is accompanied by a branch as far as the intervertebral foramina, where it joins the other veins from the spinal canal.

There are no valves in the spinal veins.

VEINS OF THE LOWER EXTREMITY, ABDOMEN, AND PELVIS
(Figs. 467, 468).

The Veins of the Lower Extremity are subdivided, like those of the upper, into two sets, superficial and deep, the superficial veins being placed beneath the
integument, between the two layers of superficial fascia, the deep veins accompanying the arteries, and forming the venae comites of those vessels. Both sets of veins are provided with valves, which are more numerous in the deep than in the superficial set. These valves are also more numerous in the lower than in the upper limb.

The Superficial Veins of the Lower Extremity.

The Superficial Veins of the Foot.—On the sole of the foot there is a subcutaneous venous plexus (rete venosum plantare cutaneum), from which some branches go to the deep veins, but most of the branches pass around the margins to the dorsum of the foot. There is a transverse venous arch at the root of the toes which receives plantar vessels from the toes and sends branches between the toes (vv. intercapitulares) to the venous arch of the dorsum. On the dorsum of each toe the veins gather into two vessels, known as the dorsal digital veins (vv. digitales pedis dorsales). The dorsal digital veins from the opposed margins of two toes unite to form a dorsal interdigital vein. There are four dorsal interdigital veins (vv. digitales communes pedis), and they pass into the venous arch of the dorsum. The dorsal digital vein, from the inner surface of the great toe, passes directly into the internal saphenous vein, and the dorsal digital vein, from the outer surface of the little toe, passes directly into the external saphenous vein.

On the dorsum of the foot is a venous arch (arcus venosus dorsalis pedis [cutaneus]), situated in the superficial structures over the anterior extremities of the metatarsal bones. It has its convexity directed forward, and receives digital tributaries from the upper surface of the toes; at its concavity it is joined by numerous small veins which form a plexus on the dorsum of the foot (rete venosum dorsale pedis cutaneum). The arch terminates internally in the long saphenous, externally in the short saphenous vein.

The chief superficial veins of the lower extremity are the internal or long saphenous and the external or short saphenous.

The Internal or Long Saphenous Vein (v. saphena magna) (Figs. 467 and 470) commences at the inner side of the arch on the dorsum of the foot; it ascends in front of the inner malleolus and along the inner side of the leg, behind the inner margin of the tibia, accompanied by the internal saphenous nerve. At the knee it passes backward behind the inner condyle of the femur, ascends along the inside of the thigh, and, passing through the saphenous opening in the fascia lata, terminates in the femoral vein about an inch and a half below Poupart’s ligament. This vein receives in its course cutaneous tributaries from the leg and thigh, and at the saphenous opening receives the superficial epigastric, superficial circumflex iliac, and external pudic veins. The veins from the inner and back part of the thigh frequently unite to form a large vessel, which enters the main trunk near the saphenous opening; and sometimes those on the outer side of the thigh join to form another large vessel; so that occasionally three large veins are seen converging from different parts of the thigh toward the saphenous opening. The internal saphenous vein communicates in the foot with the internal planter vein; in the leg, with the posterior tibial veins by branches which perforate the tibial origin of the Soleus muscle, and also with the anterior tibial veins; at the knee, with the articular veins; in the thigh, with the femoral vein by one or more branches. The valves in this vein vary from two to six in number; they are more numerous in the thigh than in the leg.

The External or Short Saphenous Vein (v. saphena parva) (Fig. 468) commences at the outer side of the arch on the dorsum of the foot; it ascends behind the outer malleolus, and along the outer border of the tendon Achilles, across which it passes at an acute angle to reach the middle line of the posterior aspect of the leg.
Passing directly upward, it perforates the deep fascia in the lower part of the popliteal space, and terminates in the popliteal vein, between the heads of the Gastrocnemius muscle. It receives numerous large tributaries from the back part of the leg, and communicates with the deep veins on the dorsum of the foot and behind the outer malleolus. Before it perforates the deep fascia it gives off a communicating branch, which passes upward and inward to join the internal saphenous vein. This vein has a variable number of valves, from three to nine (Gay), one of which is always found near its termination in the popliteal vein. The external saphenous nerve lies close beside this vein.

**Surgical Anatomy.**—The saphenous veins are of considerable surgical importance, since a varicose condition of these vessels is more frequently met with than of those in other parts

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1 Mr. Gay calls attention to the fact that the external saphenous vein often (he says invariably) penetrates the fascia at or about the point where the tendon of the Gastrocnemius commences, and runs below the fascia in the rest of its course, or sometimes among the muscular fibres, to join the popliteal vein. (See Gay on Varicose Disease of the Lower Extremities, p. 24, where there is also a careful and elaborate description of the branches of the saphena vein.)—Ed. of 15th English edition.
of the body, except perhaps the spermatic and hemorrhoidal veins. The course of the internal saphenous is in front of the tip of the inner malleolus, over the subcutaneous surface of the lower end of the tibia, and then along the internal border of this bone to the back part of the internal condyle of the femur, whence it follows the course of the Sartorius muscle, and is represented on the surface by a line drawn from the posterior border of the Sartorius on a level with the internal condyle to the saphenous opening. The external saphenous lies behind the external malleolus, and from this follows the middle line of the calf to just below the ham. It is not generally so apparent beneath the skin as the internal saphenous. Both these veins in the leg are accompanied by nerves, the internal saphenous being joined by its companion nerve just below the level of the knee-joint. No doubt much of the pain of varicose veins in the leg is due to this fact.

The Deep Veins of the Lower Extremity.

The deep veins of the lower extremity accompany the arteries and their branches and are called the *venae comites* of those vessels. The *venae comites* in the lower extremity pass into one trunk, the *popliteal vein*, whereas in the upper extremity the *venae comites* continue with the artery to the axilla.

**The Deep Veins of the Foot.**—The *plantar digital veins* (*vv. digitales plantares*) form the *plantar metatarsal veins* (*vv. metatarsaeae plantares*), which communicate with the veins of the dorsum of the foot by perforating veins and also communicate with the deep venous arch of the sole of the foot (*arcus venosus plantaris profundus*). The plantar arch gives off *lateral* or *external plantar veins*, which unite with *median* or *internal plantar veins* to form the posterior tibial veins. On the dorsum of the foot the deep veins begin as the *dorsal metatarsal veins* (*vv. metatarsaeae dorsales pedis*), which form the *venae comites* of the dorsalis pedis artery.

The *Posterior Tibial Veins* (*vv. tibiales posteriores*) accompany the posterior tibial artery and are joined by the peroneal veins.

The *Anterior Tibial Veins* (*vv. tibiales anteriores*) are formed by a continuation upward of the *venae comites* of the dorsalis pedis artery. They pass between the tibia and fibula, through the large oval aperture above the interosseous membrane, and form, by their junction with the posterior tibial, the popliteal vein.

The valves in the deep veins are very numerous.

The *Popliteal Vein* (*v. poplitea*) (Fig. 469) is formed by the junction of the anterior and posterior tibial veins; it ascends through the popliteal space to the aperture in the Adductor magnus, where it becomes the femoral vein. In the lower part of its course it is placed internal to the artery; between the heads of the Gastrocnemius it is superficial to that vessel; but above the knee-joint it is close to the outer side of the artery. It receives the *sural veins* from the Gastrocnemius muscle, the articular veins, and the external saphenous vein. The valves in this vein are usually four in number.

The *Femoral Vein* (*v. femoralis*) (Figs. 470 and 471) accompanies the femoral artery through the upper two-thirds of the thigh. In the lower part of its course it lies external to the artery; higher up it is behind it; and at Poupart’s ligament it lies to its inner side and on the same plane. It receives numerous muscular tributaries, and about an inch and a half below Poupart’s ligament it is joined by
the profunda femoris (*v. profunda femoris*); near its termination it is joined by the internal saphenous vein. The valves in this vein are four or five in number.

The **External Iliac Vein** (*v. iliaca externa*) (Figs. 464, 471, and 473) *commences* at the termination of the femoral, beneath the crural arch, and, passing upward along the brim of the pelvis, terminates opposite the sacro-iliac synchondrosis by uniting with the internal iliac to form the common iliac vein. On the right side it lies at first along the inner side of the external iliac artery, but as it passes upward gradually inclines behind it. On the left side it lies altogether on the inner side of the artery. It receives, immediately above Poupart's ligament, the deep epigastric and deep circumflex iliac veins and a small pubic vein, corresponding to the pubic branch of the obturator artery. According to Friedreich, it frequently contains one and sometimes two valves.

The **Deep Epigastric Vein** (*v. epigastrica inferior*) (Fig. 471).—Two veins accompany the deep epigastric artery; they usually unite into a single trunk before their termination in the external iliac vein.

The **Deep Circumflex Iliac Vein** (*v. circumflexa ilium profunda*) (Fig. 471).—Two veins accompany the deep circumflex iliac artery. These unite into a single trunk which crosses the external iliac artery just above Poupart's ligament and terminates in the external iliac vein.

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**Fig. 470.**—The femoral vein and its tributaries. (Poirier and Charpy.)
The **Hypogastric or Internal Iliac Vein** (v. iliaca interna or v. hypogastrica) (Figs. 464, 471, and 473) is formed by the veins corresponding to all the branches of the internal iliac artery except the umbilical branch. It receives the blood from the exterior of the pelvis by the gluteal, sciatic, internal pudic, and obturator veins, and from the organs in the cavity of the pelvis by the middle hemorrhoidal veins, the superior vesical plexus and the prostatico-vesical plexus in the male, and the superior vesical, inferior vesical, uterine and vaginal plexuses in the female. The vessels forming these plexuses are remarkable for their large size, their frequent anastomoses, and the number of valves which they contain. The internal iliac vein lies at first on the inner side, and then behind the internal iliac artery, and terminates opposite the sacro-iliac articulation by uniting with the external iliac to form the common iliac vein. This vessel has no valves.

The **Internal Pudic Veins** (vv. pudendae internae) (Fig. 471) have the same course as the internal pudic artery. They receive tributaries corresponding to the branches of the artery, except the tributary corresponding to the dorsal artery of the penis; that is, the deep dorsal vein of the penis, which opens into the prostatico-vesical plexus.

The **Inferior or External Hemorrhoidal Veins** (vv. hemorrhoidalis inferiores) (Figs 472 and 473) collect blood from the anus. They pass outward over the External sphincter muscle, unite with numerous subcutaneous veins, and form larger vessels which join the internal pudic veins.

The **Middle Hemorrhoidal Veins** (vv. hemorrhoidalis media) (Figs. 472 and 473) help to form the hemorrhoidal plexus, perforate the rectal wall, and empty into the internal iliac vein. These veins, by their anastomoses in the hemorrhoidal plexus, establish a communication between the portal and systemic venous systems.

The **Lateral Sacral Veins** (vv. sacrales laterales) (Fig. 471) accompany the lateral sacral arteries and terminate in the internal iliac vein.
**Surgical Anatomy.**—The veins of the hemorrhoidal plexus are apt to become dilated and varicose, and form piles, *hemorrhoids*. This is due to several anatomical reasons: the vessels are contained in very loose, or connective tissue, so that they obtain less support from surrounding structures than most other veins, and are less capable of resisting increased blood pressure: the condition is favored by gravitation, being influenced by the erect posture, either sitting or standing, and by the fact that the superior hemorrhoidal and portal veins have no valves. The veins pass through muscular tissue and are liable to be compressed by its contraction, especially during the act of defecation, and they are affected by every form of portal obstruction.

The **Obturator Vein** (v. obturatoriae) (Figs. 471 and 473) follows the course of the obturator artery, lying below the artery as it passes over the side of the pelvis; this vein empties into the front part of the internal iliac vein.

The **Sciatic Veins** are two in number; they accompany the sciatic artery in the upper part of the back of the thigh, and just before their termination in the internal iliac the two veins unite.

The **Gluteal Veins** (vv. glutea) are usually two in number, and return to the internal iliac vein the blood that has been distributed by the gluteal artery and its branches.

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![Diagram of venous anatomy](image)

**Fig. 472.**—Scheme of the anastomosis of the veins of the rectum. (Poirier and Charpy.)

The **Superior Vesical Plexus** (Fig. 473) is placed upon the fundus and lateral aspects of the bladder on the external aspect of the muscular coat. It receives vessels from the mucous membrane and from the muscular walls. It empties into the internal pudic vein: in the male it communicates with the prostatico-vesical plexus, and in the female with the inferior vesical plexus.

The **Prostatic** or the **Prostatico-vesical Plexus** (Fig. 473) surrounds the prostate gland and the neck of the bladder. It is contained between the rectovesical fascia which surrounds the base and sides of the gland and the true capsule of the gland. It communicates with the superior vesical plexus behind and above, and receives the deep dorsal vein of the penis, which enters the pelvis between the subpubic and triangular ligaments. This plexus receives veins from the seminal vesicles and vasa deferentia. On each side one or more vessels pass
from the prostatico-vesical plexus to the internal iliac vein. The veins composing the prostatic plexus are very liable to become varicose, and often contain hard, earthy concretions called **phleboliths**.

The **Inferior Vesical Plexus** exists only in the female, and corresponds to the prostatico-vesical plexus in the male, and surrounds the neck of the bladder and the upper portion of the urethra. It receives the dorsal vein of the clitoris and sends efferents to the internal iliac vein.

**Surgical Anatomy.**—The prostatico-vesical plexus is wounded in the lateral operation of lithotomy, and it is through it that septic matter finds its way into the general circulation after this operation. In enucleating the prostate the gland is shelled out from its capsule of recto-vesical fascia. The veins of the plexus remain attached to the sheath.

**The Dorsal Veins of the Penis.**—The **Superficial Dorsal Vein of the Penis** (Fig. 474) receives blood from the prepuce and runs backward beneath the skin, and divides into two branches which terminate in the superficial external pudic vein.

The **Deep Dorsal Vein of the Penis** (*v. dorsalis penis*) (Figs. 473 and 474) is a vessel of large size which returns the blood from the body of that organ. At first it con-
sists of two branches, which are contained in the groove on the dorsum of the penis, and it receives numerous superficial veins and veins from the glans penis and the corpus spongiosum. These vessels unite into a single trunk, which passes between the two parts of the suspensory ligament of the penis, and through an aperture between the subpubic ligament and the apex of the triangular ligament, and divides into two branches, which enter the prostatico-vesical plexus. The dorsal vein of the clitoris corresponds in woman to the dorsal vein of the penis in man, and runs into the inferior vesical plexus.

The Vaginal Plexuses and Veins (Fig. 475).—The vaginal plexuses are placed at the sides of the vagina, being especially developed at the orifice of the canal. They receive vessels from the vaginal walls. The plexuses communicate with the uterine plexus above, with the bulbar veins below, with the inferior vesical plexus in front and with the hemorrhoidal plexus behind. From the upper part of each vaginal plexus comes a vaginal vein which passes to the internal iliac.

The Uterine Plexuses (Fig. 475) are situated along the sides and superior angles of the uterus, between the layers of the broad ligament. They receive the veins from the uterus, which veins are without valves. During pregnancy these veins become large venous canals known as the uterine sinuses, and bring blood from the substance of the placenta. These veins join the ovarian above and the vaginal below, and Anastomose with each other. They are not tortuous like the artery.

The Uterine Veins (vv. uterinae) (Fig. 475) arise from the lower part of the plexus, and there are usually two veins on each side and they are without valves. These veins for the first portion of their course are placed in the base and inner portion of the broad ligament; they then pass back with the uterine artery in a peritoneal fold between the back of the broad ligament and the recto-uterine fold (Cunningham); they then pass upward and enter the internal iliac vein.
The Common Iliac Vein (v. iliaca communis) (Figs. 464, 471, and 473) on each side is formed by the union of the external and internal iliac veins in front of the sacro-iliac articulation: passing obliquely upward toward the right side, each vein terminates upon the intervertebral substance between the fourth and fifth lumbar vertebrae, where the veins of the two sides unite at an acute angle to form the postcava or inferior vena cava. The right common iliac (v. iliaca communis dextra) is shorter than the left, nearly vertical in its direction, and ascends behind and then to the outer side of its corresponding artery. The left common iliac (v. iliaca communis sinistra), longer and more oblique in its course, is at first situated on the inner side of the corresponding artery, and then behind the right common iliac. Each common iliac receives the ilio-lumbar, and sometimes the lateral sacral, veins. The left receives, in addition, the middle sacral vein. No valves are found in these veins.

The Middle Sacral Veins (Figs. 471 and 472) accompany the corresponding artery along the front of the sacrum, and join to form a single vein (v. sacralis media), which terminates in the left common iliac vein; occasionally in the angle of junction of the two iliac veins. The middle sacral veins communicate with the inferior hemorrhoidal.

The Ilio-lumbar Veins (vv. iliolumbales) receive branches from the iliac fossæ, spinal muscles, and spinal canal. One vein on each side runs with the artery, passes posterior to the psoas muscle, and joins the common iliac vein.

Peculiarities.—The left common iliac vein, instead of joining with the right in its usual position, occasionally ascends on the left side of the aorta as high as the kidney, where, after receiving the left renal vein, it crosses over the aorta, and then joins with the right vein to form the postcava. In these cases the two common iliacs are connected by a small communicating branch at the spot where they are usually united.1

The Postcava, Ascending, or Inferior Vena Cava (v. cava inferior) (Figs. 464 and 471) returns to the heart the blood from all the parts below the Diaphragm. It is formed by the junction of the two common iliac veins on the right side of the intervertebral substance between the fourth and fifth lumbar vertebrae. It passes upward along the front of the spine on the right side of the aorta, and, having reached the under surface of the liver, is contained in a groove on its posterior surface. It then perforates the central tendon of the Diaphragm, enters the pericardium, where it is covered for a very short distance by the serous layer of the pericardium, and terminates in the lower and back part of the right auricle. At its termination in the auricle it is provided with a valve, the Eustachian valve (valvula v. cavae inferioris [Eustachii]), which is of large size during foetal life.

Relations.—In front, from below upward, with the mesentery, right spermatic artery, transverse portion of the duodenum, the pancreas, portal vein, and the posterior surface of the liver, which, in most cases, partly and occasionally completely surrounds it; behind, with the vertebral column, the right crus of the Diaphragm, the right renal and lumbar arteries, and the right semilunar ganglion; on the left side, with the aorta.

Peculiarities. In Position.—This vessel is sometimes placed on the left side of the aorta, as high as the left renal veins, after receiving which it crosses over to its usual position on the right side; or it may be placed altogether on the left side of the aorta, as far upward as its termination in the heart: in such cases the abdominal and thoracic viscera, together with the great vessels, are all transposed.

Point of Termination.—Occasionally the postcava joins the right azygos vein, which is then of large size. In such cases the precava receives the whole of the blood from the body before transmitting it to the right auricle, except the blood from the hepatic veins, which passes directly into the right auricle.

1 See two cases which have been described by Mr. Walsham in St. Bartholomew's Hospital Reports, vols. xvi. and xvii.—Ed. of 15th English edition.
The deep veins of the lower extremity

Tributaries.—It receives in its course the following veins:

- Lumbar.
- Right Spermatic.
- Renal.
- Suprarenal.
- Phrenic.
- Hepatic.

The **Lumbar Veins** (*vv. lumbales*), four in number on each side, collect the blood by dorsal tributaries from the muscles and integument of the loins and by abdominal tributaries from the walls of the abdomen, where they communicate with the epigastric veins. At the spine they receive veins from the spinal plexuses, and then pass forward, round the sides of the bodies of the vertebrae beneath the Psoas magnus muscle, and terminate at the back part of the postcava. The left lumbar veins are longer than the right, and pass behind the aorta. The lumbar veins of a side are connected together by a longitudinal vein which passes in front of the transverse processes of the lumbar vertebrae, and is called the **ascending lumbar vein** (*v. lumbalis ascendens*) (Fig. 464). It forms the most frequent origin of the corresponding vena azygos, and serves to connect the common iliac, ilio-lumbar, lumbar, and azygos veins of the corresponding side of the body.

The **Spermatic Veins** (*vv. spermaticae*) (Fig. 476) emerge from the back of the testis, and receive tributaries from the epididymis; they unite and form a convoluted plexus called the **spermatic plexus** (*plexus pampiniformis*), which forms the chief
mass of the cord: the vessels composing this plexus are very numerous, and ascend along the cord in front of the vas deferens; below the external abdominal ring they unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the internal abdominal ring, coalesce to form two veins, which ascend on the Psoas muscle behind the peritoneum, lying one on each side of the spermatic artery, and unite to form a single vein, which opens on the right

Fig. 477.—Terminations of the right and left spermatic veins. (Poirier and Charpy.)

side into the postcava at an acute angle; on the left side into the left renal vein at a right angle (Fig. 477). The termination of the left spermatic vein is called the emulgent vein. Professor John H. Brinton pointed out that a valve is usually absent in the emulgent vein (Fig. 478), but regularly present in the right spermatic vein. The left spermatic vein passes behind the sigmoid flexure of the colon, and is thus exposed to pressure from the contents of that bowel.

Surgical Anatomy.—The spermatic veins are very frequently varicose, constituting the disease known as varicocele. Though it is quite possible that the originating cause of this affection may be a congenital abnormality either in the size or number of the veins of the pampiniform plexus, still it must be admitted that there are many anatomical reasons why these veins should become varicose—viz., the imperfect support afforded to them by the loose tissue of the serotum; their great length; their vertical course; their dependent position; their plexiform arrangement in the scrotum, with their termination in one small vein in the abdomen; their few and imperfect valves; and the fact that they may be subjected to pressure in their passage through the abdominal wall. The left veins more often become varicose than the right veins, probably, as Brinton suggests, because the right spermatic vein practically always has a valve and opens into the postcava at an acute angle, whereas the left spermatic vein is not unusually destitute of a valve at its opening and passes into the left renal vein at a right angle.

The Ovarian Veins (vv. ovaricae) (Fig. 475) are analogous to the spermatic in the male; they form a plexus near the ovary in the broad ligament and about the Fallopian tube, communicating with the uterine plexus. They terminate in the same way as the spermatic veins in the male. Valves are occasionally found in these veins. These vessels, like the uterine veins, become much enlarged during pregnancy.

1 See John H. Brinton in the American Journal of the Medical Sciences, and also Handbuch der Topographischen Anatomie, von Joseph Hyrtl. Rivington maintains that a valve is usually found at the orifices of both the right and left spermatic veins. When no valves exist at the opening of the left spermatic vein into the left renal vein, valves are generally present in the left renal vein within a quarter of an inch from the orifice of the spermatic vein. (Journal of Anatomy and Physiology, vol. vii, p. 163).—Ed. of 15th English edition.
The Renal Veins (vv. renales) (Fig. 465) are of large size, and are placed in front of the renal arteries. The left is longer than the right, and passes in front of the aorta, just below the origin of the superior mesenteric artery. It receives the left spermatic, the left inferior, and, generally, the left suprarenal veins. It opens into the postcava a little higher than the right. The utero-venous triangle of Robinson is formed by the ureter, the renal veins, and the ovarian veins.

The Suprarenal Veins (vv. suprarenales) (Fig. 464) are two in number: that on the right side terminates in the postcava; that on the left side, in the left renal or in the left phrenic vein.

The Phrenic Veins (vv. phrenicae) follow the course of the phrenic arteries. The two superior phrenic veins (vv. phrenicae superiores), of small size, accompany the phrenic nerve and comes nervi phrenici artery, and join the internal mammary vein. The two inferior phrenic veins (vv. phrenicae inferiores) follow the course of the phrenic arteries, and terminate, the right in the postcava, the left in the left renal vein.

The Hepatic Veins (vv. hepaticae) commence in the substance of the liver, in the capillary terminations of the portal vein and hepatic artery, intralobular veins: these tributaries, gradually uniting into sublobular veins; usually form three large hepatic veins, which converge toward the posterior surface of the liver and open into the postcava, whilst that vessel is situated in the groove at the back part of this organ. Of these three veins, one from the right and another from the left

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1 The student may observe that all veins above the Diaphragm, which do not lie on the same plane as the arteries which they accompany, lie in front of them, and that all veins below the Diaphragm, which do not lie on the same plane as the arteries which they accompany, lie behind them, except the renal and profunda femoris vein.—Ed. of 15th English edition.
lobe open obliquely into the postcava, that from the middle of the organ and lobulus Spigellii having a straight course. The hepatic veins run singly, and are in direct contact with the hepatic tissue. They are destitute of valves.

The Portal System of Veins (Fig. 479).

The portal venous system is composed of four large veins which collect the venous blood from the viscera of digestion (stomach, intestine, and pancreas) and from the spleen. The trunk formed by their union, the portal vein, enters the liver and ramifies throughout its substance after the manner of an artery and ends in capillaries, from which the blood is collected into the hepatic veins, which terminate in the postcava. The branches of this vein are in all cases single, and destitute of valves.

The veins forming the portal system are—the

Superior Mesenteric.
Splenic.
Cystic.
Inferior Mesenteric.
Gastric.

The Superior Mesenteric Vein (v. mesenterica superior) (Fig. 479) returns the blood from the small intestines and from the cecum and ascending and transverse portions of the colon, corresponding with the distribution of the branches of the superior mesenteric artery. The large trunk formed by the union of these branches ascends along the right side and in front of the corresponding artery, passes in front of the transverse portion of the duodenum, and unites, behind the upper border of the pancreas, with the splenic vein to form the portal vein. It receives the right gastro-epiploic vein. The appendicular vein is a tributary of the superior mesenteric vein.

The Splenic Vein (v. lienalis) (Fig. 479) commences by five or six large branches which return the blood from the substance of the spleen. These, uniting, form a single vessel, which passes from left to right, grooving the upper and back part of the pancreas below the artery, and terminates at its greater end by uniting at a right angle with the superior mesenteric to form the portal vein. The splenic vein is of large size, and not tortuous like the artery. It receives the vasa brevia from the left extremity of the stomach, the left gastro-epiploic vein, pancreatic branches from the pancreas, the pancreatico-duodenal vein, and the inferior mesenteric vein.

The Inferior Mesenteric Vein (v. mesenterica inferior) (Fig. 479) returns the blood from the rectum, sigmoid flexure, and descending colon, corresponding with the ramifications of the branches of the inferior mesenteric artery. It lies to the left of the artery, and ascends beneath the peritoneum in the lumbar region; it passes behind the transverse portion of the duodenum and pancreas, and terminates in the splenic vein. Its hemorrhoidal branches, the superior hemorrhoidal veins (vv. hemorrhoidalis superior), inosculate with the middle hemorrhoidal branches of the internal iliac, and thus establish a communication between the portal and the general venous system.\(^1\)

The Gastric Veins (vv. gastricae) (Fig. 479) are two in number: one, a small vein, corresponds to the pyloric branch of the hepatic artery; the other, considerably larger, corresponds to the gastric artery. The former, the pyloric vein (v. pylorica), runs along the lesser curvature of the stomach toward the pyloric end, receives branches from the pylorus and duodenum, and ends in the portal vein. The latter, the gastric or coronary vein (v. coronaria ventriculi), begins near the pylorus.

\(^1\) Besides this anastomosis between the portal vein and the branches of the vena cava, other anastomoses between the portal and systemic veins are formed by the communication between the gastric veins and the oesophageal veins, which empty themselves into the vena azygos minor; between the left renal vein and the veins of the intestines, especially of the colon and duodenum; between the veins of the round ligament of the liver and the portal veins; and between the superficial branches of the portal veins of the liver and the phrenic veins, as pointed out by Mr. Kiernan. (See Physiological Anatomy, by Todd and Bowman, 1839, vol. ii. p. 348).—Ed. of 16th English edition.
runs along the lesser curvature of the stomach toward the oesophageal opening in the diaphragm, and then passes across the front of the spine from left to right to end in the portal vein, at a point a little above the junction of the pyloric vein.

The Cystic Vein (v. cystica) (Fig. 479).—The portal vein generally receives the cystic vein, although that vessel sometimes terminates in the right branch of the portal vein.

**NOTE.**—In this diagram the right gastro-epiploic vein opens into the splenic vein; generally it empties itself into the superior mesenteric, close to its termination.

The Portal Vein (vena portae) (Fig. 479) is formed by the junction of the superior mesenteric and splenic veins, their union taking place in front of the vena cava and behind the upper border of the head of the pancreas. Passing upward through the right border of the lesser omentum to the under surface of the liver, it enters the transverse fissure, where it is somewhat enlarged, forming the sinus of the portal vein, and divides into two branches which accompany the ramifications of the hepatic artery and hepatic duct throughout the substance of the liver. Of
these two branches, the right is the larger, but the shorter, of the two. The portal vein is about three or four inches in length, and, whilst contained in the lesser omentum, lies behind and between the common bile-duct and the hepatic artery, the former being to the right, the latter to the left. These structures are accompanied by filaments of the hepatic plexus of nerves and numerous lymphatics, and are surrounded by a quantity of loose areolar tissue, the capsule of Glisson.

The portal vein divides, in the substance of the liver, like an artery, and its minute ramifications end in capillaries, from which the blood is carried to the postcava by the hepatic veins; these veins also collect the blood which has been brought to the liver by the hepatic artery. It will therefore be seen that the blood which is carried to the liver by the portal vein passes through two sets of capillary vessels—viz.: (1) the capillaries in the stomach, intestine, pancreas, and spleen, and (2) the capillaries of the portal vein in the liver.

**THE CARDIAC VEINS** (Fig. 480).

The veins which return the blood from the substance of the heart are—the

Great Cardiac Vein.
Posterior Cardiac Vein.
Left Cardiac Veins.

Anterior Cardiac Veins.
Right or Small Coronary Vein.
Coronary Sinus.
Veæ Thebesii.

The Great Cardiac or Left Coronary Vein (v. cordis magna) is a vessel of considerable size, which commences at the apex of the heart, and ascends along the anterior interventricular groove to the base of the ventricles. It then curves to the left side, around the auriculo-ventricular groove, between the left auricle and ventricle, to the back part of the heart, and opens into the left extremity of the coronary sinus, its aperture being guarded by two valves. It receives, in
its course, tributaries from both ventricles, but especially from the left, and also from the left auricle; one of these ascending along the thick margin of the left ventricle is of considerable size, and is called the left marginal vein. The vessels joining the great cardiac vein are provided with valves.

The Posterior or Middle Cardiac Vein (v. cordis media) commences by small tributaries, at the apex of the heart, communicating with those of the preceding. It ascends along the posterior interventricular groove to the base of the heart, and terminates in the coronary sinus, its orifice being guarded by a valve. It receives veins from the posterior surface of both ventricles.

The Left Cardiac Vein (v. posterior ventriculi sinistri) receives three or four small vessels, which collect the blood from the posterior surface of the left ventricle. It opens into the lower border of the coronary sinus.

The Anterior Cardiac Veins (vv. cordis anteriores) are three or four small vessels, which collect the blood from the anterior surface of the right ventricle. One of these, the vein of Galen, larger than the rest, runs along the right border of the heart. They open separately into the lower part of the right auricle.

The Right Cardiac or Small Coronary Vein (v. cordis parva) runs along the groove between the right auricle and ventricle, to open into the right extremity of the coronary sinus. It receives blood from the back part of the right auricle and ventricle.

The Coronary Sinus (sinus coronarius) is that portion of the anterior or great cardiac vein which is situated in the posterior part of the left auriculo-ventricular groove. It is about an inch in length, presents a considerable dilatation, and is covered by the muscular fibres of the left auricle. It receives most of the veins of the heart. Besides those mentioned it receives the oblique vein of Marshall (v. obliqua atrii sinistri) from the back part of the left auricle, the remnant of the obliterated left Cuvierian duct of the foetus, described by Mr. Marshall. The great coronary sinus terminates in the right auricle, between the postcava and the auriculo-ventricular aperture, its orifice being guarded by a semilunar fold of the lining membrane of the heart, the Thebesian valve. All the veins joining this vessel, excepting the oblique vein above mentioned, are provided with valves.

The Venae Thebesii (venae cordis minimae) are numerous minute veins, which return the blood directly from the muscular substance, without entering the venous current. They open by minute orifices, foramina Thebesii (foramina venarum minarum), chiefly on the inner surface of the right auricle.
THE LYMPHATIC SYSTEM.

Lymph is obtained from the blood-plasma. From lymph the body cells obtain food, into lymph they discharge their waste materials, and there is a distinct lymphatic circulation, the constituents of the plasma passing into the perivascular lymph-spaces and returning to the heart by way of the lymphatics and certain veins.

The lymphatic system consists of lymphatic glands—large lymph-vessels, small lymph-vessels (lymphatic capillaries), the perivascular lymph-spaces, the lymph canalicular system, and the body cavities. To this system also belong the lacteal or chyliferous vessels. The lacteals are the lymphatic vessels of the small intestine, and differ in no respect from the lymphatics generally, excepting that during the process of digestion they contain a milk-white fluid, the chyle, which passes into the blood through the thoracic duct.

The lymph canalicular system is the system of spaces in areolar connective tissue. The spaces are called lymph-spaces, and are found practically in every region of the body. In these spaces lie the cells of the tissue. The larger spaces are lined with endothelium, the smaller spaces are not lined with endothelium; they form connections with each other by anastomotic channels and constitute a system of spaces and channels which many observers believe join the lymphatic capillaries. Others maintain that lymph-spaces are not direct continuations or expansions of lymph-capillaries, but that networks of lymphatic capillaries exist in the tissue immediately around each space, an arrangement which permits of interchange between the contents of a space and the contents of the surrounding capillaries. Mall seems to have proved this by his experimental injections into the portal vein. He showed that colored fluid injected into the portal vein passes through the walls of the venous capillaries, enters the lymph-spaces, and finally gets into the lymph-capillaries of the liver.

The perivascular lymph-spaces are found around certain blood-vessels. Each space is lined with endothelium, and is joined to other spaces by trabeculae of connective tissue. The spaces form a system, and the fluid in these spaces reaches the lymphatic capillaries. Perivascular lymph-spaces have been demonstrated in the Haversian canals and in the subdural space of the pia.

The pleural, pericardial, peritoneal, and synovial cavities are lined by endothelial cells. Beneath the layer of lining cells are lymph-spaces or lymph-vessels. It was long thought that these lymph-vessels communicate directly with the body cavity by means of numerous openings in the lining membrane. This view is probably incorrect. The subarachnoid space, the subdural space, the cavity for the aqueous humor of the eye, the cavity for the vitreous humor, and the space of Tenon are probably lymph-spaces.

Lymph-capillaries are arranged in networks, are larger than blood-capillaries, but the diameter of a lymph-capillary is different at different points, at some places being much larger than at others. Lymph-capillaries are formed of flattened endothelial cells. In some situations networks of lymphatic capillaries surround the blood-vessels. The lymph-vessels are called the lymphatics.

The lymphatics have derived their name from the appearance of the fluid contained in their interior (lympha, water). They are also called absorbents, from the
THE LYMPHATIC SYSTEM

property they possess of absorbing certain materials from the tissues and conveying them into the circulation. Larger lymphatics are called trunks and the largest are called ducts.

The lymphatics are exceedingly delicate vessels, the coats of which are so transparent that the fluid they contain is readily seen through them, and they appear milky-white; hence the name Ascellius gave them of lacteal veins. They retain a nearly uniform size, and may be cylindrical in shape, but usually are interrupted at intervals by constrictions which give them a knotted, beaded, or sac-like appearance. These constrictions are due to the presence of valves in the interior of the vessel. Lymphatic vessels do not invariably contain valves. Valves are absent at the starting points of lymphatics, are absent in lymphatic capillaries, are not numerous in the largest ducts (thoracic duct), and are seldom found in visceral lymphatics. The valves are not found in fixed situations and vary in number. Between the ends of the fingers and the axillary glands Sappey counted from sixty to eighty. "They are arranged in pairs and resemble the aortic semilunar valves." The lymphatic capillaries are composed purely of endothelium, but the collecting trunks possess not only an endothelial inner coat, but an investing elastico-muscular coat. Vessels in the subcutaneous connective tissue are devoid of muscle. Lymphatics have been found in nearly every texture and organ of the body which contains blood-vessels. Such non-vascular structures as cartilage, the nails, cuticle, and hair have none, but with these exceptions it is probable that eventually all parts will be found to be permeated by these vessels.

A larger lymphatic vessel is composed of three coats. The inner coat is composed of elastic tissue lined with endothelium. The middle coat is composed of elastic and muscular fibres. The external coat is composed of connective tissue intermixed with smooth muscular fibres longitudinally or obliquely placed.

The thoracic duct possesses a sub endothelial layer of connective tissue like that found in the arteries, and in the middle coat there is a longitudinal layer of connective tissue. The wall of a smaller lymphatic contains no elastic and no muscular tissue, and consists merely of connective tissue lined with endothelium.

The lymphatics are arranged in superficial and deep sets. The superficial lymphatics, on the surface of the body, are placed immediately beneath the integument, accompanying the superficial veins; they join the deep lymphatics in certain situations by perforating the deep fascia. In the interior of the body the lymphatics lie in the submucous areolar tissue throughout the whole length of the gastro-pulmonary and genito-urinary tracts, and in the subserous tissue of the thoracic and abdominal cavities. In the cranial cavity the perivascular sheaths are lymph-spaces. A plexiform network of minute, closed, capillary lymphatics may be found interspersed among the proper elements and blood-vessels of the several tissues, the vessels composing which, as well as the meshes between them, are much larger than those of the capillary blood-vessel plexus. From these networks small collecting vessels emerge, pass to a neighboring gland, and divide into a capillary network in the gland. Numerous small vessels emerge from the gland, which unite into one lymphatic vessel, which joins a larger lymphatic trunk, which empties into a branch of the precava. The deep lymphatics, fewer in number and larger than the superficial, accompany the deep blood-vessels. Their mode of origin is probably similar to that of the superficial vessels. The lymphatics of any part or organ exceed the veins in number and in capacity, but in size they are much smaller. Their anastomoses also, especially those of the large trunks, are more frequent, and are effected by vessels equal in diameter to those which they connect. The continuous trunks retain the same diameter throughout. As the lymphatic vessels

approach their point of discharge their number diminishes, but the calibre of the remainder does not increase in proportion.

The gaps in the connective tissue, the larger of which are lined with endothelium, the smaller of which are devoid of endothelial lining, are known as lymphatic spaces. (See page 772.)

The lymphatic or absorbent glands (lymphoglandulae), named also conglobate glands and lymph-nodes, are small, solid, glandular bodies situated in the course of the lymphatic and lacteal vessels. They vary from microscopic dimensions to the size of an olive, and their color, on section, is of a pinkish-gray tint, excepting the bronchial glands, which in the adult are mottled with black, the hepatic glands, which are yellow, and the splenic glands, which are brown. Each gland has a layer or capsule of cellular tissue investing it, from which prolongations dip into its substance, forming partitions. The lymphatic and lacteal vessels pass through these glands in their passage to the lymphatic ducts. A lymphatic or lacteal vessel, previous to entering a gland, divides into several small branches, which are named afferent vessels (vasa afferentia). As they enter the gland, the external coat of each becomes continuous with the capsule of the gland, and the vessels becoming much thinned, and consisting only of their internal or endothelial coat, pass into the gland, and branch out upon and in the tissue of the capsule, these branches opening into the lymph-sinuses of the gland. There is an extensive sinus beneath the capsule; from this subcapsular sinus numerous branches run inward to a central sinus. From both sinuses fine branches proceed to form a plexus, the vessels of which unite to form a single efferent vessel (vas efferens), which, on emerging from the gland, is again invested with an external coat from the gland capsule. The lymph-glands are filters through which lymph and chyle flow. Carcinoma cells are caught in them, and the dissemination of the disease is retarded. In the glands are masses of newly formed leukocytes which attack any bacteria in the lymph or chyle.

The size of the lymphatic glands decreases as age advances, and in very old individuals many glands actually disappear. It is impossible to estimate the number of macroscopic glands. Sappey estimated the number to be from 600 to 700. Glands are embedded in fat and are distinctly movable. Some of them are superficial (above the deep fascia); others are deep (below the deep fascia). Occasionally a gland exists alone, but, as a rule, they are assembled in communities or chains of from eight to twelve, or even more. They are usually arranged around vessels, and often are upon vessels. The glands have a plentiful blood-supply, and contain not only vascular nerves, but definite nerve-plexuses. Besides the glands, the body contains numerous lymphoid areas, which, in structure and function, are allied to lymph-glands (tonsils, Peyer's patches, etc.).

Hemolymph nodes exist in various regions, but are most common in the abdomen in front of the vertebrae. They are like ordinary lymph-nodes in form and also in size, but differ from them in being deep red instead of light pink. Some regard hemolymph nodes as structures like the spleen; others regard them as very vascular but otherwise ordinary nodes.
Surgical Anatomy.—In an operation for cancer it is not sufficient to cut wide of the growth and remove it; it is imperatively necessary to remove the lymphatic glands which receive lymph from the diseased area, and also, when possible, the lymphatic vessels between the cancer and the glands. Glands are diseased very early in cancer, long before they are palpably enlarged, and are usually infected by emboli of cancer cells. The rule is in any cancer, however recent, to regard the associated glands as diseased, whether enlarged or not, and to thoroughly remove them, if possible, in one piece, with the intervening lymph-vessels and the area of primary malignant growth.

THE THORACIC DUCT AND THE RIGHT LYMPHATIC DUCT.

The thoracic duct or the left lymphatic duct (ductus thoracicus) (Fig. 482) conveys the great mass of lymph and chyle into the blood. It is the common trunk of all the lymphatic vessels of the body below the Diaphragm, and usually, but not always, also receives the lymph from the left side of the body above the Diaphragm. It does not drain the right side of the head and neck, the right upper extremity, the right lung, right side of the heart, and the convex surface of the liver. It partly drains the right chest wall. It varies in length from fifteen to eighteen inches in the adult, and extends from the second lumbar vertebra to the root of the neck. The duct is formed by the union of the right and left lumbar trunks (trunci lumbales), from the lumbar lymph-nodes. The left lumbar trunk also obtains lymph from the coeliac and mesenteric nodes. A little distance above its origin the thoracic duct usually presents a triangular dilatation, the receptaculum chyli or the reservoir or cistern of Pecquet (cisterna chyli), which is situated upon the front of the bodies of the first and of the second lumbar vertebra, to the right side and behind the aorta, by the side of the right crus of the Diaphragm. The receptaculum is absent in some individuals. The thoracic duct ascends into the thorax through the aortic opening in the Diaphragm, lying to the right of the aorta, and is placed in the posterior mediastinum in front of the vertebral column, lying between the aorta and vena azygos major. Opposite the fourth thoracic vertebra it inclines
toward the left side, and ascends behind the arch of the aorta on the left side of the oesophagus, and behind the first portion of the left subclavian artery, to the upper orifice of the thorax. Opposite the seventh cervical vertebra it turns outward and then curves downward over the subclavian artery and in front of the Scalenus anticus muscle, so as to form an arch, and terminates in the left subclavian vein at its angle of junction with the left internal jugular vein. It usually opens at the apex of the angle in the superior and outer surface, but may open on the posterior surface. Sometimes it terminates by two branches. Figs. 482 and 484 show the termination of the thoracic duct. The thoracic duct, at its commencement, is about equal in diameter to that of a goose-quill, diminishes considerably in its calibre in the middle of the thorax, and is again dilated just before its termination, the ampulla. It is generally flexuous in its course, the older the person the greater the flexuosity, and it is constricted at intervals so as to present a varicose appearance. The thoracic duct not infrequently divides in the middle of its course into two branches of unequal size, which soon reunite, or divides into several branches, which form a plexiform interlacement. It occasionally divides, at its upper part, into two branches, of which the one on the left side terminates in the usual manner, while that on the right opens into the right subclavian vein, in connection with the right lymphatic duct. The thoracic duct has several valves throughout its whole course, but they are more numerous in the upper than in the lower part, and the lower valves are not competent; at its termination it is provided with a pair of competent valves, the free borders of which are turned toward the vein, so as to prevent the passage of venous blood into the duct.

The common intestinal trunk (truncus intestinalis) (Figs. 482, 483, and 509) empties into the receptaculum and brings lymph from the small intestine (lacteals), the stomach, the pancreas, and the spleen.

Radicals of Origin and Tributaries.—In most individuals the juxta-aortic glands which are placed on each side of the aorta send a vessel upward and inward, which unite to form the thoracic duct. The right vessel is known as the truncus lymphaticus lumbalis dextra. The left vessel is known as the truncus lymphaticus lumbalis sinistra. A vessel from the glands in front of (pre-aortic) and back (retro-aortic) of the aorta empties into each of the above-named vessels. In some cases a large vessel forms from the glands in front of the aorta and helps form the duct. The receptaculum chyli receives the common intestinal lymphatic trunk, which conveys lymph from the small intestine, stomach, spleen, pancreas, and a portion of the liver.

![Fig. 482.—Modes of origin of the thoracic duct. a, thoracic duct; a', receptaculum chyli; b, common trunk of the efferents of the right juxta-aortic glands; c, common trunk of the efferents of the left juxta-aortic glands; d, one of these efferents passing through the left pillar of the diaphragm; e, right juxta-aortic gland; f, left juxta-aortic gland; h, retro-aortic gland; j, common trunk of the pre-aortic glands (truncus intestinalis); j, collecting trunks of the intercostal lymphatics, which reach the receptaculum chyli by taking the downward course. (Poirier and Charpy.)](image-url)
The branches of the left lymphatic duct are: 1. A descending trunk, which collects lymph from the posterior intercostal glands of the seven lower intercostal spaces. 2. A trunk is formed by vessels coming from the superior juxta-aortic glands beneath the Diaphragm. 3. The lymphatic vessels form the upper five intercostal spaces. 4. The lymphatic vessels form the posterior mediastinal glands and retrosternal glands. 5. The left jugular trunk (truncus jugularis), although this may open directly into the junction of the subclavian and internal jugular veins. 6. In rare cases the thoracic duct receives near its termination the left subclavian trunk (truncus subclavius) and a broncho-mediastinal trunk. As a rule, however, the two last-mentioned trunks empty into the jugulo-subclavian junction separately or as one duct.

The thoracic duct receives the lymph from the extremities, the deep portion of the abdominal wall and of the pelvic wall, the pelvic viscera, the kidneys and suprarenal capsules, the large intestine, the small intestine, the walls of the thoracic cavity, the under surface and anterior portion of the liver, the stomach, the spleen, the pancreas, the sternal and intercostal glands, the left lung, left side of the heart, trachea, and oesophagus, and often, just before its termination, the lymphatics of the left side of the head and neck, and of the left upper extremity.

Structure.—The thoracic duct is composed of three coats, which differ in some respects from those of the lymphatic vessels. The internal coat consists of a single layer of flattened endothelial cells; of a subendothelial layer, similar to that found in the arteries; and an elastic fibrous coat, the fibres of which run in a longitudinal direction. Each endothelial cell is shaped like a lance-head and has serrated borders. The middle coat consists of a longitudinal layer of white connective tissue with elastic fibres, external to which are several laminae of muscular tissue, the fibres of which are for the most part disposed transversely, but some are oblique or longitudinal. The muscular fibres are intermixed with elastic fibres. The external coat is composed of arcular tissue, with elastic fibres and isolated fasciculi of muscular fibres.

The Right Lymphatic Duct (Ductus Lymphaticus Dexter) (Figs. 482, 485, 486, 509).

A right lymphatic duct is frequently present. It is a short trunk, about half an inch in length and a line or a line and a half in diameter. It is formed by the union of the right jugular, right broncho-mediastinal, and right subclavian trunks. Often on the right side the jugular, subclavian, and broncho-mediastinal trunks
are double. Usually they open into the junction of the internal jugular and subclavian veins separately. Sometimes they unite and open by one duct, and that is the right lymphatic duct. The orifice of the right lymphatic duct is guarded by two semilunar valves, which prevent the passage of venous blood into the duct.

**Tributaries.**—The right lymphatic duct, if present, receives lymph from the right side of the head and neck, the right upper extremity, the right side of the thorax, the right lung, and the right side of the heart, and from part of the convex surface of the liver.

**LYMPHATICS OF THE CRANIAL REGION, FACE, AND NECK.**

It is customary to divide the lymphatics of this region into *intracranial* and *extracranial* lymphatics. The statement is made by Poirier and Cunéo¹ that the brain and its membranes are without lymphatics. They state that there are spaces in the nervous centres comparable to lymphatic channels, but which are not truly lymphatic vessels and which are regarded by most as independent of the lymphatic system. Other writers believe that there are *cerebral* and *meningeal lymphatic vessels*. It is highly probable that the perivascular spaces around the cerebral arteries are the beginning of a cerebral lymph system, and that these perivascular lymph-channels pass out of the cranium with the arteries and the internal jugular vein and terminate in the superior deep cervical glands. It is also probable that lymph-spaces surround the dural blood-vessels and terminate in the superior deep cervical and the internal maxillary glands.

The *extracranial lymphatics* are divided into *superficial* and *deep*, and the two systems freely communicate. All of these vessels run into glands about the head and neck. The superficial lymphatics take origin in the subcutaneous tissue and superficial muscles. The deep vessels arise in the orbit, mouth, nose, pharynx, esophagus, tongue, larynx, and the muscular, ligamentous, and osseous structures.

**The Lymphatic Glands of the Head and Face.**

The lymphatic glands of the head and face are as follows:

1. The Occipital.
2. The Posterior Auricular.
3. The Parotid and Subparotid.
4. The Internal Maxillary.
5. The Facial.

¹ Article on the Lymphatics in the Treatise on Human Anatomy. By Poirier and Charpy.
The Occipital or Suboccipital Glands (lymphoglandulae occipitales) (Figs. 486 and 487).—There are only two or three of these glands on each side. They are situated beneath the deep fascia, a little in front of the anterior edge of the Trapezius muscle, near to but seldom upon the insertion of the Complexus muscle. They receive lymph from the occipital region of the scalp and from them it is sent to the upper deep cervical glands.

The Posterior Auricular Retro-auricular or Mastoid Glands (lymphoglandulae auriculares posteriores) (Figs. 486, 487, and 491).—There are two of these on each side. They are situated just beneath the lower margin of the Retrahens aurem muscle. They receive lymph from the parietal lymph-vessels, "from the internal surface of the auricle, with the exception of the lobule, and from the posterior surface of the external auditory meatus." The lymph-vessels from these glands empty into the upper deep cervical glands.

The Parotid Lymph-glands (lymphoglandulae auriculares anteriores) (Figs. 486, 487, and 488) are divided into two groups, the superficial and the deep.

The Superficial Parotid or Pre-auricular Lymph-glands.—The superficial parotid lymph-glands are not the subcutaneous lymph-glands occasionally but very rarely found in this region, and which have been described by Richet, but are lymph-nodes situated between the parotid fascia and the parotid salivary gland. There may be three glands, two glands, or only one gland.

The Deep Parotid Lymph-glands.—The deep parotid lymph-glands are situated within the parotid salivary gland. There are from fifteen to twenty of the deep glands. The parotid glands receive lymph from the eyelids, eyebrows, the root of the nose, upper portion of the cheek, frontal portion of the scalp, temporal portion of the scalp, from the outer surface of the pinna, from the external auditory meatus, from the tympanum, and possibly from the mucous membrane of the nose, the
posterior alveolar region of the superior maxillary bone, and the soft palate. Lymphatics pass from the superficial parotid glands into the superficial cervical and the upper deep cervical glands. Lymphatics pass from the deep parotid glands into the upper deep cervical glands.

The Subparotid Glands (*lymphoglandulae parotidae*).—The subparotid glands lie between the parotid salivary gland and the pharynx, and they are close to the internal carotid artery and the internal jugular vein. They receive lymph from the nasal fossae, naso-pharynx, and Eustachian tube, and send vessels to the upper deep cervical glands.

The Internal Maxillary or Zygomatic Glands (*lymphoglandulae faciales profundae*) (Fig. 486).—The internal maxillary glands lie in the course of the internal maxillary artery in the anterior pharyngeal wall. They receive vessels from the naso-pharynx, palate, zygomatic fossa, temporal fossa, and orbit. From them vessels go to the upper deep cervical glands.

The Facial Glands or Genial Glands (*lymphoglandulae faciales*) (Figs. 487, 488, and 489).—The facial glands lie in three groups in the course of the lymphatic vessels which are passing to the submaxillary glands. According to Poirier and Cunéo the supramaxillary or inferior group (Fig. 489) lies upon the outer surface of the mandible, at the anterior margin of the Masseter muscle, and beneath the Platysma myoides. There may be only one or two glands in this group, but often there are ten or twelve. These glands lie about the facial artery and vein and are not constantly present. In many cases a salivary gland, the inframaxillary (Fig. 489), is interposed between the supramaxillary and submaxillary glands. The buccinator, buccal, or middle group (Figs. 486 and 489) is present in about one-third of the subjects and lies upon the outer surface of the Buccinator muscle external to the buccal fascia. Some of these glands are situated in the region where Steno’s duct perforates the Buccinator muscle. Others are beneath the posterior fibres of the Zygomaticus major muscle.

The superior group of facial glands (Fig. 489) includes a malar gland, a suborbital gland, and a gland in the naso-genial groove.¹ An anterior gland is sometimes found, subcutaneous, on the outer surface of the Orbicularis oris muscle, the commissural gland.

The Lymphatic Vessels of the Cranial Region (Fig. 486).

The lymphatic vessels of the cranial subcutaneous tissues are divided into anterior, lateral, and posterior. The anterior or frontal terminate in the parotid

lymph-glands. The lateral or parietal terminate in the parotid and mastoid lymph-glands. The posterior or occipital terminate in the sterno-mastoid and occipital glands.

The Lymphatic Vessels of the Face, the Interior of the Nose, Tongue, Floor of the Mouth, Pharynx, Larynx, and Thyroid Gland (Figs. 486, 488, 489, 490, 491, 492).

The lymphatic vessels of the face are more numerous than those of the cranial region, and commence over its entire surface. Those from the frontal region accompany the frontal vessels; they then pass obliquely across the face, running with the facial vein, pass through the glands on the buccal surface of the Buccinator muscle, and join the submaxillary lymphatic glands. The submaxillary lymph glands receive the lymphatic vessels from the lips, and are often found enlarged in cases of malignant disease of those parts.

The lymphatics of the orbit and of the temporal and zygomatic fossae run with the branches of the internal maxillary artery to the maxillary glands, and afterward to the deep cervical glands.

![Diagram](image_url)  
**Fig. 490.—The lymphatics of the tongue; anterior view. (Poirier and Charpy.)**

The lymphatics of the nose can be injected from the subdural and subarachnoid spaces. They terminate in the retro-pharyngeal and suprahyoid glands. The lymphatics of the tongue (Fig. 490) chiefly accompany the ranine vein first to the
lingual glands and from these to the deep cervical glands. The lymphatics from the anterior part of the tongue and floor of the mouth pierce the Mylo-hyoid muscles and so reach the submaxillary lymph-glands. From the upper part of the pharynx the lymphatics pass to the retro-pharyngeal glands; from the lower part of the pharynx to the deep cervical glands. From the larynx two sets of vessels arise: an upper, piercing the thyro-hyoid membrane and joining the upper set of deep cervical glands; and a lower, perforating the crico-thyroid membrane to join the lower set of deep cervical glands. The lymphatics of the thyroid gland accompany the superior and inferior thyroid arteries, and open partly into the upper and partly into the lower set of deep cervical glands.

The Lymphatic Glands of the Neck.

The lymphatic glands of the neck are:
1. The Superficial Cervical, including the external jugular and the superficial anterior cervical.
2. The Submaxillary.
3. The Submental.
4. The Retro-pharyngeal.
5. The Deep Cervical, including the anterior deep cervical.

The Superficial Cervical Glands (lymphoglandulae cervicales superficiales) (Figs 486 and 491).—The superficial cervical glands are composed of two groups, the external jugular and the superficial anterior cervical glands.

The External Jugular Glands (Figs. 488 and 491).—The external jugular glands are superficial to the Sterno-cleido-mastoid muscle. They are four to six in number and lie along the external jugular vein upon the outer surface of the deep cervical fascia, each gland occupying a depression in the fascia. The sternocleido-mastoid muscle is beneath them. They are usually gathered in a group a little below the parotid gland, but sometimes extend to the middle of the vein. They receive vessels from the occipital, the posterior auricular, the parotid, and the submaxillary lymph-glands, from the auricle, and from the skin and subcutaneous structures of the neck. From them lymphatic vessels pass to the upper deep cervical and to the lower deep cervical glands.
The Superficial Anterior Cervical Glands.—The superficial anterior cervical glands lie along the anterior jugular vein and from them vessels pass to the deep cervical glands.

The Submaxillary or Lateral Suprahyoid Glands (lymphoglandulae submaxillares) (Figs. 486, 487, and 488).—The submaxillary glands are in the submaxillary triangle beneath the deep fascia. They number three to six; are embedded in the superficial surface of the sheath of the submaxillary gland, but are not found within the sheath. Occasionally one or two are found in the deep portion of the sheath toward the floor of the mouth. The middle gland of Stahr is situated at the point where the submaxillary group is crossed by the facial artery. This is the largest gland of the group. The submaxillary glands receive vessels from the "nose, the cheek, the upper lip, and the external part of the lower lip, almost the whole of the gums, and the anterior third of the lateral border of the tongue." They also obtain lymph from the floor of the mouth and from the sublingual and submaxillary salivary glands. They send vessels to the jugular and to the upper deep cervical glands.

The Submental or Median Suprahyoid Glands (Figs. 486, 487, and 490).—There are usually two glands situated between the anterior bellies of the two digastric muscles and upon the Mylo-hyoid muscle. They receive lymph from the cutaneous surface of the chin, from the cutaneous and mucous surfaces of the central portion of the lower lip, from the central portion of the gums, from the floor of the mouth, and from the tip of the tongue. They send some vessels to the submaxillary lymph-glands, and frequently a gland is interposed on the anterior belly of the Digastric muscle. They send other vessels to the upper deep cervical glands.

The Retro-pharyngeal or Post-pharyngeal Glands (Fig. 492).—The retro-pharyngeal glands are placed between the upper lateral portion of the posterior part of the pharynx and the first two cervical vertebrae. Leaf tells us that, as a rule, there is but one gland on each side, though two may be present. The retro-pharyngeal glands lie upon the Rectus capitis anticus major muscle, which separates them from the vertebra. They receive vessels from the muscles and fascia in front of the vertebrae, from the nasal fossæ and accessory cavities, from the naso-

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THE LYMPHATIC GLANDS OF THE NECK

pharynx and Eustachian tube, and possibly from the cavity of the tympanum. They send vessels to the upper deep cervical glands.

The Deep Cervical, Carotid, or Sterno-mastoid Glands (lymphoglandulæ cervicæ profundæ) (Figs. 486, 487, 488, 490, 491, and 492).—The deep cervical glands are divided into the upper deep cervical and the lower deep cervical, and are associated with certain accessory glands, including the jugular and superficial anterior cervical, which have been discussed under the head of superficial cervical glands; and the anterior deep cervical and the recurrent glands, which have not yet been studied. The deep cervical chain extends from the apex of the mastoid process of the temporal bone to the junction of the internal jugular and subclavian veins.

The Upper Deep Cervical or Substernomastoid Glands (lymphoglandulæ cervicæ profundæ superiores).—The upper deep cervical glands extend from the tip of the mastoid process of the temporal bone to about the region where the common carotid artery is crossed by the Omo-hyoid muscle. One group, the external group, is placed external and posterior to the internal jugular vein. The glands are small and numerous, are embedded in the fatty tissue about the nerves from the deep cervical plexus, and at the posterior margin of the Sterno-cleido-mastoid muscle constitute a continuous mass passing to join the subclavian glands. Another group, known as the internal group or the internal jugular glands, lie directly upon or close by the outer border of the internal jugular vein. This group forms a chain along the internal jugular vein, and the glands are of larger size than those of the external group. Some glands of this group are beneath the vein. The glands of the internal jugular group communicate freely with each other and with the external group. The external group receives lymph-vessels from the posterior auricular, occipital, and external jugular glands, from the occipital region of the scalp, from the auricle, and from the skin, subcutaneous tissue, and muscles of the upper portion of the neck. The internal group receives lymph-vessels from the retro-pharyngeal, parotid, subparotid, sub-maxillary, and submental glands, the anterior cervical glands (superficial and deep), and the recurrent glands, and from the tongue, naso-pharynx, larynx, soft palate, roof of the mouth, oesophagus (cervical portion), nasal fossae, trachea (cervical portion), and the thyroid gland. The external group terminates in the supraclavicular glands. The internal jugular group terminates in the jugular trunk, which, on the right side, helps to form the right lymphatic duct or empties directly into the junction of the internal jugular and subclavian veins, and on the left side empties directly into the venous junction or into the thoracic duct.

The Lower Deep Cervical or Supraclavicular Glands (lymphoglandulæ cervicæ profundæ inferiores).—The lower deep cervical glands lie along the internal jugular vein in the lower part of its course. They receive lymph-vessels from the superficial cervical glands, the upper deep cervical glands, the axillary glands, the accessory chain, the occipital region of the scalp, the skin of the neck, the lower prevertebral muscles, the skin of the pectoral and mammary regions, and the skin of the arm. The supraclavicular glands send vessels which unite with the vessels of the upper deep glands to form the jugular lymphatic trunk. The jugular trunk on the right side may empty directly into the junction of the internal jugular and subclavian veins or may unite with the subclavian trunk to form the right lymphatic duct. On the left side it may empty into the thoracic duct or directly into the venous junction.

Accessory Chains to the Deep Cervical Glands.—The accessory chains to the deep cervical glands are: 1. The external jugular glands (p. 783). 2. The superficial anterior cervical (p. 784). 3. The prelaryngeal or infralaryngeal glands (Fig. 486)

2 Ibid.
between the Crico-thyroid muscles. They receive lymph from the trachea, larynx, and thyroid gland, and send vessels to the pretracheal glands and to the upper deep cervical glands. 4. The **tracheal or pretracheal glands** (Fig. 486) lie upon the front of the trachea, receive vessels from the trachea, thyroid body, and prelaryngeal glands, and send vessels to the lower deep cervical glands. Some anatomists speak of the prelaryngeal and the pretracheal glands as the **anterior deep cervical glands**. 5. The **recurrent glands** lie on the sides of the oesophagus and trachea, by the recurrent laryngeal nerves. They receive vessels from the larynx, trachea, oesophagus, and thyroid gland, and send vessels to the upper and lower deep cervical glands.

**The Lymphatic Vessels of the Neck** (Figs. 486, 490, 491).

The superficial and deep cervical lymphatic vessels are continuations of those already described on the cranium and face. After traversing the glands in those regions, they pass through the chain of glands which lie along the sheath of the carotid vessels, being joined by the lymphatics from the pharynx, oesophagus, larynx, trachea, and thyroid gland. At the lower part of the neck, after receiving some lymphatics from the thorax, they unite to form the **jugular trunk** (Fig. 485), which often terminates, on the left side, in the thoracic duct, and on the right side, in the right lymphatic duct, but which may on either side open directly into the vein.

**Surgical Anatomy.**—In **secondary syphilis** there is general enlargement of the lymphatic glands, and in the posterior triangle of the neck the enlarged glands are distinctly palpable. The occipital glands may enlarge because of inflammation or suppuration about the occipital region of the scalp, and the posterior-auricular glands enlarge from inflammation or suppuration of the temporal portion of the scalp, the external ear (except the lobule), and the external auditory meatus. Otorrhoea sometimes causes them to enlarge.

The cervical glands are very frequently the seat of **tuberculous disease**. This condition is usually preceded by a lesion in those parts from which they receive their lymph. The lesion may be tuberculous or inflammatory. If tuberculous it furnishes bacilli directly to the lymph. If inflammatory it lessens tissue resistance and opens the portals to infection. The glands receive the lymph from the seat of primary disease and become tuberculous. It is very desirable, therefore, for the surgeon, in dealing with these cases, to possess a knowledge of the relation of the respective groups of glands to the periphery. Some years ago Sir Frederick Treves prepared a table to show to what glandular group lymph from each region is sent. The table is practically as follows:

**Scaple.**—Posterior part = suboccipital and mastoid glands. Frontal and parietal portions = parotid glands.

Lymphatic vessels from the scalp also enter the superficial cervical set of glands.

**Skin of face and neck** = submaxillary, parotid, and superficial cervical glands.

**External ear** = superficial cervical glands.

**Lower lip** = submaxillary and submaxillary glands.

**Buccal cavity** = submaxillary and upper set of deep cervical glands.

**Gums of lower jaw** = submaxillary glands.

**Tongue.**—Anterior portion = submaxillary and submaxillary glands. Posterior portion = upper set of deep cervical glands.

**Tonsils and polate** = upper set of deep cervical glands.

**Pharynx.**—Upper part = parotid and retro-pharyngeal glands. Lower part = upper set of deep cervical glands.

**Larynx, orbit, and roof of mouth** = upper set of deep cervical glands.

**Nasal fossae** = retropharyngeal glands, upper set of deep cervical glands. Some lymphatic vessels from posterior part of the fossae enter the parotid glands.

Treves’s table indicates the glands usually involved, but the seat of primary disease cannot invariably be affirmed from the knowledge of the seat of glandular involvement, because the course of the lymphatic vessels is sometimes varied from that which usually maintains; for instance, in some cases lymphatics from the right side of the tongue pass to glands in the left side of the neck.

Glands may **enlarge** directly because of primary inflammation, injury, or tumor; but usually a glandular enlargement is secondary to a bacterial disease or to cancer involving the lymph-vessels which come to the gland. The seat of disease may be distant. Disease of the nasal fossae may cause **retropharyngeal abscess** or enlargement of the submaxillary glands. **Cancer of the breast, stomach, or oesophagus** may be followed by disease of the cervical glands. Dis-
THE LYMPHATIC GLANDS OF THE UPPER EXTREMIT Y 787

ease of the teeth, tongue, gums, floor of the mouth, and alveolar processes may cause enlargement of the submaxillary and other glands, and disease of the tonsil may lead to enlargement of the glands at the angle of the jaw.

The modern radical surgery of cancer depends on a knowledge of these glandular relations, and consists in thoroughly removing the growth and also the associated lymphatic glands, and, when possible, the lymph-vessels running from the tumor to the glands. The lower deep cervical glands occasionally enlarge secondarily to malignant growths of the abdomen or mediastinum, but this is not due to a direct flow of lymph, as the mediastinal glands do not send vessels to the supravacuicular glands. It is due to blocking of lymphatic vessels and reversal of the lymph-stream, so that lymph containing cancerous cells regurgitates.

A retropharyngeal abscess begins to the side of the pharynx. It enlarges toward the centre rather than from it, because the constrictions of the pharynx limit the outward progress of the pus.

The glands within the parotid salivary gland not unusually become tuberculous, and the surgeon may be led to believe that the salivary gland is the seat of primary disease.

Sometimes, though seldom, after the extensive removal of lymph-glands the region drained by their tributaries becomes the seat of persistent hard oedema (lymph oedema). It used to be thought that wounds of the thoracic duct were of necessity fatal, but it is now known that, unless close to the vein, they are seldom even very dangerous. It may be possible to suture a partly divided duct. In an unsutured wound of the duct recovery follows if a collateral lymphatic circulation is established.

THE LYMPHATICS OF THE UPPER EXTREMIT Y.

The Lymp thic Glands of the Upper Extremity.

The lymphatic glands of the upper extremity are divided into two sets, superficial and deep.

Superficial Lymphatic Glands (Figs. 493 and 501).—The superficial lymphatic glands of the upper extremity are few in number and small in size. They lie in the subcutaneous tissue. They are not receiving depots of great areas, but interrupt lymphatic vessels here and there. The glands in the axilla receive all of the lymphatic vessels, superficial and deep. There may be three sets of superficial glands.

One set, the ante-cubital glands, lies in front of the elbow. These glands are often absent. When these glands are present they receive vessels from the anterior portion of the forearm and the middle of the palm. The vessels from them pass upward along the front and inner aspect of the arm.

Another superficial gland lies above the internal condyle. It is the supratrochlear or supraepitrochlear gland or group of glands. There is usually but one gland, but there may be two or more. It receives vessels from the inner portion of the hand, the three inner fingers; and the inner portion of the forearm, but, because of free anastomoses, also may receive lymph from any portion of the hand and forearm. Lymph-vessels from the supratrochlear gland pass up along the basilic vein to the axillary glands.

There are sometimes several small glands by the cephalic vein in the groove between the Deltoid and great Pectoral muscles. These are called infraclavicular glands. The lymph-tract from the infraclavicular glands does not terminate in the axillary glands, but ends in the subclavian glands.

The Deep Lymphatic Glands of the Upper Extremity or the Axillary Glands (lymphoglandulae axillares) (Figs. 493, 494, 495, 496, and 501).—The chief deep glands are situated adjacent to the axillary vessels. There are also a few small glands along the radial, ulnar, and brachial arteries which receive deep lymphatics from bones, muscles, and ligaments, and send lymphatics to the axillary glands. The axillary glands number from fifteen to thirty-five in each axilla. They are embedded in the axillary fat and receive the lymphatic vessels from the upper

1 Dudley P. Allen's case. See Allen and Briggs, in American Medicine, September 21, 1901.
2 Harvey Cushing, Annals of Surgery, June, 1898.
extremity, from the skin of the upper portion of the chest, from the Pectoral muscles, and from the mammary gland. The following division of the axillary glands is made by Poirier, Cunéo, and Delamare: 1. An **external** group, the **humeral chain**, lying on the inner surface of the vessels and nerves, particularly the axillary vein, to the sheath of which they are adherent. Occasionally one or several of these glands are found beneath the vein. Some of the vessels from these glands pass into the central group of lymph-nodes; others enter the subclavian glands; others pass above the clavicle and terminate in glands situated in that region. 2. An **anterior group**, the **thoracic chain**, called also the **pectoral glands** (*lymphoglandulae pectorales*). One mass of this chain, the **supero-internal**, is situated in the second or third intercostal space in front of the long thoracic artery and beneath the lower edge of the great Pectoral muscle. Another mass, the **infero-external**, is situated in the fourth and fifth intercostal spaces along the course of the long thoracic artery. The vessels from this chain end in the central group, and some few of them in the subclavian glands. 3. A **posterior group**, the **scapular chain**, lying along the dorsalis

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1 The Lymphatics. Translated and edited by Cecil H. Leaf.
scapulae artery in the groove between the Teres major and the Subscapularis muscles. They send vessels to the humeral and central chains.

4. A central

![Diagram of lymphatic system](image)

**Fig. 494.**—Axillary glands and lymphatics of the breast. (Poirier and Charpy.)

**Fig. 495.**—Lymphatics of the antero-lateral portion of the thorax. (Sappey.)
group, the intermediate glands, placed near the base of the axilla, between the previously described chains. Their efferent vessels end in the subclavian glands. The glands of the central group in many individuals protrude through the opening in the axillary fascia known as the foramen of Langer (Fig. 312). 5. A subclavian group, situated above the upper margin of the lesser Pectoral muscle. Most of them are internal to the axillary vein, "between this vein and the first digitation of the Serratus magnus." The humeral chain and the thoracic chain come together and form the subclavian group of glands situated at the apex of the axilla. From the axillary glands come many vessels which, by anastomosing, form the infraclavicular plexus, they then unite into a trunk, the subclavian trunk, which courses between the subclavian vein and Subclavius muscle. On the right side it empties into the junction of the internal jugular and subclavian vein or unites with the jugular trunk to form the right lymphatic duct. On the left side it may empty into the venous junction or into the thoracic duct.

![Diagram of the lymphatic system](image)

**Fig. 496.—Scheme of the axillary glands.** The dotted line indicates the position of the clavicle. (Poirier and Charpy.)

### The Lymphatic Vessels of the Upper Extremity (Figs. 493, 494, 495, 496, 497).

The lymphatic vessels of the upper extremity are divided into the superficial and the deep.

**The Superficial Lymphatic Vessels of the Upper Extremity.**—The superficial vessels begin as plexuses in the skin and form vessels which ascend in the subcutaneous tissue. These plexuses are particularly plentiful in the palm and palmar surface of the digits (Fig. 497). On each side of each finger two lymph-vessels are formed; they ascend toward the hand, cross the dorsum, and anastomose frequently with each other. The vessels from the dorsum of the hand join the lymph-vessels of the forearm, which ascend chiefly along the superficial veins. The lymph-vessels which ascend with the superficial ulnar vein pass into the supratrochlear gland. The vessels which accompany the median veins pass into the ante-cubital or supratrochlear glands. Some of the lymph-vessels on the radial side of the forearm run up along the cephalic vein. All the other lymph-vessels of the upper extremity pass direct to the axillary glands. In the forearm there are about thirty vessels, in the middle of the arm there are from fifteen to eighteen (Sappey).

**The Deep Lymphatic Vessels of the Upper Extremity.**—The deep lymph-vessels convey the lymph from bone, periosteum, muscle, ligament, etc. They pass up the limb with the chief vessels, there usually being two trunks to each artery.
In the arm there are two or three vessels. Some few vessels terminate in the small glands along the radial, ulnar, and brachial arteries, but most of them pass directly to the axillary glands.

**Surgical Anatomy.**—In malignant diseases, or other affections implicating the upper part of the back and shoulder, the front of the chest and mamma, the upper part of the front and side of the abdomen, or the hand, forearm, or arm, the axillary glands are liable to be found enlarged.

In *secondary syphilis* the supratrochlear gland is found to be enlarged. This gland is subcutaneous and readily palpable when enlarged. Normal axillary glands cannot be palpated. The axilla is a passage-way for structures between the neck and the upper extremity, and purulent collections or tumors may extend from the neck into the axilla or from the axilla into the neck.

The axillary glands are involved early in cases of cancer of the mammary gland, and later the lower deep cervical glands are involved, and, as Snow has pointed out, regurgitation of lymph-containing cancer cells leads to retrosternal involvement and to secondary cancer of the head of the humerus. In operating for cancer of the breast, follow the principle of Halsted and remove the breast, the skin over it, the muscles and fascia, the lymph-vessels, and the axillary glands in one piece. By this plan thorough removal is possible, and as lymph-vessels containing carcinoma cells are not cut across, the wound is not grafted with malignant epithelial cells. Diseased axillary glands are apt to adhere to the sheath of the vein. In removing cancerous glands, always excise the sheath of the vein.

**THE LYMPHATICS OF THE LOWER EXTREMITY.**

The Lymphatic Glands of the Lower Extremity.

The lymphatic glands of the lower extremity are divided into two sets, superficial and deep. The superficial are confined to the inguinal region, forming the superficial inguinal lymphatic glands.

The **Superficial Inguinal Lymphatic Glands** (*lymphoglandulae inguinales superficiales*) (Figs. 498, 499, 500, and 501).—The superficial inguinal lymphatic glands, placed immediately beneath the integument in Scarpa's triangle, are of large size, and vary in number from ten to twenty. It is customary to divide these glands into groups according to the region in which they are found. The following division is suggested by Poirier, Cunéo, and Delamare: A horizontal line carried through the saphenous opening divides the glands into two groups, a **superior group** and an **inferior group**. A vertical line through the saphenous opening divides each of the two groups into two secondary groups, an **external** and an **internal group**. We thus have an **external and superior group**, and an **internal and superior group**, an **external and inferior group**, and an **internal and inferior group**.

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1 The Lymphatics. Translated and edited by Cecil H. Leaf.
Directly in the saphenous opening there are often several glands constituting a central group.

Leaf points out that a gland usually exists near the saphenous opening, which is interposed between the superficial inguinal and deep inguinal glands. The superior group of glands, sometimes called the oblique group, is so placed that the
glands lie with a certain regularity along and below Poupart's ligament, the long axis of each gland corresponding with the direction of the ligament. It is now known that each group of the superficial glands does not receive with regularity the lymph from and only from a definite and accurately determined area. Hence, it is not possible, as was once taught, to determine with certainty the exact situation of a lesion by the group of superficial glands involved. The superficial inguinal
glands receive vessels from the skin of the lower extremity, gluteal region, perineum, abdominal wall, scrotum, anus, and from the prepuce of the clitoris and penis. Occasionally, though not normally, they receive vessels from the glans penis and glans clitoris. The superficial glands send vessels to the deep inguinal glands and to the external iliac glands, and these vessels penetrate the femoral sheath. The vessels which go to the iliac glands ascend with the femoral vessels. Leat figures some of the efferent vessels from these glands as terminating directly in the veins of this region.

Surgical Anatomy.—The superficial inguinal glands frequently become enlarged in diseases implicating the parts from which their lymphatics originate. Thus, in malignant or syphilitic affections of the prepuce and penis, or of the labia majora in the female, in cancer scroti, in abscess in the perineum, and in other diseases affecting the integument and superficial structures in those parts, or the subumbilical part of the abdominal wall or the gluteal region, the upper chain of glands is almost invariably enlarged, the lower chain being implicated in diseases affecting the lower limb.

The Deep Lymphatic Glands of the Lower Extremity.—The deep glands are the inguinal, anterior tibial, popliteal, gluteal, and ischiatic.

The Deep Inguinal or Deep Femoral Lymphatic Glands (lymphoglandulae inguinales profundae).—The deep inguinal lymphatic glands are beneath the deep fascia. There are only two or three of them, and they lie to the inner side of the femoral vein, the upper gland being in the crural canal and projecting into the pelvis. It is called the gland of Cloquet or the gland of Rosenmüller. The deep inguinal glands receive vessels from the superficial inguinal glands, deep lymphatics from along the femoral vessels, and vessels from the glans penis or clitoris. They send vessels to the ilio-pelvic glands.

The Anterior Tibial Gland (lymphoglandula tibialis anterior).—The anterior tibial gland is not constant in its existence. It is generally found by the side of the anterior tibial artery, upon the interosseous membrane at the upper part of the leg. Occasionally two glands are found in this situation. It receives a deep anterior tibial lymphatic trunk and sends off a vessel to the popliteal glands.

The Popliteal Glands (lymphoglandulae popliteae).—The popliteal glands are embedded in the cellular tissue and fat of the popliteal space and about the peroneal vessels. The juxta-articular gland receives lymph-vessels from the knee-joint. The popliteal glands send vessels to the superficial and deep inguinal glands.

The popliteal glands are divided into three groups:
1. A gland external to the termination of the external saphenous vein, the external saphenous gland.
2. A middle group of three or four glands on the sides of the popliteal vessels. The inferior glands of this group are the intercondylar glands of Leaf.
3. A gland adherent to the posterior ligament of the knee-joint, the juxta-articular gland of Poirier and Cunéo.

The Gluteal and Ischiatic Glands.—The gluteal and ischiatic glands are placed, the former above, the latter below, the Pyriformis muscle, resting on their corresponding blood-vessels as they pass through the great sacro-sciatic foramen.

The Lymphatic Vessels of the Lower Extremity (Figs. 500, 501).

The lymphatic vessels of the lower extremity, like the veins, may be divided into two sets, superficial and deep.

1 The Surgical Anatomy of the Lymphatic Glands, 1898.
The Superficial Lymphatic Vessels of the Lower Extremity.—The superficial lymphatic vessels are placed beneath the integument in the superficial fascia, and are divisible into three sets: trunks which follow the course of the internal saphenous vein, trunks which accompany the external saphenous vein, and trunks from the gluteal region. 1. Trunks which follow the course of the internal saphenous vein arise from a plexus on the dorsum of the foot, which plexus obtains lymphatics from all the toes, the sole, and both borders of the foot. The internal trunks, three or four in number, pass to the superficial inguinal glands. The external trunks run upward and inward and end in the internal trunks. 2. The trunks which follow the external saphenous vein number two or three, and they take origin from the heel and from the posterior half of the outer edge of the foot. They empty into the superficial inguinal glands. 3. The lymph-trunks from the gluteal region join vessels from the anus and enter the superficial inguinal glands.

The Deep Lymphatic Vessels of the Lower Extremity.—The deep lymphatic vessels of the lower extremity are few in number and accompany the deep blood-vessels. In the leg they consist of three sets, the anterior tibial, peroneal, and posterior tibial, which accompany the corresponding blood-vessels, two or three to each artery; they ascend with the blood-vessels and enter the lymphatic glands in the popliteal space; the efferent vessels from these glands accompany the femoral vein and join the deep inguinal glands; from these glands vessels pass beneath Poupart's ligament and communicate with the chain of glands surrounding the external iliac vessels. The deep lymphatic vessels of the gluteal and ischiatic regions follow the course of the blood-vessels, and join the gluteal and ischiatic glands at the great sacro-sciatic foramen.

THE LYMPHATICS OF THE PELVIS AND ABDOMEN.

The lymphatics of the pelvis and abdomen constitute a continuous chain, but for convenience of study it is customary to divide them into two groups, which we call, with Poirier and Cunéo, the ilio-pelvic glands and the abdomino-aortic glands; the first group being below and the second above the level of the bifurcation of the aorta into the two common iliac arteries.

The Iliac or Ilio-pelvic Glands (Lymphoglandulae Iliaca) (Figs. 502, 503).

The ilio-pelvic glands are at the level of the inlet of or in the cavity of the pelvis. They follow the course of the blood-vessels and are divisible into the external iliac, the internal iliac, and the common iliac chains.

The External Iliac Glands.—The external iliac glands form chains around the external iliac vessels. There are three chains of these glands. An external chain of three or four glands lies between the artery and the Psoas muscle. The lowest gland of the external chain is called by Poirier and Cunéo the external retro-crural gland (Fig. 502). A middle chain of three glands lies upon the front surface of the external iliac vein. The lowest gland of this group is called by Poirier and Cunéo the middle retro-crural gland. An internal chain of three or four glands is placed to the inner side of the external iliac vein. The lowest gland of this chain is called the internal retro-crural gland, and is close to the upper gland of the deep inguinal chain, the gland of Cloquet. The obturator gland belongs to the inner chain of external iliac glands. The external iliac glands receive vessels from the superficial and deep iliac glands, from the glans penis or glans clitoris, deep lymphatics from the umbilicus and lower part of the belly wall, vessels from the superior portion of the vagina, the uterine neck, the prostate gland, the bladder,

1 Treatise on Human Anatomy.
the membranous portion of the urethra, and the internal iliac glands, and the obturator gland receives deep lymph-vessels from along the course of the obturator vessels. The external iliac glands send vessels direct to the common iliac glands and also lymphatics to join vessels from the internal iliac glands on their way to the common iliac group. The glands along the deep epigastric artery and those along the deep circumflex iliac artery are accessory chains to the main group of external iliac glands.

**Fig. 502.—Ilio-pelvic glands.** (Poirier and Charpy.)

**The Internal Iliac or Hypogastric Glands** (lymphoglandulae hypogastricae).—The internal iliac glands are placed along the internal iliac artery and its branches. The gland on the middle hemorrhoidal artery is called the **middle hemorrhoidal gland**. The **lateral sacral gland** is on the lateral sacral artery. The internal iliac glands receive lymph from the pelvic viscera, perineum, and penile portion of the urethra, deep tissues of the posterior portion of the thigh, and from the buttocks. They send vessels to the common iliac glands and also to the external iliac glands.

**The Common Iliac Glands.**—The common iliac glands are found about the common iliac artery and are divided into an **external group**, which lies upon the inner edge of the Psoas muscle; a **middle group**, behind the artery, and an **internal group**, which lies upon the front of the body of the fifth lumbar vertebra or upon the sacro-vertebral junction. They receive vessels from the external and internal
iliac glands and from the pelvic viscera, the vessels from the pelvic viscera ascending to the promontory of the sacrum and containing perhaps, here and there, interrupting glands, known as sacral glands (lymphoglandulae sacrales) (Fig. 509). They also receive lymph-vessels from the lumbo-sacral region. They send vessels to the aortic glands. Some anatomists place the common iliac glands and the glands about the lower portion of the aorta and vena cava in a group called the lumbar glands (lymphoglandulae lumbales) (Fig. 509).

The Abdomino-aortic Glands (Figs. 483, 509).

The abdomino-aortic glands are placed about the abdominal aorta. There are twenty-five or thirty of them. They are divided by Poirier, Cunéo, and Delamaré into the right and left juxta-aortic glands, the retro-aortic glands, and the pre-aortic glands.

The Right Juxta-aortic Glands.—The right juxta-aortic glands are grouped in front of and behind the postcava, the posterior glands lying upon the Psoas muscle and the adjacent pillar of the Diaphragm. They receive lymph-vessels from the right common iliac glands, from the right testicle or the right half of the uterus, and the right tube, ovary, broad ligament, the right kidney and suprarenal capsule, and also lymph-vessels which pass along the lumbar arteries. They send vessels to the pre-aortic and the retro-aortic glands and the receptaculum chyli.

1 The Lymphatics. Translated and edited by Cecil H. Leaf.
The Left Juxta-aortic Glands.—The left juxta-aortic glands lie by the side of the abdominal aorta, upon the Psoas muscle, and the left pillar of the Diaphragm. They receive tributaries from the left side corresponding to those received by the glands of the right side, and also send out corresponding efferent vessels, and several additional vessels which pass through the left pillar of the Diaphragm and empty into the thoracic duct.

The Retro-aortic Glands.—The retro-aortic glands are placed beneath the receptaculum chyli and in front of the bodies of the fourth and fifth lumbar vertebrae. They receive lymph-vessels from both juxta-aortic groups, and also from the pre-aortic glands, and they send vessels to the receptaculum chyli.

The Pre-aortic Glands.—The pre-aortic glands lie upon the front of the aorta, and in most subjects are divisible into three groups: an inferior, lying at the origin of the inferior mesenteric artery; a middle, at the origin of the superior mesenteric artery, and a superior, about the celiac axis, the cæliac glands (lymphoglandulae coeliacae). Glands which are found along the course of all the branches of the abdominal aorta empty into and belong to the group of pre-aortic glands. The pre-aortic glands receive vessels from the juxta-aortic glands and from all the glands along the mesenteric vessels and the cæliac axis and its branches, and receive lymph from the stomach, intestines, liver, pancreas, and spleen. They anastomose with each other and send vessels to the retro-aortic glands and to the receptaculum chyli. Instead of the glands terminating in the receptaculum by separate vessels, the vessels may unite and form a common trunk, the intestinal trunk (truncus intestinalis), which runs along with the common trunk from the juxta-aortic glands, and empties into the receptaculum (Fig. 483).

1. The Glands along the Mesenteric Arteries (lymphoglandulae mesentericae) receive the lymph from the colon, cæcum, appendix, ileum, jejunum, duodenum, and perhaps also some from the stomach.

2. The Glands Connected with the Cæliac Axis and its Branches.—There are three groups of these glands: the gastric or coronary, the splenic, and the hepatic (including those of the bile-duets).

The Gastric Glands (lymphoglandulae gastricae).—One group is situated in the gastro-pancreatic fold; another group is connected with the lesser curvature of the stomach (Fig. 506). Some of them are in the lesser omentum close to insertion of the thicker part upon the stomach, and lie near the ascending branches of the gastric artery, that is to say, upon the vertical portion of the lesser curvature. Others lie within the lesser omentum and accompany the descending branches of the gastric artery, and particularly gather near the point where the gastric artery comes toward the stomach wall. The gastric glands receive lymph from most of the stomach. They send lymph to the upper group of pre-aortic glands, the cæliac glands.

The Splenic Glands (lymphoglandulae pancreaticolienales).—The splenic glands accompany the splenic artery and lie upon the posterior surface of the spleen, between the spleen and pancreas. They receive lymph from the fundus of the stomach, from the spleen, and from the pancreas, and send it to the cæliac glands.

The Hepatic Glands (lymphoglandulae hepaticae).—These glands lie along the hepatic artery, some on the level of the floor of the foramen of Winslow, others by the left side of the portal vein. The authors previously quoted point out that there is a secondary chain of hepatic glands about the right gastro-epiploic artery, the gastro-epiploic chain, and that this comprises a subpyloric group and a retro-pyloric group. The subpyloric group (Fig. 506) is placed in the great omentum below the pylorus, and is usually distinctly separated from it. The retro-pyloric group is not constant. It is placed along the gastro-duodenalis artery back of the pylorus. There is also a group of glands, secondary to the hepatic glands, to the right of

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1 The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
or posterior to the cystic duct and the common bile-ducts. The hepatic glands proper receive lymph from the liver and send it to the celiac glands. The subpyloric glands receive lymph from the inferior portion of the stomach and from the superior portion of the great omentum. They send lymph to the hepatic glands proper, the retro-pyloric glands, and sometimes also to the glands about the superior mesenteric artery. The retro-pyloric glands receive lymph from the subpyloric glands, from the upper surface and from the posterior surface of the pylorus, and from the duodenum. They send lymph to the hepatic glands proper and sometimes to the glands along the superior mesenteric artery. The glands along the gall-ducts empty into the hepatic glands proper.

The Lymphatic Vessels of the Abdomen and Pelvis.

The lymphatic vessels of the abdomen and pelvis may be divided into two sets, superficial and deep.

The Superficial Lymphatic Vessels of the Walls of the Abdomen.—The superficial lymphatic vessels of the walls of the abdomen follow the course of the superficial blood-vessels. The superficial lymphatics are derived from the integument. Those of the lower part of the abdomen below the umbilicus follow the course of the superficial epigastric vessels and converge to the superior group of the superficial inguinal glands (Figs. 499 and 501). Those from the costal margins of the abdomen terminate in the axillary glands (Fig. 495). The superficial lymphatics from the sides of the lumbar part of the abdominal wall wind around the crest of the ilium, accompanying the superficial circumflex iliac vessels, to join the superficial inguinal glands (Fig. 499).

The Superficial Lymphatic Vessels of the Gluteal Region.—The superficial lymphatic vessels of the gluteal region turn horizontally around the outer side of the ischial tuberosity, and join the superficial inguinal glands.

The Superficial Lymphatic Vessels of the Scrotum and Perineum.—The superficial lymphatic vessels of the scrotum and perineum terminate in the superficial inguinal glands.

The Superficial Lymphatic Vessels of the Penis.—The superficial lymphatic vessels of the penis occupy the sides and dorsum of the organ, the latter receiving the lymphatics from the prepuce; they all converge to the superficial inguinal glands. Lymph vessels from the glans penis empty into the deep inguinal and the external iliac glands.

In the female the lymphatic vessels of the vulva and prepuce of the clitoris pass to the superficial inguinal glands; those of the glans of the clitoris pass to the deep inguinal and the external iliac glands.

The Deep Lymphatic Vessels of the Abdominal Wall.—The deep lymphatic vessels of the abdominal wall take the course of the principal blood-vessels, and arise from muscular or aponeurotic layers. One set of lymph-vessels runs along with the deep epigastric artery and terminates in the external iliac glands. Another accompanies the deep circumflex iliac artery, and also terminates in the external iliac glands. Several lymph-vessels accompany the lumbar arteries and empty into the juxta-aortic glands. A vessel accompanies the internal mammary artery and empties into the internal mammary glands. Lymph-vessels of the parietes of the pelvis, which accompany the gluteal, ischiatic, and obturator vessels, follow the course of the internal iliac artery, and ultimately join the external iliac, internal iliac, and common iliac glands, and the glands about the lower portions of the aorta and vena cava.

The Lymphatic Vessels of the Umbilicus.—The lymphatics of the umbilicus are divided into three groups: 1 The cutaneous lymphatics, which are very superficial,
and empty into the superficial inguinal glands. The lymphatics of the fibrous nucleus, which pass through the rectus sheath, reach the deep epigastric artery and join the deep lymphatics which come from the muscular and aponeurotic layers of the belly wall. The lymphatics of the aponeurotic margin are in two sets: An anterior set, some of which penetrate the rectus sheath and join the lymphatics from the fibrous nucleus; others of which pass outward, penetrate the external and internal oblique muscles, and join the posterior lymph-vessels from the aponeurotic margin. A posterior set, which forms a collection of vessels on the posterior aspect of the rectus sheath, from which several trunks emerge. One trunk passes outward, penetrates the Transversalis muscle, joins the anterior trunk from the aponeurotic margin, and empties into the external iliac glands. Other ducts run along with the deep epigastric artery and pass into the external iliac glands. Glands lie along the lower portion of these lymph-ducts, and are known as the superior epigastric glands, and a gland may exist in the subperitoneal tissue beneath the umbilicus.

The Lymphatic Vessels of the Peritoneum.—It seems probable that the peritoneal cavity is a lymph-sac and that lymphatics take origin from the peritoneum in several ways. Robinson points out three modes of origin: 1. By stomata between endothelial cells. These stomata are in direct communication with lymph-vessels. 2. By interstitial spaces in the subperitoneal tissue. 3. By a plexiform origin similar to interstitial spaces.

Surgical Anatomy.—The fact emphasized by Robinson that the peritoneum is a great lymph-sac explains the quick absorption of septic material and the rapid spread of infectious processes. If the exudate clots and blocks the lymph-channels, absorption is slow and life may be saved. If it does not clot, absorption is rapid and death is certain. Whether it clots or not depends on the nature of the bacteria present. Fowler, impressed by the fact that absorption takes place most rapidly from the diaphragmatic region and least rapidly from the pelvic region, advises placing the victim of peritonitis in bed, with his head and body elevated.

The Lymphatic Vessels of the Bladder.—No lymphatics exist in the mucous membrane of the bladder, although they do exist in the mucous membrane of the prostate. There are some lymphatics in the bladder muscle, and numerous lymphatics in the subperitoneal tissue. The network of lymph-vessels in the muscles is connected with the network beneath the peritoneum and prevesical fascia, and collecting trunks come from both the anterior and posterior surfaces of the bladder. The anterior collecting trunks are divided into two sets. One set comes from the inferior portion of the anterior surface and passes outward to terminate in an external iliac gland "between the external iliac vein and the obturator nerve." The other set comes from the superior and anterior vesical surface, runs upward and outward, and terminates in the external iliac glands. Each set of vessels possesses interrupting lymph-nodes, some of which are directly in front of the bladder.

The posterior collecting trunks are divided into four sets. The first set comes from the superior and posterior portion and passes outward, exhibiting interrupting nodes in its course. These trunks terminate in the external iliac glands. The second set runs directly back into the external iliac glands. The third set comes from the middle of the posterior portion of the bladder and terminates in the hypogastric glands. The fourth set comes from the vesical neck, passes back and then ascends and terminates in the glands in front of the sacral promontory. This fourth set joins with the lymphatics from the prostate and seminal vesicles.

The Lymphatic Vessels of the Prostate Gland.—These vessels form a peri-prostatic plexus, which receives its afferents from the gland structure. This plexus is drained by four vessels, three of which commence on the posterior surface of the

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1 The Lymphatics. By Poirier, Cunéo, and Delamarre. Translated and edited by Cecil H. Leaf.
2 The Peritoneum.
3 George Ryerson Fowler, on Diffuse Septic Peritonitis, in the Medical Record, April 14, 1906.
4 The Lymphatics. By Poirier, Cunéo, and Delamarre. Translated and edited by Cecil H. Leaf.
gland. Although these vessels begin on the posterior surface of the prostate, their termination in each case is different. One passes on the under surface of the bladder, crosses the superior vesical artery, runs outward, and ends in the middle chain of the external iliac group. Another passes upward, outward, and backward, and terminates in the hypogastric group. A third passes along the floor of the pelvis, runs by the side of the rectum, and ascends on the anterior surface of the sacrum to terminate in the lateral sacral glands and in the hypogastric group. Occasionally a fourth trunk is found on the anterior surface of the prostate, which descends and joins the vessels from the membranous urethra and ends in the hypogastric glands.

The Lymphatic Vessels of the Male Urethra.—These vessels are divided into two groups: First, those of the penile portion of the urethra; second, those of the bulb and membranous portion. The lymphatics of the prostatic urethra belong to those of the prostate gland. The lymph-vessels of the penile urethra in front of the sulcus all run toward the frenum, at which point they bend backward to the sulcus; here they run to the dorsal surface of the penis and terminate in the same manner as the vessels from the glans. The trunks from the remainder of the penile urethra emerge from the inferior surface, run around the corpus cavernosa, and mostly unite with the vessels from the glans penis. One vessel, though, passes over the symphysis and enters in the internal retro-crusal gland, whilst another passes beneath the symphysis and terminates with the vessels from the bulb and membranous portion of the urethra. The lymphatics of the bulb and membranous portions end in three trunks, one of which accompanies first the artery of the bulb and then the internal pudic artery, and ends in the hypogastric gland attached to the pelvic portion of this artery. A second trunk runs behind the pubes, to end in the internal retro-crusal gland. A third trunk runs on the bladder, where it joins with vessels from this organ, to end in the internal chain of external iliac glands.

The Lymphatic Vessels of the Female Urethra.—The lymphatics of the female urethra terminate in the same manner as do the lymphatics of the bulb and membranous portions of the male urethra.

The Lymphatic Vessels of the Uterus.—These consist of three sets, each of which arises by a network of capillaries. There is a mucous network, a muscular network, and a peritoneal network. The vessels from these three regions of origin are collected in the subperitoneal tissue, from which area the collecting trunks take origin. From the cervix, according to Poirier and Cunéo, come from five to eight collecting trunks, which pass toward the sides of the body of the uterus, forming on each side, by twisting and dilatation, the juxta-cervical lymphatic knot of Cunéo. The cervical connecting trunks are divisible into three groups on each side. One group is composed of two vessels, which pass to the middle chain of the external iliac glands (superior and middle glands). Another group is composed of two vessels, which enter the hypogastric glands. A third group is composed of several vessels, some of which enter the lateral sacral glands, and the balance of which terminate in the glands of the sacral promontory. From the body of the uterus come three groups on each side. One group is composed of four or five vessels which emerge below the uterine cornu, pass beneath the ovary, where they receive the ovarian lymphatics, and terminate in the juxta-aortic glands of the same side. One so-called accessory lymphatic pedicle terminates in the external iliac glands, the other in the inguinal glands.

The Lymphatic Vessels of the Fallopian Tube.—The lymphatics of the Fallopian tube join with those of the uterus and ovary and terminate in the lateral aortic glands.

The Lymphatic Vessels of the Ovary.—The ovary is extremely rich in lymphatics; they form a plexus which is superficial to the veins. The vessels leading from this plexus, four or five in number, pass upward in company with the ovarian vessels
and end in the lateral aortic glands. Above the fifth lumbar vertebra these vessels anastomose with the lymphatics from the fundus of the uterus and Fallopian tube. Quite often there is a lymph-vessel which emerges from the ovary, passes downward and outward and ends in the middle chain of the internal iliac glands.

The Lymphatic Vessels of the Vagina.—The lymphatics of the vagina are divided into those of the mucous coat and those of the muscular coat; these anastomose freely with each other and terminate in a peri-vaginal network, which is drained by three groups of trunks. One group drains the upper third of the vagina and passes to the middle chain of the external iliac glands. A second group is efferent to the middle third of the vagina and ends in the hypogastric glands. A third group carries the lymph from the lower third of the vagina to the gland of the promontory.

The Lymphatic Vessels of the Testicle.—The lymphatic vessels of the testicle consist of two sets, superficial and deep; the former commence on the visceral surface of the tunica vaginalis, the latter in the epididymis and body of the testis. They form several large trunks which ascend with the spermatic cord, and, accompanying the spermatic vessels into the abdomen, terminate in the juxta-aortic and sometimes also in the pre-aortic glands; hence the enlargement of these glands in malignant disease of the testis.

The Lymphatic Vessels of the Vas Deferens.—These lymphatics empty into the external iliac glands.

The Lymphatic Vessels of the Seminal Vesicles.—A network exists on the surface of each vesicle, formed by a collection of lymph-vessels from the mucous lining and from the muscular structure of the vesicle. The trunks from this network empty into the external and internal iliac glands.

The Lymphatic Vessels of the Kidney, Ureter, and Suprarenal Capsule.—Their courses and terminations differ on the two sides. They take origin from a superficial network just beneath the capsule of the kidney and a deep network in the interior of the organ. The superficial network is connected to the collecting vessels of the deep network at the hilum. From the superficial network numerous vessels penetrate the capsule of the kidney and join the lymphatics of the fatty capsule. According to Poirier, Cunéo, and Delamare,¹ anterior and posterior trunks come off from the deep lymphatics of the right kidney. The anterior trunk usually terminates in the right juxta-aortic glands which lie upon the vena cava. The posterior trunks terminate in the juxta-aortic glands which lie behind the vena cava. On the left side all the collecting trunks terminate in the juxta-aortic glands of the left side of the aorta.

The lymphatics of the fatty capsule of the kidney communicate with the lymphatics of the kidney, and both terminate in the same glands. The lymphatics of the suprarenal capsule terminate in the juxta-aortic glands of the same side. From the ureter lymph-vessels come off and terminate in the juxta-aortic and adjacent glands.

The Lymphatic Vessels of the Liver.—The lymphatic vessels of the liver are divisible into two sets, superficial and deep. The former arise in the lobules at the periphery of the liver and pass to the subperitoneal connective tissue over the entire organ. The latter arise from the deeper lobules, and emerge from the liver along the portal vein or the hepatic veins.

According to Poirier, Cunéo, and Delamare,² three groups of superficial collecting trunks arise from the subperitoneal network. The posterior trunks divide into three groups. The single right posterior trunk terminates in a gland about the celiac axis. The middle posterior trunks (five to seven in number) pass through the opening in the Diaphragm. The left posterior trunks pass into glands

¹ The Lymphatics. Translated and edited by Cecil H. Leaf.
² Ibid.
about the subdiaphragmatic portion of the oesophagus. The anterior collecting trunks terminate in the lymph-glands of the hilum of the liver. The superior trunks ascend. One of these trunks or a posterior trunk passes with the vena cava through the Diaphragm and terminates in glands about the vena cava. Another trunk, an anterior one, passes over the anterior border of the liver, runs for a time with the round ligament, and terminates in the hepatic glands. Numerous middle trunks ascend in the suspensory ligament, unite beneath the Diaphragm and divides into several smaller ducts, which terminate in the glands back of the xiphoid cartilage. Trunks from the superficial lymphatic network also emerge from the inferior surface of the liver. The posterior trunks from the right lobe reach the vena cava and terminate in the glands about the intra-thoracic end of that vessel. The middle and anterior trunks from the right lobe reach the glands along the cystic duct. The trunks from the left lobe terminate in the glands along the hepatic artery. The trunks from the lobus Spigelii reach the glands of the hilum and the glands about the lower intra-thoracic portion of the vena cava. The trunks from the quadrato lobe terminate in the glands of the hilum. The deep collecting trunks are divisible into two groups. One group descends along the portal vein, the other ascends along the hepatic veins.

Sappey pointed out that the deep descending trunks accompany the bile passages and the branches of the portal vein, several anastomosing vessels accompanying each branch of the portal vein. The same authority affirmed that from fifteen to eighteen trunks emerge from the hilum and terminate in the adjacent glands. The deep ascending trunks surround as a sheath the branches of the hepatic vein (Sappey). As they approach the Diaphragm they diminish in number to five or six, pass through the opening for the vena cava, and terminate in the glands about the lower portion of the intra-thoracic cava.

The Lymphatic Vessels of the Bile-ducts.—The lymphatics of the bile-ducts arise from the mucous membrane and from within the muscular tissue, and terminate in glands along the cystic and common ducts.
The Lymphatic Vessels of the Stomach (Figs. 505 and 506).—The lymphatic vessels of the stomach consist of two sets, superficial and deep. The superficial arise from the outer (serous) and the middle (muscular) coats. The deep arise from the mucous membrane and form a network in the submucous tissue. Trunks from the submucous network pass through the muscular tunic and terminate in the trunks coming from the sero-muscular layers. These latter, the musculo-serous collecting trunks, are divided into three groups. The first group is composed of six or eight vessels which pass toward the lesser curvature (Sappey). There are from three to ten glands upon the lesser curvature along the course of the gastric artery which receive these superior trunks. Vessels come to these glands from the cardia, from the body of the stomach, and from the pyloric end. In the lesser curvature the lymphatic vessels lie in the wall of the stomach. According to Cunéo, two-thirds of the stomach is drained by the lymph-vessels of group I. The second group comprises the trunks from the greater curvature which end in the subpyloric glands. The glands along the greater curvature are some distance from the stomach wall in the pyloric region, and lymph-streams flow from left to right, that is, toward the pylorus and not from it. These lymphatics drain one-third of the stomach. The first and second groups send lymph eventually to the celiac glands and juxta-aortic glands. The third group comprises trunks which come from the fundus of the stomach and enter the lymphatic glands about the spleen.

Surgical Anatomy.—Mikulicz pointed out the early infection of the glands of the lesser curvature in pyloric cancer, and insisted that in operation for pyloric cancer the entire lesser curvature must be removed. Cunéo showed us that in pyloric cancer the fundus and two-thirds of the greater curvature usually remain free from disease, because the lymph-current is toward the pylorus and not from it. Of course, if the lymphatics become blocked, the lymph-current may be reversed (regurgitation), and then infection of these parts can occur. William J. Mayo has noted the "lymphatic isolation" of the dome of the stomach. In operating for cancer of the pylorus, make the section of the stomach as directed by Hartmann, that is, a section which removes all of the lesser curvature and cuts the greater curvature well to the left of the subpyloric glands.

The Lymphatic Vessels of the Pancreas.—The lymphatics of the pancreas arise from a network about the pancreatic lobules. The collecting trunks anastomose freely on the surface of the pancreas. Some of the trunks terminate in the splenic glands, which send vessels to the celiac glands. Others terminate directly in the celiac glands. The lymphatics of the head of the pancreas communicate with the duodenal lymphatics and the lymphatics of the lower end of the common duct. The pancreatic and splenic lymphatics probably communicate.

The Lymphatic Vessels of the Spleen.—The lymphatics of the spleen consist of two sets, superficial and deep; the former are placed beneath its peritoneal covering, the latter in the substance of the organ; they accompany the blood-vessels, passing
through a series of small glands, and pass into the splenic glands which are placed in the omentum between the spleen and pancreas. The gastro-splenic omentum contains no glands.

THE LYMPHATIC SYSTEM OF THE INTESTINES.

The Lymphatic Glands of the Small Intestine (Fig. 507).—The lymphatic glands of the small intestine are placed between the layers of the mesentery, and are

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**Fig. 506.**—General view of the subperitoneal lymphatic plexus of the stomach prepared by the method of Gerota. (Cuéno.)

called *mesentery glands* (*lymphoglandulae mesentericae*). They vary in number from a hundred to a hundred and fifty, and in size from that of a pea to that of a small almond. These glands are most numerous and largest above, the glands of the jejunum being more numerous than those of the ileum. This latter group becomes enlarged and infiltrated with deposit in cases of fever accompanied with ulceration of the intestines. The glands diminish in number as we descend until the ileocecal region is reached, when a number of glands appear about the ileo-cecal artery. The mesenteric glands receive the lacteals and send out trunks to the receptaculum chylæ. The chyle from the intestine passes through the glands on its way to the thoracic duct.

The glands may be divided into: I. A group of glands the members of which are chiefly found along the terminal vessels from the vascular loops of the intestinal branches of the superior mesenteric artery. Some glands of this group are placed upon "the anterior surface of the upper end of the jejunum." II. A group of

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1 Leaf (Surgical Anatomy of the Lymphatic Glands) says it is very common to find not more than forty or fifty.

2 Ibid.
glands along the vascular loops of the superior mesenteric artery. Most of them are between the primary loops. Some of them are between the secondary and tertiary loops. III. A group of glands along the trunk of the superior mesenteric artery.

The Lymphatic Vessels of the Small Intestine (Fig. 507).—The lymphatic vessels of the small intestine are called lacteals, from the milk-white fluid they usually contain. They take origin in the intestinal villi and in lymphatic sinuses around the bases of the solitary glands. Lymphatic plexuses exist in the submucous tissue, the muscular coat, and the subserous tissue. The lymphatic vessels pass between the layers of the mesentery, enter the mesenteric glands, and finally unite to form two or three large trunks which terminate separately in the receptaculum chyli; frequently, however, they first unite to form a single large trunk, termed the intestinal lymphatic trunk (Figs. 483 and 509).

The Lymphatic Glands of the Large Intestine.—The lymphatic glands of the large intestine are divided into the colic glands and rectal glands.

The Colic Glands (lymphoglandulae colicae).—The colic glands are subdivided into: 1. The ileo-colic or ileo-caecal glands (Fig. 508), which lie along the course of the ileo-colic artery, one or two of the glands being placed upon the anterior surface of the caecum. The mesoappendix also contains a gland which communicates with glands in the mesocolon, and receives lymph from the appendix and, in the female, from the ovary. 2. Glands in the mesocolon along the right colic artery, which receive lymph from the ascending colon and the hepatic flexure. 3. Glands in the mesocolon along the middle colic artery, which receive lymph from the hepatic flexure and transverse colon. 4. Glands in the mesocolon along the left colic artery, which receive lymph from the descending colon and sigmoid flexure. The vessels from the colic glands pass to the pre-aortic glands.

The Rectal Glands.—The rectal glands lie in the mesorectum; they receive lymph from the anus and rectum and it passes from them to the lumbar and sacral glands.

The Lymphatic Vessels of the Large Intestine.—The lymphatic vessels of the large intestine consist of three sets: those of the caecum, ascending and transverse colon, which, after passing through their proper glands, enter the mesenteric glands; those of the descending colon and sigmoid flexure, which pass to the lumbar
glands, and those of the rectum and anus, which pass to the sacral and superficial inguinal glands.

Lymphatics of the Anus and Rectum.—These vessels take origin from two networks, one from the skin and mucous membrane and the other from the muscular coat. The lymph-vessels from the skin at the anal margin pass to the superficial inguinal glands. Some vessels from the skin of the anus ascend and reach the submucous plexus of the rectum, from which region lymph-vessels pass to the rectal glands, to the glands along the middle hemorrhoidal artery, and along the inferior hemorrhoidal artery, and to a pelvic gland near the origin of the internal pudic artery.¹ The vessels from the anal mucous membrane and from the muscular wall of the rectum penetrate the muscular wall of the rectum with the arteries and reach the rectal glands.

The thoracic lymphatics are divided into the deep lymphatics of the chest wall, the diaphragmatic lymphatics, and the visceral lymphatics.

The Lymphatic Glands of the Thoracic Wall or the Parietal Lymphatics.

The lymphatic glands of the thoracic wall include the internal mammary and intercostal glands.

The Internal Mammary Glands.—The internal mammary, retro-sternal, or sternal glands (lymphoglandulae sternalis) form a chain of five or six glands on each side of the sternum along the course of the corresponding internal mammary artery, and back of the internal intercostal muscles. The glands are separated from the pleura by cellular tissue. The internal mammary glands receive vessels from the diaphragmatic glands, the abdominal muscles above the umbilicus, the anterior

¹ The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
ends of the intercostal spaces, the skin over the sternum, and the mammary gland. The vessels given off by each chain from a single trunk. On the right side this trunk terminates at the junction of the internal jugular and subclavian veins, unites with the subclavian lymph-trunk to form the right lymphatic duct, or empties directly into the subclavian trunk (Fig. 485). On the left side it empties either at the junction of the subclavian and internal jugular veins or into the thoracic duct.

**The Intercostal Glands (lymphoglandulae intercostales)** (Fig. 509).—The intercostal glands are small glands lying in the intercostal spaces along the intercostal arteries. In the posterior end of each space they are constantly found. These are called the posterior glands, and there are one, two, or three in each space. These glands are opposite the neck of the rib or over the articulation of the rib with the vertebra. The pleura is in front of them, and they lie upon the external intercostal muscles. In the middle of the intercostal spaces are inconstant glands which are called lateral glands. They are merely interrupting nodes in the trunks from the intercostal muscles. The intercostal glands receive vessels from the intercostal muscles and pleura. They send vessels back toward the spine, which unite with lymphatics from the back part of the thorax and spinal canal, and which pass down the spine and terminate in the thoracic duct.

**The Diaphragmatic Lymphatics.**—The diaphragmatic lymph-glands are distinct and numerous. These glands are on the convex surface of the Diaphragm and are divided into an anterior, a middle, and a posterior group. They receive vessels from the Diaphragm and liver and send vessels to the internal mammary and posterior mediastinal glands. The lymph-vessels of the Diaphragm take origin from a capillary network contained in the spaces between the muscular and tendinous fasciculi of the Diaphragm. Numerous lymph-vessels descend until they reach the subperitoneal tissues and then ascend. Others immediately ascend to beneath the pleura. The collecting trunks are all on the convex surface of the Diaphragm. The lymphatic vessels of the Diaphragm anastomose with the lymphatic vessels of the pleura and the peritoneum. This subperitoneal network is so extensive that absorption in this region is extremely rapid. Hence, after an abdominal operation, if salt solution has been left in the abdomen, it will be very rapidly absorbed if the foot of the bed is elevated. Influenced by the knowledge that the pelvic peritoneum absorbs comparatively slowly and the peritoneum in the upper abdomen very rapidly, and that septic processes in the upper abdomen are more rapidly fatal than septic processes in the pelvis, Fowler was led to recommend the elevation of the head of the bed after operations for abdominal infections. This posture causes poisonous fluids to gravitate away from the Diaphragm.

**The Visceral Lymphatics.**—The visceral lymphatics include the anterior mediastinal glands, the posterior mediastinal glands, and the peritracheo-bronchial glands.

**The Anterior Mediastinal Glands (lymphoglandulae mediastinales anteriores).**—The anterior mediastinal glands are in the upper portion of the anterior mediastinum, a group of six or seven glands lying above and upon the front of the transverse portion of the arch of the aorta and sending glandular chains toward the neck. On the right side these glands are found between the innominate artery and vein and in front of the vein. On the left side they are in front of and behind the left common carotid and left subclavian arteries. They receive lymph from the heart, pericardium, thymus gland, and anterior mediastinum.

**The Posterior Mediastinal Glands (lymphoglandulae mediastinales posteriores)** (Fig. 509).—The posterior mediastinal glands are behind the pericardium and in front of the oesophagus. Occasionally one or two are placed back of the oesophagus. They receive vessels from the intercostal glands, aortic glands, deep cervical glands, and pleura, and send vessels to the thoracic duct.
The Peritracheo-bronchial Glands.—The peritracheo-bronchial glands are divided by Baréty into four groups. One group is in the angle formed by the junction of the trachea and right bronchus. Another group is in a corresponding situation on the left side. Another group is below the tracheal bifurcation. The glands of the fourth group are about the points of division of the larger bronchi. The peritracheo-bronchial glands receive lymph-vessels from the lung, heart, pericardium, oesophagus, trachea, and thymus.

In infancy these glands present the same appearance as the lymphatic glands in other situations. In early adult life they assume a brownish tinge, and in old age become deep black, because they arrest particles of carbon brought from the bronchi. This change is known as anthracosis, and the darkened glands are usually sclerotic. In fact, in old age these glands often lose all lymphatic characters and become fibrous masses. These glands enlarge from infection,
and when very large may compress the bronchi, the pulmonary artery, etc. They are often the seat of tuberculous deposits.

The Lymphatic Vessels of the Thoracic Wall.—The lymphatic vessels of the thoracic wall include the deep lymphatic vessels, intercostal and internal mammary, which have been described, the cutaneous lymphatics, and the lymphatics of the mammary gland.

The Cutaneous Lymphatics (Fig. 495).—The area drained by these lymphatics is very extensive. It is divided by Poirier, Cunéo, and Delamare into three regions. The anterior region extends from over the middle of the sternum to the anterior axillary line. The trunks pass to the axilla and terminate in the thoracic chain of the axillary glands. From this anterior region some accessory trunks pass above the clavicle and reach the supra-clavicular glands, and trunks may arise to one side of the mid-sternal line and pass to the opposite axilla. From the lateral region the trunks ascend to the thoracic chain of axillary glands. This region is between the anterior and posterior axillary lines. The posterior region is back of the posterior axillary line, and includes the thorax to the mid-line, and the posterior portion of the root of the neck. The trunks from the posterior area empty into the scapular group of axillary glands.

Lymphatics of the Mammary Gland (Figs. 494 and 510).—There are two sets of lymphatics in this gland, the cutaneous or superficial and the glandular or deep.

The Peripheral Cutaneous Lymphatics of the Mammary Gland.—The peripheral cutaneous lymphatics do not arise from the nipple. Their collecting trunks are arranged as are other collecting trunks of the anterior portion of the thorax, and end in the thoracic group of axillary glands of the same side. Trunks arising from the sternal margin of the skin of the breast may run to the glands of the opposite axilla.

The Central Deep Lymphatics of the Mammary Gland.—The central lymphatics form a very extensive network in the nipple and areola, and from this network numerous vessels pass into a plexus beneath the areola, Sappey's subareolar plexus; most of the trunks coming from the gland also enter the subareolar plexus.

The Glandular Lymphatics of the Mammary Gland.—The glandular lymphatics arise from spaces about the lobules and from networks about the milk-duets. We can distinguish a chief lymphatic channel and three accessory channels.

The chief lymphatic channel takes origin from collecting trunks which begin in the spaces about the lobules and in the lymph-capillaries about the milk-duets. These collectors pass toward the nipple and terminate in the subareolar plexus, which plexus also receives the vessels from the areola and nipple. Two large trunks take origin from the subareolar plexus: one from its inner side, the other from its outer side. "The internal trunk runs at first downward and then outward, turning round the inferior border of the subareolar plexus. It is thus directed toward the axilla and runs in the subcutaneous cellular tissue, along the lower border of the Pectoralis major, which it crosses at the level of the third rib to reach the base of the axilla. This collecting trunk constantly receives as afferents one or two fair-sized trunks coming directly from the inferior portion of the mammary gland. The external trunk, which is usually smaller than the preceding, runs directly outward toward the axilla. Before it reaches the latter it is augmented by a vessel coming from the superior part of the gland. At the base of the axilla these two collecting trunks perforate the axillary aponeurosis and terminate in one or two glands, placed on the inner wall of the axilla on the third digitation of the Serratus magnus muscle. These glands (the principal regional glands of the breast) may or may not be covered by the lower part of the Pectoralis major muscle according to the muscular development of the subject (Surgins)."  

1 The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
chain. An interrupting gland is sometimes found in the course of these two trunks, the paramammary gland.

The Accessory Channels from the Mammary Gland.—The accessory channels from the mammary gland, according to Poirier, Cuneo, and Delamare, are three. They call one the accessory axillary channel. It is not constant, and there may be interrupting glands on its collectors. Its collectors come off from the inferior portion of the mammary gland and pass directly to the axillary glands. Another channel is the subclavian channel. Neither is it constant. It comes off from the posterior surface of the mammary gland, pierces the great Pectoral muscle, and ascends between the greater and lesser Pectorals to reach the subclavian glands. There

Fig. 510.—The vessels and lymphatics of the anterior face of the mammary glands. (Sappey.)

are usually interrupting glands along this channel, the retro-pectoral glands. The subclavian channel runs along the superior thoracic artery. They call the third accessory channel the internal mammary channel. The collecting trunks arise from the inner portion of the mammary gland and pass along the vessels sent off from the internal mammary artery to the gland. They pierce the Pectoral and Intercostal muscles and reach the internal mammary glands. This channel is constant and along it there may be interrupting glands.

Lymphatics of the Great Pectoral Muscle.—The lymphatics of the great Pectoral muscle end in the subclavian glands, the thoracic group of axillary glands, and the internal mammary glands.

Surgical Anatomy.—A knowledge of the lymphatics of the breast and of the glands into which the lymphatics drain is of the first importance to a surgeon. Certain surgical deductions from the anatomy of this region are perfectly obvious—viz.: 1. If the skin of the mammary gland is involved in carcinoma, the thoracic group of axillary glands of the same side is involved. If the skin over the sternal margin of the gland is involved, the glands of the opposite axilla may be cancerous, as from this point lymph-vessels rise and pass across the mid-line. If the skin of the sternal margin is involved the prognosis is worse than if it is free, the opposite axilla may be cancerous, and the opposite breast may become diseased. 2. When lymphatic ducts become blocked by cancer cells the lymph backs up, flows backward instead of in its proper direc-
tion, and may cause infection in the most unsuspected situations. For instance, a block in the cutaneous lymphatics of a portion of the breast may lead to infection of the opposite breast and axilla, though, of course, it is not so likely to as is cancer of the skin of the sternal margin. By regurgitation of lymph the head of the humerus or the retro-sternal structures may become diseased in mammary cancer. 3. If the nipple or areola is cancerous, the entire gland is sure to be diseased, as the lymphatic network of this region empties into the subareolar plexus, and most of the trunks coming from the gland also enter this plexus. 4. If the mammary gland is cancerous, all of the axillary glands are regarded as diseased, as the main lymphatic channel from the breast reaches the glands on the inner wall of the axilla upon the third digitation of the Serratus magnus. Furthermore, in many cases an accessory lymph-channel comes off from the lower portion of the mammary gland and passes directly to the axilla. 5. The subclavian glands are to be regarded as diseased, because in a certain proportion of cases (the exact proportion being uncertain) an accessory lymph-channel comes off from the posterior surface of the mammary gland, passes through the great Pectoral muscle and ascends between the greater and lesser Pectorals to reach the subclavian glands. 6. The element which greatly interferes with the cure of mammary carcinoma is the existence of lymph-channels which arise from the inner portion of the mammary gland, pierce the greater Pectoral and Internal intercostal muscles, and reach the internal mammary glands. Mediatinal involvement is apt to be earlier in carcinoma of the inner portion of the breast than in carcinoma of other portions, and the prognosis is particularly bad in cancer of the inner portion of the breast. What is known as the sternal symptom of Snow is bulging of the sternum due to involvement of the thymus gland. 7. The sternal portion of the great Pectoral and the tissue between it and the lesser Pectoral muscle are to be regarded as diseased, because in some cases an accessory lymph-channel from the breast penetrates the greater Pectoral and ascends to the subclavian glands. This trunk has several interrupting or satellite glands, the retro-pectoral glands, in the tissue back of the great Pectoral muscle. 8. When the great Pectoral muscle is diseased, cancer cells soon spread widely through the sternal portion of the muscle, and this entire portion of the muscle becomes cancerous. The clavicular portion does not suffer early, but escapes until the cancer becomes extensive, as it is anatomically distinct from the sternal portion. If the fibres of the great Pectoral are extensively diseased, the thoracic group of axillary glands, the subclavian glands, and possibly the internal mammary glands are involved. 9. The only operation in cancer of the breast which offers any real hope of cure is one which is done early and is radical. 10. It must be done early, because delay permits involvement of the mediastinum, and if the disease has entered the mediastinum operation is hopeless. If the sternum is bulged operation is useless, and nothing short of amputation at the shoulder-joint could be of help if the head of the humerus is enlarged by the disease. Even this radical procedure is of no avail, because the mediastinum is certainly involved if the head of the humerus is diseased. 11. If the lymph-glands above the clavicle are extensively diseased operation is useless, as in such cases the mediastinum is sure to be involved. 12. A radical operation means the removal of the skin of the breast with the nipple and areola, the subcutaneous tissue of this region, the entire breast the sternal portion of the great Pectoral with its fascia, the retro-pectoral glands and tissue, all the contents of the axilla except vessels and nerves, the glands and cellular tissue beneath the anterior margin of the Latissimus dorsi, and the subclavian glands. It is probably always wisest to open above the clavicle as well as below to facilitate the removal of glands. It is seldom necessary to remove the clavicular portion of the greater Pectoral. The lesser Pectoral does not require removal, but it should be taken away, because of the added safety and speed thus obtained in cleaning the great vessels and because its retention does not improve the functional result. The surgeon must remember that the breast is a much larger organ than we used to think, and all of its irregular projections and outlying lobules must be removed (p. 791). Formerly, surgeons did not completely remove the breast, but only got rid of a large portion of it.

The Pulmonary Lymphatics.—The pulmonary lymphatics arise from networks between the lobules, around the bronchi and under the mucous membrane. The collecting trunks are in two sets, superficial and deep: the former are placed beneath the pleura, forming a minute plexus which covers the outer surface of the lung; the latter accompany the blood-vessels and run along the bronchi; they both terminate at the root of the lungs in the tracheo-bronchial glands.

The Pleural Lymphatics.—The lymphatics of the pulmonary pleura pass into the superficial pulmonary trunks; those from the costal pleura enter the intercostal trunks; those from the diaphragmatic pleura enter the diaphragmatic trunks, and those from the mediastinal pleura enter the posterior mediastinal glands.

The Cardiac Lymphatic Vessels.—The cardiac lymphatic vessels consist of two sets, superficial and deep: the former arise in the subpericardial areolar tissue of

1 The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
the surface, and the latter in the subendocardial tissue. From the network of deep lymphatics trunks pass to the superficial lymphatics. The superficial lymphatics follow the course of the coronary vessels. Two trunks are formed: an anterior, which lies in the anterior interventricular furrow, and an inferior, which lies in the inferior interventricular furrow. These two trunks collect the lymph from the ventricles and pass to the base of the heart, where they receive lymph from the auricles. The anterior or left trunk ascends between the left auricle and the pulmonary artery on the posterior surface of the artery, perforates the pericardium, and enters the glands about the tracheal bifurcation. The right, posterior or inferior trunk ascends between the aorta and pulmonary artery and terminates in the same group of glands as the left trunk.

**The Thymic Lymphatic Vessels.**—The thymic lymphatic vessels arise from the under surface of the thymus gland, and enter the anterior mediastinal, the internal mammary, and the peritracheo-bronchial glands.

**The Lymphatic Vessels of the Öesophagus.**—The lymphatics of the thoracic oesophagus arise from two networks, one beneath the mucous membrane and one beneath the muscular fasciculi. The connecting trunks terminate in the peri-oesophageal glands.

**The Lymphatic Vessels of the Thoracic Trachea.**—The lymphatics of the thoracic trachea take origin from a network in the submucous tissue. From this a number of collecting trunks pass through the trachea in the line of junction of the cartilaginous with the membranous portion. They terminate the peritracheo-bronchial glands.
THE NERVE SYSTEM.

THE SPINAL CORD AND BRAIN, WITH THEIR MENINGES.

REVISED AND LARGELY REWRITTEN, WITH NEW ILLUSTRATIONS.

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The nerve system of man is an apparatus by means of which he appreciates and becomes influenced by impressions from the outer world, reacts on these impressions, and hence is enabled to adapt himself to his environment. It is the organic substratum for those manifestations of nerve force engaged in the characteristic attributes of animal life—sensation and motion. Broadly stated, the nerve system connects the various parts of the body with each other and coordinates them into one harmonious whole in order to carry on the bodily functions methodically and to control the physiological division of labor throughout the organism. With the evolution of the higher forms of animal life through an immense phylogenetic past the nerve system has undergone remarkable differentiation and specialization, attaining its maximum as to dominant position and complexity of structure in the human species.

The description of the nerve system is assisted by the accommodation of physiological data to the anatomical basis in order to demonstrate more clearly and to render more practical our knowledge of the mutual relations of its structure and function. The cycle of events which accompanies nerve action is determined by impressions received by the peripheral end-organs, apperception and reflexes of these impressions in the lower nerve-centres, correlation of these with other impressions in higher centres, as well as voluntary reactions or inhibitions, liberated in compliance with the organic or higher needs of the individual.

Conventionally, the nerve system is usually considered as consisting of (1) the cerebro-spinal system, comprising (a) the central nerve-axis (brain and spinal cord) and (b) the peripheral nerves (cranial and spinal), and (2) the sympathetic nerve system. This subdivision, like others formulated by various authors, is an arbitrary one. No part of the system stands isolated, and the manifold groupings and chainings of the units of the system intimately connect the central nerve organs with the peripheral nerve-endings, the organs of special sense and the vegetative organs. The distinction between the central and the sympathetic systems has been too absolute, and the only justification for adhering to the classification given above is based upon the fact that the sympathetic system is preponderantly related to the interconnection and coördination of the nutritive (digestive, pulmonary, and vascular) apparatus, and, therefore, exercises a special control over its activities.
Structurally considered, the nerve system consists of cell-elements peculiarly differentiated from all other tissue cells in that their protoplasm is extended, often to great distances from the nuclear region, in the form of processes. The cell-elements are held in place by supporting tissues, partly of ectodermal and partly of mesodermal origin, and receive an abundant blood-supply.

The cell-element of the nerve system is called the neurone. The neurone is the developmental, structural, and functional unit of the nerve system. It is in reality a single cell presenting unusual structural modifications. It comprises not only the nerve cell-body with its numerous protoplasmic processes or dendrites, but also the axone, which may vary in length from a fraction of a millimetre to fully half a man's stature; so that, despite the delicacy of the axone; its bulk may be almost two hundred times greater than that of the cell-body from which it proceeds. The long axones serve to make a connection with a peripheral or distant nerve-cell, muscle-cell, or gland-cell, while the shorter axones of certain neurones divide into terminal branches in the immediate vicinity of its cell-body, presumably to come into relation with other nerve-cells in the same or adjacent groups.

Neurones, being devoted to the maintenance of functions manifested by various phenomena of nerve-force, are differentiated in their polarity, both structurally and dynamically. Receptive neurones are so arranged as to receive afferent nerve-impulses from other tissues; emissive or excitatory neurones give out efferent nerve-impulses. The former are generally termed sensor neurones, the latter motor (excito-motor) neurones if connected with muscle, excito-glandular if connected with gland-cells. Were the nerve system made up solely of such initial and terminal neurones the apparatus would be merely a system of reflex arcs. Such it is in low forms of animal life which, by their very organization, and because of the close juxtaposition of their sensory and motor elements, are compelled to react to stimuli from without. In higher forms, with more profoundly differentiated nerve systems, the sensory impression must pass through an interposed medium which is capable of either transmitting the molecular change in the form of an excito-motor impulse or, on the other hand, is capable of reducing or checking the impulse. In other words, reaction is not imperative; there is a freedom of choice exercised by intermediate neurones endowed with inhibitory function. The simple arc, composed of an afferent sensory neurone and an efferent motor neurone, would act independently of all other arcs were it not for the interposition of this intermediate neurone and of other association neurones which, by their relations toward similar arc-elements, produce harmony of action. The basis, then, of the nerve system is a series of neurones, with projecting and association processes, coordinated for the purpose of performing specific actions manifested either by motion, by trophic changes, or by the apperception of stimuli of a chemical, mechanical (tactile and auditory), thermal, or photic nature. When we consider the profoundly complex manifestations of nerve-phenomena in the mental and physical life of man it is not surprising to learn that his nerve system is made up of an immense multitude of aggregations of neurones.

**Fundamental Facts Regarding the Development of the Nerve System.**

The nerve system is formed by a remarkable metamorphosis of the ectodermic layer of the developing ovum. Along the mid-dorsal line of the embryonic mass a thickening of the ectoderm forms a well-defined layer of cells, the neural plate. The proliferative process passes rapidly from the cephalic toward the caudal end, and as development advances it is seen that the most intense growth-energy takes place at the cephalic end, indicative of the higher functional potentiality of what is to become the brain. The neural plate undergoes a trough-like formation as its edges become elevated cephalad and laterally to form the neural groove (Fig. 511). The edges become more and more elevated and bend toward
the median line until the margins of the groove coalesce to form a tube, the neural tube, which sinks into the subjacent mesodermal tissues. The fusion of the margins of the neural plate occurs first in the cervical region and rapidly continues both cephalad and caudad. The cephalic portion, destined to become the brain, expands and grows considerably, while the caudal portion is chiefly elongated to form the spinal cord.

Eventually the neural tube, as it sinks into the subjacent mesodermal tissues, severs all connection with the ectoderm from which it developed; but for a brief period the continuity is preserved in an attenuated septal mass, the neural crest (Fig. 511). The cell-elements of this crest subsequently become detached from the superficial ectoderm, the continuity of which is again restored to form the integu-

![Fig. 511.—Diagrams showing development of neural tube and crest.](image)

They pass ventrad to either side of the neural tube, proliferate by mitosis, and accumulate in paired masses, corresponding in number to the segments of the body, to become, in part at least, the cerebro-spinal ganglion cells of the afferent system, while other similarly paired masses migrate farther ventrad to a pre-vertebral position to form the gangliated cord and widely spread plexuses of the sympathetic system. From the tissues of the wall of the neural tube and its tem-
porary crest the entire nerve system of complex and intricate structure is developed. The cavity of the tube shares in the developmental growth-changes to become the ventricular system of the brain and central canal of the spinal cord. The major details of the development of the principal divisions will be considered in appropriate chapters.

**Development of Nerve-tissue.** 1. In the Wall of the Neural Tube.—The single layer of nucleated epithelial cells of ectodermal origin which makes up the wall of the neural tube early becomes modified into a layer of tall columnar cells called spongioblasts (Fig. 513). Their protoplasmic ends undergo differentiation in that the central ends become elongated and attenuated or collapsed to form a series of striated pillars with intervening spaces. The free ends retain their breadth, however, and form an internal limiting membrane. The ectal ends undergo differentiation to form a spongy felt-work or reticulum (*peripheral veil of His*); eventually these spongioblasts become (*a*) ciliated endymal cells and (*b*) neuroglia.

In the intercellular spaces of the central zone there appear spherical cells of different structure and destiny. These are the *germinal cells*, seen in very early stages and proliferating rapidly by karyokinesis. They soon lose their spherical form, becoming pear-shaped as a protoplasmic process extends ectad. These pear-shaped cells are now termed *neuroblasts* (Fig. 513), the protons of the neurones, and as development advances they leave the central zone and migrate into the marginal reticulum to the positions in which they are found in the gray substance of the brain and spinal cord. The protoplasmic process is at first slightly bulbous and elongates to form the axone extending toward other nerve-cells or to the peripheral tissue-elements with which they become associated by the contiguity of the terminal arborizations into which the bulbous extremity develops. The precision with which the axones travel toward their allotted goal is one of the most remarkable manifestations of organic development. An American experimenter, Ross G. Harrison, has devised a method for directly observing the living,
growing nerve. In isolated pieces of frog embryos the differentiation of the living nerve-elements could be observed from day to day during several weeks. The bulbous end of the outflowing protoplasmic fibre, showing a faint fibrillation, was seen to reveal a continuous change of form particularly in a number of fine simple and branched filaments which were in constant amoeboid movement. Harrison's demonstration\(^1\) is of great significance in connection with the "retraction theory" and other ideas related to the neurone doctrine.

2. In the Neural-crest Tissues.—The nerve-tissue elements of the sympathetic system and of the ganglia of the cranial nerves and dorsal roots of the spinal nerves are derived from the neural crest. Omitting, for the present, the development of the sympathetic system, it is found that the cells of the paired masses which eventually become the cerebro-spinal ganglia are at first somewhat spherical, then oval in form, sending out from either extremity or pole a protoplasmic process. One process migrates centrad, the other toward the tissues of the periphery. The central process penetrates the tissues of the neural tube and, assuming the typical form of an axone with its collaterals and end arborizations, comes into contiguous association with certain cells of the central axis. The peripheral process is in reality an unusually long dendrite, for it is centripetal in function; but owing to the fact that it is usually provided with a myelin sheath it is also termed the peripheral axone of an afferent (or sensor) neurone. The central processes of the cells of a single spinal nerve-ganglion form the dorsal nerve-roots; the peripheral processes constitute the afferent portion of a spinal nerve. The cells themselves are transformed from bipolar into apparently unipolar cells by the migration of the cell-body to one side and the consequent approximation of the two processes to form a common pedicle in a T-shaped manner (Fig. 533).

Structure of the Nerve System.—The whole of the nerve system is composed of nerve-tissue and supporting connective tissue. The neurones constitute the nerve-tissue, while the supportive tissue is composed of the neuroglia and of white fibrous tissue derived either from the investing membrane or from the sheaths of its numerous vascular channels.

\(^1\) American Journal of Anatomy, June 1, 1907, vii, 1. (Anatomical Record, p. 116.)
The Neurone.—The neurone or nerve cell-element, whose individuality has already been pointed out, exhibits remarkable variations as to external characters, dimensions, and form. The neurone presents a concentrated or swollen cell-mass and nucleus, formerly known as the nerve-cell (ganglion-cell) and still retaining the name. From this cell-body are given off a number of processes of two distinct kinds: (1) protoplasmic processes which are commonly branched and generally called the dendrites; (2) a single, thinner, and paler process, the axone (axis-cylinder process; Deiters' process; neuraxone; neurite).

Varied Forms of Neurones.—Bearing in mind that each neurone includes not only the cell-body and its dendritic processes, but also the axone or axis-cylinder process with all its ramifications, we may consider each of these divisions under separate heads.

1. Nerve Cell-body. External Morphology.—The bodies of nerve-cells vary much in size, measuring from 4 to 135 microns or more in diameter. The largest cells are found in the ventral horns of the spinal cord, in the spinal ganglia, in the large pyramidal cell-layer of the cerebral cortex, in the Purkinjean cell-layer of the cerebellum, and in the column of Clarke (dorsal nucleus) of the spinal cord. Very small cells are found in the olfactory bulbs, in the granular layers of the cerebral and the cerebellar cortex, and in the gliosum cornualis of the cord.

Although all nerve-cells begin in the embryonic ectoderm as spherical germinal cells, they later assume, in different regions, very different shapes. These external morphological relations have been best revealed by the methods of Ehrlich and Golgi. According to the number of processes arising from the cell-body, neurones are referred to as (1) unipolar, (2) bipolar, and (3) multipolar nerve-cells.

(1) Unipolar cells are met with frequently in early stages of embryonic development, but are rare in the adult, being found only in the retina, olfactory bulb, and within the baskets of the Purkinjean cells of the cerebellum.

(2) Bipolar cells are found almost exclusively in the peripheral sensor systems, as in the olfactory membrane, in the retina, in the cochlear and vestibular ganglia, and in the cerebro-spinal ganglia of the embryo.

(3) Multipolar cells are the most numerous and form the principal elements of nerve-centres throughout the system. They are termed multipolar because of the Purkinjean cells of the cerebellum. The cells of the cerebro-spinal ganglia (excepting the cochlear and vestibular) are apparently unipolar, but they are developmentally and functionally of bipolar nature.
of the greater or lesser number of dendrites given off in addition to the single axone.\footnote{Exceptionally, more than one axone has been observed arising from a single cell, as in the Cajal cells of the cerebral cortex.}

The terms "unipolar" and "multipolar" must be restricted to the morphological sense; dynamically all nerve-cells are bipolar.

According to the relations of the axone we distinguish, after Golgi, two kinds of neurones.

I. Neurones with long axones which become the axis-cylinder of a central or peripheral nerve-fibre. The axones give off several collaterals which, like the parent stem, break into finely branched terminals or telodendria.

II. Neurones with relatively short axones which do not go into the formation of a nerve-fibre, but break up into terminal twigs in the vicinity of the cell-bodies from which they arise.

Type II is generally termed, for brevity's sake, the \textit{Golgi cell}.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig516.png}
\caption{Purkinjean cell from human cerebellum. \textit{a}, axone; \textit{clt}, collaterals. (Golgi method.)}
\end{figure}

According to the morphological relations of the dendrites, neurones are classified as follows:

\begin{enumerate}[leftmargin=*, label=(\alph*)]
\item \textbf{Stellate cells}, the dendrites of which spring at intervals from the whole circumference of the cell-body and pass toward all directions (motor cells in ventral horn and tract-cells of the cord).
\item Cells with one principal stout dendrite (among other lesser dendrites) which gives off side branches and ends in fine terminal twigs (pyramidal cells of cerebral cortex; mitral cells of olfactory bulb).
\item \textbf{Arboriform cells}, giving off branched dendrites from both base and apex, resembling the roots and the branches of a tree; the axone often springs from the base of one of the root-like dendrites (pyramidal cells of the hippocampus).
\item Cells with \textbf{monopolar dendrites}. Several main dendritic stems spring from one pole of the cell and, undergoing frequent subdivision, break up into a fine terminal arborization. The axone springs from the opposite pole (Purkinjean cells of the cerebellum; granular cells of the fasciola).
\end{enumerate}
2. Nerve Cell-body. Internal Morphology.—The nucleus of the nerve-cell differs in no essential from the typical nuclear structure. Regarding the organization of the cytoplasm several conflicting views exist. In the present state of our knowledge concerning this still obscure field of investigation it may be said that the nerve-cell protoplasm is roughly divided into a peripheral exoplasmic portion and a central endoplasmic portion. There is shown throughout the cytoplasm a tendency to fibrillary structure, more pronounced in the exoplasmic portion. Within the meshes of a more or less homogeneous ground-substance, which pervades the whole, are deposited larger and smaller masses of a granular substance. Nerve-cells fixed and stained by the methods of Nissl and Held show that the granule-masses are "stainable" (chromatophiles; tigroid bodies; Nissl bodies), probably of the nature of a nucleo-proteid (MacCallum) and looked upon as a sort of nutritive reserve. Many of the larger cells possess more or less pigmented material, adjacent to the nucleus. The cells of the intercalatum (substantia nigra) and of the locus ceruleus contain an abundance of such pigment-granules.

The "unstainable" homogeneous ground-substance of the cytoplasm is probably the more important functionally, for numerous delicate neuro-fibrils have, by special methods, been shown to traverse the cell-body and its processes, crossing and interlacing, perhaps anastomosing with each other, and traceable into the axone.\(^1\) Nissl, after years of painstaking investigation has classified nerve-cells into a great many different species in accordance with their reaction to staining agents.

The Dendrites.—The dendrites are usually numerous attenuated processes resembling in structure and staining reactions the cytoplasm and, being extensions thereof, represent an increase in the surface of the cell-body. Emerging by a broad base they become narrower as they divide into many branches in a dichotomous or arborescent manner to end free, according to most observers, or to be joined with the dendrites of other neurones by means of minute fibrille (as claimed by Apathy) or by concrescence (Held). The contour of the dendrite is usually irregular in some specimens, revealing varicosities along its course; in others, and more constantly, being seen to be beset with numerous lateral buds called

\(^1\) That the neuro-fibrils form such an intracellular network and that the axones arise therefrom is disputed by Ramon y Cajal, Bielschowsky, and others.
gemmules. Various hypotheses have been advanced in explanation of these appearances, it being held by some investigators that they are related to conditions of activity as contrasted to those of repose, while others believe them to be artifacts produced by the fixing and staining methods at present employed. However, it is no longer disputed that the function of the dendrites is receptive and conductive (or celluli-petal) for nerve-impulses, although they probably serve the nutritional requirements of the cell-body as well.

This functional distinction gives the clue to the correct interpretation of the central and peripheral prolongations of the cerebro-spinal ganglionic neurones. The cells of these ganglia are at first bipolar in form, but gradually undergo transformation into apparently unipolar cells by the migration of the cell-body to one side and the consequent approximation of the two processes to form a common pedicle in a T-shaped manner so typical of the spinal ganglion cell of the adult. The central branch invariably remains cellulifugal, the peripheral branch invariably remains celluli-petal, and as such is equivalent to the dendrites of all other neurones. It is merely a modified dendrite in that it courses a longer distance without branching until it reaches the periphery and is usually myelinic. Such a peripheral prolongation of the ganglion cell is also termed a centripetal nerve-fibre or medullated (myelinic) peripheral axone of a peripheral centripetal neurone.

The Axone.—The axone is usually much longer than any of the dendrites, thin, pale, smooth, emerging from the nerve-cell as a direct continuation of the neuro-fibrillar ground-substance of the cell-body, and devoid, so far as at present known, of chromatophile granules. Its calibre varies for the different cells, corresponding in general to the length of its course, but it is practically of uniform diameter throughout its extent. Axones may be extremely short or fully a metre in length. Most cells give rise to only one axone (monaxonic neurones), but in certain localities diaxonic (two axones) and polyaxonic (several axones) neurones are found. In a Golgi preparation axones stand out like pieces of black thread, taking a more direct course than do the irregular dendrites, and rarely branching before reaching the ultimate termination, although giving off collaterals along their course. The central axones of spinal ganglion (sensor) neurones are the principal exception to this rule in that they bifurcate in a Y-shaped manner after their entrance into the central nervous axis. In the case of another group of neurones, Golgi's Cell, Type II, the axone is observed to break up into numerous branches soon after its departure from the cell; such axones are called dendraxones. The axones and their collaterals end in terminal arborizations, the telodendria.

The axone is the distributive or emissive (cellulifugal) conductor of nerve-impulses. There is, therefore, a functional opposition attributable to the two extremities of the neurone, based upon its dynamic polarity and upon a physiological principle which is established by all experiments to which the nerve system is submitted; namely, that nerve-impulses pass through the neurone in a definite direction which is invariably and admitting of anatomical localization.

The majority of the peripheral spinal and cerebral axones as well as those constituting the white matter of the brain and cord are invested by a myelinic sheath.

The Collaterals (paraxones; cylindro-dendrites; side fibrils).—The collaterals are accessory branchings of the axones which are more numerous in the cytoproximal portion and are usually directed at right angles to the parent stem. Some axones possess few or no collaterals, while others possess many. The collaterals, especially those in the gray substance of the central axis, are frequently myelinic. They unquestionably play an important part in the grouping and chaining of neurones within the system, in yielding up to neighboring neurones a portion of the impulse that the cell has received by its dendrites and transmits along its axone to a distance.

STRUCTURE OF THE NERVE SYSTEM
Varieties of Axones.—Axones are divided into two main groups depending upon the presence or absence of a myelin sheath—myelinic axones and amyelinic axones, or medullated and non-medullated axones.

Myelinic axones or medullated axis-cylinder processes are axones enveloped by a relatively thick sheath composed of semifluid phosphorized fat which gives to the bundles of these structures their opaque, white appearance. The myelin sheath is in turn invested by a delicate membrane (neurilemma) in one group, while another group is devoid of such covering, giving rise to the further subdivision into (a) myelinic axones with a neurilemma; (b) myelinic axones without a neurilemma.

Myelinic axones with a neurilemma constitute the bulk of the cerebro-spinal nerves and, in lesser proportion, of the sympathetic nerves. The myelin sheath (medullary sheath of Schwann) does not invest the axone throughout its course nor in a uniform manner. The axone after its emergence from the cell-body and likewise in its preterminal portion is naked; and the delicate external membrane or neurilemma comes in contact with the axone. The myelin sheath consists of a number of tubular segments demarcated by nodal intersections which are only 0.08 mm. apart in the very small myelinic axones, while for larger axones the intervals may be 1 mm. or more. At the internodes (nodes or constrictions of Ranvier) the neurilemma dips into the constriction to come in contact with the axone, and any branches of the axone are invariably given off at such points. The interruptions in the continuity of the myelin sheath have been assumed to be provisions facilitating nutritive diffusion between the axone and the surrounding lymph. Each internodal myelinic segment is further characterized by oblique clefts, irregularly distributed—the incisures of Schmidt-Lautermann—seen only in fixed specimens and probably artifacts. Extraction of the fatty substance of the myelin sheath by boiling alcohol and ether brings out a fine network which

Fig. 519.—A, myelinic axones in fresh state, showing a few internodes; B, portion of a myelinic axone treated with boiling ether and alcohol to remove the myelin and leaving the neurokeratin network; a, axone.
resists trypsin digestion, and termed neurokeratin on account of its resemblance to the keratin of epidermal structures.

The neurilemma (primitive sheath of Schwann; neurolemma), a delicate structureless membrane, encloses the myelin and the axone, wherever the myelin sheath is wanting. Against the inner surface of the neurilemma, and embedded as it were in the myelin, usually midway between two nodes, lies the oval-shaped nucleus of the neurilemma.

Myelinic axones are usually from 4 to 10 microns in diameter; the extremes range from 2 to 20 microns.

Myelinic axones without a neurilemma constitute the white substance of the brain and spinal cord as well as the optic nerves. They differ from the axones just described in two particulars: the neurilemma is absent and there are no internodes interrupting the continuity of the myelin sheath. A network of neuroglia replaces the neurilemma as a supporting tissue.

Amyelinic axones with a neurilemma (Remak's fibres; sympathetic nerve-fibres) constitute the majority of the sympathetic axones and the axones of the olfactory nerves. The myelin sheath is absent and the axone is invested, more or less completely, by a nucleated cellular sheath or neurilemma.

Amyelinic axones without a neurilemma are naked axones, most numerous in the central ganglia. Most axones of longer course are devoid of any sheath in the cytoproximal and preterminal portions, whatever investment they may receive in the intermediate portion.

"NERVE-FIBRES" AND NERVES.

Prior to the general adoption of the neurone concept it was customary to designate the conducting elements of the nerve system by the term nerve-fibres in distinction from the nerve-cells. As has been pointed out above, the distinction no longer holds, but the designation "nerve-fibre" is still retained in anatomical vocabulary and recurs so frequently in common parlance that, even with the new conception which has been formed of the architecture of the nerve system, the term cannot yet be discarded in favor of "axone," although it probably will eventually.

Nerves are round or flattened bundles of axones which serve to bring the central axis into relation with the periphery and other tissues of the body. The nerves of the body are subdivided into two great classes—the cerebro-spinal, which are
attached to the cerebro-spinal axis, and the sympathetic or ganglionic nerves, which are attached to the ganglia of the sympathetic. The cerebro-spinal nerves consist of numerous nerve-fibres (myelinic axones) collected together into small or large bundles or fasciculi and enclosed in a membranous sheath.

In structure the common membranous investment, or sheath of the whole nerve, which is called the epineurium, as well as the septa given off from it, and which separate the fasciculi, consists of connective tissue, composed of white and yellow elastic fibres, the latter existing in great abundance. The tubular sheath of the smaller fasciculi composing the nerve-trunk, called the perineurium, consists of a fine, smooth, transparent membrane, which may be easily separated, in the form of a tube, from the fibres it encloses; in structure it consists of connective tissue which has a distinctly lamellar arrangement, being composed of several lamellae, separated from each other by spaces containing lymph. The nerve-fibres are held together and supported within the fasciculus by delicate connective tissue called the endoneurium (sheath of Henle). It is continuous with septa which pass inward from the innermost layer of the perineurium, and consists of a ground-substance in which are embedded fine bundles of fibrous connective tissue which run for the most part longitudinally. It serves to support the capillary vessels, which are arranged so as to form a network with elongated meshes. The cerebro-spinal nerves consist almost exclusively of myelinic axones, the myelinic axones existing in very small proportions.

The blood-vessels supplying a nerve terminate in a minute capillary plexus, the vessels composing which pierce the perineurium and run, for the most part, parallel with the fibres; they are connected together by short, transverse vessels, forming narrow, oblong meshes, similar to the capillary system of muscle. Fine myelinic axones accompanying these capillary vessels, the vasomotor fibres, and break up into elementary fibrils, which form a network around the vessel. Horsley has also demonstrated certain myelinic fibres as running in the epineurium and terminating in small bulboid tactile corpuscles or end-bulbs of Krause. These nerve-fibres, believed to be sensor, and termed nervi nervorum, are considered to have an important bearing upon certain neuralgic pains.

Nerves, in their course, subdivide into branches, and these frequently communicate with branches of a neighboring nerve.

The axones, as far as is at present known, do not coalesce, but pursue an uninterrupted course from the centre to the periphery. In separating a nerve, however, into its component fasciculi, it may be seen that they do not pursue a perfectly insulated course, but occasionally join at a very acute angle with other fasciculi proceeding in the same direction; from this branches are given off, to join again in like manner with other fasciculi. It must be distinctly understood, however, that in these communications the axones do not coalesce, but merely pass into the sheath of the adjacent nerve, become intermixed with its axones, and again pass on, to become blended with the axones in some adjoining fasciculus.

The communications which take place between two or more nerves form what is called a plexus. Sometimes a plexus is formed by the primary branches of the trunks of the nerves—as the cervical, brachial, lumbar, and sacral plexuses—and occasionally by the terminal fasciculi, as in the plexuses formed at the periphery of the body. In the formation of a plexus the component nerves divide, then join, and again subdivide in such a complex manner that the individual fasciculi become interlaced most intricately; so that each branch leaving a plexus may contain filaments from each of the primary nerve-trunks which form it. In the formation also of smaller plexuses at the periphery of the body there is a free interchange of the fasciculi and primitive fibres. In each case, however, the individual filaments or axones remain separate and distinct, and do not inosculate with one another.
It is probable that through this interchange of fibres the different branches passing off from a plexus have a more extensive connection with the spinal cord than if they each had proceeded to be distributed without such connection with other nerves. Consequently the parts supplied by these nerves have more extended relations with the nerve-centres; by this means, also, groups of muscles may be associated for combined action, as is best exemplified in the formation of the limb-plexuses.

The sympathetic nerves are constructed in the same manner as the cerebro-spinal nerves, but consist mainly of myelinic axones, collected into fasciculi and enclosed in a sheath of connective tissue. There is, however, in these nerves a certain admixture of myelinic axones, and the amount varies in different nerves, and may be known by their color. Those branches of the sympathetic which present a well-marked reddish-gray color are composed more especially of myelinic axones, intermixed with a few myelinic axones; while those of a white color contain more of the latter and a few of the former. Occasionally, the gray and white cords run together in a single nerve, without any intermixture, as in the branches of communication between the sympathetic ganglia and the spinal nerves, or in the communicating cords between the ganglia.

The nerves, both of the cerebro-spinal and sympathetic systems, convey impressions of a twofold kind. The afferent or centripetal nerves, generally called sensor, transmit to the nerve-centres impressions made upon the peripheral ends of their components, to produce reflexes in the lower centres while the mind, through the medium of the brain, becomes conscious of environmental conditions or changes. The efferent or centrifugal (in large part "motor") nerves transmit impulses from the centres to the parts to which the nerves are distributed; these impulses either excite muscular contraction or influence the processes of nutrition, growth, and secretion.

The Ganglia may be regarded as separate small aggregations of nerve-cells, connected with each other, with the cerebro-spinal axis, and with the nerves in various situations. They are found on the dorsal root of each of the spinal nerves; on the sensor root of the trigeminus; on the facial and auditory nerves; and on the glosso-pharyngeal and vagus nerves. They are also found in a connected series along each side of the vertebral column, forming the gangliated cord or trunk of the sympathetic; and on the branches of that nerve, generally in the plexuses or at the point of junction of two or more nerves with each other or with branches of the cerebro-spinal system. On section they are seen to consist of a reddish-gray substance, traversed by numerous white nerve-fibres; they vary considerably in form and size; the largest are found on the sensor root of the trigeminus and in the cavity of the abdomen; the smallest, not visible to the naked eye, exist in considerable numbers upon the nerves distributed to the different viscera. The ganglia are invested by a smooth and firm, closely adhering membranous envelope, consisting of dense areolar tissue; this sheath is continuous with the perineurium of the nerves, and sends numerous processes into the interior of the ganglion, which support the blood-vessels supplying its substance.

Origin and Termination of Nerves.—To the central and the peripheral ending of a nerve are usually given the names of "origin" and "termination." These designations have been rendered inappropriate, in many cases, by the newer concept of neuronic arrangement. They have not yet become obsolete, however, particularly in dissecting-room anatomy, and warrant description here with a certain degree of reserve alluded to above.

Origin.—The origin in some cases is single—that is to say, the whole nerve emerges from the nerve-centre by a single root; in other instances the nerve arises by two or more roots, which come off from different parts of the nerve-centre, sometimes widely apart from each other; and it often happens, when a
nerve arises in this way by two roots, that the functions of these two roots are

different; as, for example, in the spinal nerves, each of which arises by two
roots, the ventral of which is motor and the dorsal sensor. The point where
the nerve-root or roots emerge from the nerve-centre is named the superficial or
apparent origin, but the axones of which the nerve consists can be traced for
a certain distance into the nerve-centre to some portion of the gray substance,
which constitutes the deep or real origin of the nerve.

The manner in which these fibres arise at their deep origin varies with their
functions. The centrifugal or efferent nerve-fibres originate in the nerve-cells
of the gray substance, the axones of these cells being prolonged to form the fibres.
In the case of the centripetal or afferent nerves the axones grow inward either from
nerve-cells in the organs of special sense (e.g., the retina) or from nerve-cells
in the ganglia. Having entered the nerve-centre, they branch and send their
ultimate twigs among the cells, without, however, uniting with them.

![Diagrams of motor nerve-endings](image)

**Fig. 521.**—Diagrams of motor nerve-endings in A, striated muscle; B, cardiac muscle; C, unstriated muscle
a, axone; t, telodendria. (After Huber, Böhm and Davidoff, and others.)

**Termination.**—Axones terminate peripherally in various ways and may be most
conveniently studied in the efferent and afferent systems respectively. The
so-called peripheral terminations of afferent neurones are better called peripheral
nerve-beginnings, on account of their functional relations; the impulse is excited
in the peripheral end and conducted centrad through the rest of the neurone.

**Modes of Termination of Axones.**—The ultimate terminals of the axones and their
collaterals are called telodendrions (or telodendria). As far as can be determined
by present methods they invariably end “free,” commonly by exhaustion through
multiple division. This manifold branching presumably puts the neurone in a
condition to influence the processes of many other neurones (“avalanche conduc-
tion” of Ramón y Cajal). In some localities the formation by axonic terminals
of pericellular and peridendritic networks has been observed. Upon muscle-
fibres the axone terminals form chains of flattened disks, the motor end-plates.
Among gland-cells the terminal fibrils form more or less intricate plexuses.

**Peripheral Nerve-beginnings of Centripetal Neurones.**—Nerve-beginnings of the
centripetal (sensor) fibres are found in nearly all the tissues of the body. They
are peculiarly differentiated and of various forms in different localities and their function is apparently the conversion of mechanical, thermal, chemical, and other stimuli into nerve-impulses. The organs of vision, hearing, smell, and taste possess variously modified nerve-beginnings which are described under appropriate titles in the chapter on the Organs of Special Sense. The end-organs of the centripetal neurones collecting bodily impressions (tactile sense, muscular sense) and connected with the central axis are often very complicated structures. The principal varieties are:

Terminal fibrillae.
Tactile corpuscles (Meissner’s).
“Ruffini’s endings.”

I. Lamellated corpuscles (Pacini’s).
   Bulboid corpuscles (Krause’s).
   Genital (nerve) corpuscles.
   Articular (nerve) corpuscles.

II. Neuro-muscular spindles (Ruffini).
    Neuro-tendinous spindles (Golgi).

Fig. 522.—Showing some varieties of peripheral terminations of afferent neurones (or "peripheral nerve beginnings"): A, terminal fibrille in epithelium (after Retzius); B, tactile corpuscle (Meissner’s, after Dogiel); C, bulboid corpuscle (Krause’s, after Dogiel); D, lamellated corpuscle (Pacini’s, after Dogiel, Sala, and others); E, genital nerve corpuscle from human glans penis (after Dogiel); a, axone; t, telodendria.
**Terminal Fibrillae** are best demonstrable in the epithelium of the skin, mucous membranes, and cornea. The axone is seen to break up into its constituent fibrillae, which often present regular varicosities and Anastomose with each other in a plexiform manner.

**Tactile Corpuscles** (*corpuscula tactus; touch corpuscles of Meissner and Wagner*) consist of elongated oval lobules of delicate epithelioid tissue invaded by one or more axones which divide into their primitive fibrils, each terminal branch ending free usually as a somewhat flattened, disk-like plate in among the wedge-shaped cells of the corpuscle. Tactile corpuscles occur in large numbers in the cutaneous papillae of the finger-tips, in the conjunctiva, and, less abundantly, in the rest of the skin; they appear to be concerned with the finer tactile sensations.

Ruffini has described a special variety of sensor nerve-beginning in the subcutaneous tissue of the human finger (Fig. 523). They are principally situated at the junction of the corium with the subcutaneous tissue; they are of oval shape, and consist of a strong connective-tissue sheath within which the axone divides into numerous varicose fibrils ending in small, free knobs.

**Lamellated Corpuscles** (*corpuscula lamellosa; Pacinian corpuscles; Vater's corpuscles; Herbst's corpuscles*) are among the largest of the tactile end-organs and are found chiefly in the palmar surface of the hand, the sole of the foot, the genital organs, the serous membranes, and many other structures. Each corpuscle

![Diagram of a nerve-ending of Ruffini.](After A. Ruffini, Arch. Ital. de Biol., Turin, 1894, t. xxI.)

consists of a number of capsular connective-tissue lamellae arranged more or less concentrically around a central granular protoplasmic core, pierced by a single axone which usually divides into two or more branches giving off collaterals of beaded appearance and terminating in rounded knobs.

**Bulboid Corpuscles** (*corpuscula bulboidea; Krause's end-bulbs*) are minute cylindrical or oval bodies, consisting of a capsule continuous with the perineurium enclosing a core (inner bulb) of semifluid, finely granular protoplasm in which an axone runs out to end quite free at the distal end, usually terminates in a bulbous extremity, or, as is frequently observed, the axone divides into a number of branches of which each one terminates in an end-bulb.

The *genital corpuscles* (*corpuscula nervorum genitalia*) and the *articular corpuscles* (*corpuscula nervorum articularia*) very much resemble the bulboid corpuscles just described.

The genital corpuscles form aggregations of from two to six knob-like masses in the penis and clitoris. The articular corpuscles are found in the synovial membranes of the joints.

**Neuro-muscular Spindles** (*muscle-spindle of Kühne*).—These are found in nearly all the skeletal muscles and are most numerous in the extrinsic muscles of the tongue, in the small muscles of the hand and foot, and in the intercostal muscles. Most elaborate investigations upon these spindles have been conducted recently by Ruffini in Italy, Sihler, Huber, and De Witt in America. Neuro-muscular
spindles are usually found in the fibrous septa of the perimysium and consist of the flattened nerve-fibrils of centripetal axones arranged in one or all of three ways: (1) annular, where the fibrils surround the muscle-fibres in rings; (2) spiral, and (3) dendritic or branched (Fig. 524). They are doubtlessly concerned with the so-called muscle-sense.

**Neuro-tendinous Spindles (Organ of Golgi).**—The nerves conveying sensory impulses from the tendons have a special modification of the terminal fibres, in the form of numerous fibrils with branching end-plates or of an annular and spiral arrangement resembling the neuro-muscular spindles. They usually occur at the junction of the tendon bundles with the muscle-fibres (Fig. 525).

**The Neurone Doctrine.**—The results of the investigations of Golgi, Cajal, Forel, and others prompted Waldeyer to enunciate a theory with regard to the nerve mechanism of the neurone. This hypothesis is generally known as the neurone theory and assumes that (1) each neurone is a distinct and separate entity; (2) the collaterals and other terminals of the neurone form no connections among themselves; (3) neurones are associated, and impulses conveyed, by contact or contiguity of the axonic terminals of one axone with the cell-body or dendrites of
another neurone. The theory postulates a nerve-cell amœbism analogous to the extension and retraction of the pseudopodia of an amœba, and the "retraction theory" has been propounded in explanation of certain functional dissociation phenomena attending nerve-force manifestations.

Opposed to the "neurone theory" or "contact theory" is the more recent continuity theory which is being earnestly advocated by Apáthy, Bethe, and Nissl. In behalf of this theory it is claimed that the neurofibrils are continuous not only within the cell and its processes, but through an extracellular network as well. The dispute now being waged does not, however, affect our fundamental ideas regarding the individuality of neurones with regard to their dynamic condition.

The Supporting Tissue Elements of the Nerve System.—A fine meshwork of non-nerve tissue, more or less dense in different localities, but apparently restricted to the central axis, serves to support the neurones. This sustentacular tissue is of two kinds: (1) the neuroglia; (2) connective-tissue trabeculae derived from (a) the pia or (b) vascular channels.

The Neuroglia.—The neuroglia consists of glia-cells of varied forms and glia-fibres. Glia-cells are divisible into two species: endymal cells and astrocytes of long-rayed and short-rayed type.

Endymal cells are the columnar epithelial cells which line the neural canal throughout. In the embryonic condition each cell is seen to project a long multi-branched filament toward the periphery of the neural tube, while the free end carries a tuft of cilia. In adult life both the cilia and the radial filament are apparently lost or very much reduced.

Regarding the structure of the glia-cells proper as well as of the glia-fibres there is a variance of opinion among different investigators. The astrocytes, as they are commonly revealed in Golgi preparations, may, as pointed out by Weigert and others, be due to an extension of the silver deposit upon glia-cell nuclei as well as upon adjacent filaments. Huber, 1 Hardesty, 2 and others regard neuroglia tissue as a syncitium resulting from an early fusion of the protoplasm of the cells of the neural tube which at first were individual and definitely bounded. The filamentous reticulum of glia-fibres ordinarily seen in adult tissues seems to result

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1 American Journal of Anatomy, 1901, pp. 45-61.
2 Ibid., 1904, pp. 229-268.
from an increase of the fine threads of the spongio-plasmic network of the original cell-protoplasm. Neuroglia occurs in both gray and white substance as an all-pervading supporting tissue. In certain localities, as upon the surface of the brain and cord, the neuroglia tissue is disposed in the form of a thin layer.

Besides the neuroglia, the central nerve system contains as supporting tissues numerous fine and coarse septa or trabeculae derived from the investing pia, or from the sheaths of blood-vessels.

**Chemical Composition.—**The amount of water in nerve-tissue varies with the situation. Thus in the gray substance of the cerebrum it constitutes about 83 per cent., in the white substance from the same region about 70 per cent., while in the peripheral nerves, such as the sciatic, it may fall to 60 per cent.

The solids consist of neuro-albumins, neuro-globulins, nucleo-proteins, neuro-keratin (in the gray substance proteins constitute about one-third of the total solids), lecithins, cerebrosides (chiefly phrenosin), cholesterol, unidentified organic sulpho-compounds, amino-fatty substances, nitrogenous extractives and inorganic salts, with some collagen, fat, etc., in the adherent connective tissue (W. J. Gies).

THE CENTRAL NERVE SYSTEM.

The central nerve system, as it is conventionally distinguished from the sympathetic system, is composed of a central axial aggregation of ganglia forming the brain and spinal cord, which are connected with the other tissues of the body by 43 pairs of nerves, of which 12 pairs are attached to the brain and 31 pairs to the spinal cord. The functional relations of the central mechanisms with the periphery are maintained by the essential cell-elements of the nerve-tissues, the neurones. The chief task in the study and analysis of the structure of the nerve system lies in the dovetailing of features visible to the naked eye with those visible only under high magnifying powers. By the combination of macroscopic with microscopic features the attentive student is enabled to resolve or reconstruct, in the three dimensions of space, and see with his mental eye the opaque interior transparently resolved into intricate yet well-defined projecting and associating mechanisms. Assistance in such study may be derived from illustrations depicting hidden structures in accordance with this principle.

**Preliminary Considerations. Gray Substance and White Substance.**—The central axis of the nerve system contains two categories of substance, their difference to the eye being one of color. They are conventionally designated the gray and white substance. The white substance (alba), which forms about two-thirds of the neuraxis, is the conducting substance and its characteristic appearance is due to the myelin sheaths which invest the axones in it. The gray substance (cinerea; grisea) is the sentient and reacting mass containing the cell-bodies of neurones. Its color is due to its translucency, its greater vascularity, and to a certain amount of pigmented material in the cell-elements. The white and the gray substance is not sharply demarcated everywhere, for although the white substance is exclusively conducting substance, the gray is not exclusively ganglionic, for the former encroaches on the latter; in some localities, as in the ventral horns of the spinal gray, in parts of the cerebral cortex, in the reticular formation of the pons and oblongata, and in the column of Clarke (dorsal nucleus), the admixture of myelinic fibres is considerable. Both white and gray substance is pervaded by the neuroglia.

The specific gravity of the cortical gray is 1.021, of the great ganglia 1.034, of the gray substance in the cerebellum and mesencephalon 1.050, and of the white substance 1.028.

For convenience of study, and somewhat in correspondence with phyletic
development, the central axis of the nerve system is divided into (1) the spinal cord and (2) the brain, grossly sub-divided into (a) oblongata, pons, and cerebellum; (b) mid-brain and (c) fore-brain. This gross subdivision is arbitrary and the inter-relations of the parts would be obscured were too much stress laid upon any mode of separation.

THE SPINAL CORD (MYELON; MEDULLA SPINALIS).

The spinal cord is the attenuated, nearly cylindrical part of the cerebro-spinal axis which lies in the vertebral canal, occupying its upper two-thirds in the adult. It extends from about the level of the atlo-occipital articulation (or lower border of the pyramid decussation) to the level of the lower border of the body of the first lumbar vertebra, where it terminates in a slender filament of gray substance enveloped by pia, and, further caudad, by a sheath of dura which is attached to the dorsum of the coccyx. The spinal cord is continuous cephalad with the oblongata. Its length is 45 cm. (44 to 50 cm.) in the male and 43.5 cm. (39.5 to 47 cm.) in the female. In the course of foetal development, the spinal cord occupies the entire length of the vertebral canal up to the third month, but after this period it gradually recedes cephalad owing to the more rapid growth of the vertebral column, so that at birth the caudal end of the spinal cord has risen to the level of the third lumbar vertebra.

The spinal cord does not entirely fill the vertebral canal. A wide space, or rather a concentric series of spaces intervene between its surface and the walls
of the canal, affording a marked freedom of movement of the vertebral column without exerting undue tension upon the spinal cord. These spaces, three in number, which concentrically surround the cord, are demarcated by the three protective membranes: (1) **pia**, (2) **arachnoid**, and (3) **dura**, which are continuous with the like meninges of the brain. The arrangement of the spaces and the membranes may be shown thus:

<table>
<thead>
<tr>
<th>Bony and ligamentous wall of vertebral canal.</th>
<th>Epidural space.</th>
<th>Dura.</th>
<th>Subdural space.</th>
<th>Arachnoid.</th>
<th>Subarachnoid space and subarachnoid reticulum.</th>
<th>(Pia investing spinal cord.)</th>
<th>(Spinal cord.)</th>
</tr>
</thead>
</table>

The pia closely invests the entire surface of the spinal cord and sends septal ingrowths into its substance as well as a fold occupying the ventro-median fissure. A leaf-like, serrated fold of pia, the **ligamentum denticulatum**, passes from each lateral border to the inner surface of the dural sheath and helps to support the cord within the subarachnoid space. The arachnoid and the pia are not separable in gross dissection as they merge insensibly, though usually described as distinct membranes. The arachnoid is in reality an exceedingly delicate and transparent web-like reticulum whose meshes constitute a relatively wide cavity filled with cerebro-spinal fluid. The dura constitutes the outermost and thickest sheath, while the narrow interval between the dura and the vertebral canal is filled by a fine venous plexus, together with soft, areolo-fatty tissue. Of the three spaces which surround the cord, only the two innermost contain fluid, and that of a serous character; the amount in the sub-dural space is very small, just sufficient to moisten the contiguous endothelial surfaces of the dura and arachnoid; that in the sub-arachnoid space is considerable. (For detailed description see section on the Meninges.)

**Weight.**—The weight of the spinal cord, exclusive of all nerve-roots, averages 28 grams, or 1 ounce avoirdupois, being slightly less in the female. Including the nerve-roots as ordinarily cut in postmortem procedure, the weight averages 45 grams in the male and 40 grams in the female. The ratio of weight in proportion to that of the brain is lowest in the human species, being 1 to 51 in the male and 1 to 49.8 in the female. In the newborn the ratio is 1 to 115. Its specific gravity is 1.038.

**External Morphology.**—*In situ* the spinal cord exhibits slight curvatures in the sagittal plane, being convex ventrad in the transition from cervical to thoracic portion and slightly concave ventrad to the lumbar portion. Its position varies also according to the degree of curvature of the spinal column, being raised slightly (a few millimetres only) in flexion of the spine.
The intrinsically segmental nature of the spinal cord is expressed by the association of each definite segment with the somatic segment supplied by its nerves. Thirty-one pairs of spinal nerves are commonly enumerated, although two additional, rudimentary pairs, relics of a tailed vertebrate ancestry, are demonstrable microscopically.

The first pair of spinal nerves emerges between the occiput and atlas, and is designated the first cervical; the other cervical pairs are named after the lower of the two vertebra which form the intervertebral foramen through which the nerve emerges. Very inconsistently the pair emerging between the seventh cervical and first thoracic vertebra is called the eighth cervical pair. The remaining spinal nerves are named after the upper of the two vertebra forming the corresponding foramen. In all there are:

- Cervical pairs: 8
- Thoracic pairs: 12
- Lumbar pairs: 5
- Sacral pairs: 5
- Coccygeal pairs: 1

Total: 31
All spinal nerves are made up of two roots by which they spring from the lateral aspects of the cord, symmetrically arranged, and these nerve-root attachments are the only guides to the demarcation of the various segments of the spinal cord. The two roots are generally termed the dorsal (afferent or sensor) root, which enters the cord along the dorso-lateral fissure and the ventral (afferent or motor) root which emerges along the ventro-lateral fissure.

Although the cervical nerves pass outward through the intervertebral foramina at nearly a right angle to the long axis of the cord, those of the lower series slope more and more downward, so that the fifth lumbar pair emerges six vertebral bodies lower than it originates. In fact, the lumbar and sacral nerves descend as parallel bundles in a brush-like manner to form the cauda equina, enclosed by the dural sheath as far as about the middle of the sacral canal. The topographical relations of the levels of origin and exit of the spinal nerves to the spinous processes of the vertebra is shown in Fig. 529.

Corresponding with the degree of development of the periphery, the spinal cord is more massive in those segments which are associated with the limb. Thus, in the ground-mole, the cervical portion is very much enlarged in conformity with the powerfully developed fore-limbs, while in the kangaroo or the ostrich, with powerful legs, the lumbar portion of the spinal cord is proportionately enlarged. In man, both the cervical and lumbar portions are enlarged, and while the bulk of the lower limbs exceeds that of the upper, the cervical portion of the spinal cord is more redundant because it innervates a limb which is functionally more differentiated, capable of much more skilful and complex movements and endowed with more acutely developed tactile sensibility.

The Enlargements of the Spinal Cord.—The spinal cord is marked by two spindle-shaped enlargements in its cervical and lumbar portions, while the intervening thoracic portion is nearly cylindrical, being slightly reduced in its dorso-ventral diameter. The cervical enlargement (intumescentia cervicalis) extends from the first or second cervical segment to the level of the second thoracic vertebra, acquiring a maximum breadth (13 to 14 mm.) at the sixth cervical vertebra. At its junction with the oblongata its breadth is about 11 mm. The thoracic portion is about 10 mm. in breadth (minimum at a little below its middle) while its sagittal diameter is 8 mm. The lumbar enlargement (intumescentia lumbalis) begins at the level of the tenth thoracic vertebra,
acquires its maximum breadth (12 mm.; sagittal diameter = 9 mm.) opposite the twelfth thoracic vertebra. Below the lumbar enlargement the cord gradually tapers to form a cone (conus), the apex of which, at the level of the lower border of the body of the first lumbar vertebra, is continuous with the attenuated filum.

The cervical enlargement is characterized by a relatively greater breadth than the remaining portions of the cord which, on section, appear nearly circular.

Conus (conus medullaris).—The conus is the conical extremity of the cord. The lower three sacral segments and the coccygeal segment are usually included under this term. Its diameter becomes reduced to 2 mm., to be continued below as the filum.

Filum (filum terminale; nervus impar).—The delicate terminal thread called the filum, continuous with the tapered end of the conus, is about 24 cm. in length. As far as the level of the second sacral vertebral segment it is enclosed, together with the cauda equina, in the tapering sheath of the dura. Within the dural sac it is called the filum internum, in contradistinction to the filum externum, which is an attenuated process of connective and nerve-tissue invested by a prolongation of the dura, which finally attaches to the periosteum of the dorsum of the coccyx. The filum externum occupies one-third of the total length of the filum. Morphologically, the filum is the caudal representative of the cord, and its intradural portion is usually accompanied by slender fascicles of nerve-fibres, which are rudimentary second and third coccygeal pairs of spinal nerves.

Fissures and Grooves.—The spinal cord is a bilaterally sym-
metrical structure and exhibits a deep ventral fissure and a slight dorsal groove partially subdividing the cord into right and left halves. The ventral fissure extends throughout the entire length of the cord, being shallower in the cervical and dorsal portions (less than one-third of the sagittal diameter) than in the lumbar portion. It is lined by a fold of pia which conveys the more important nutritive vessels to the depths of the cord substance. In the depth of this fissure lies the white ventral commissure of the cord. The dorsal groove has been regarded, erroneously, as being analogous to the ventral fissure. Unlike the ventral fissure, however, the pia does not descend into its depths, but passes continuously over it. The shallow groove marks the site of a septum made up of neuroglial and endynal elements. An actual groove is best demonstrable in some of the lumbar cord and in the oblongata, where it constitutes a veritable fissure between the clavæ.

Each lateral half is marked by the lines of root-attachment of the spinal nerves. The dorsal nerve-root fascicles enter the cord in linear series and in a depression or true sulcus termed the dorso-lateral fissure. The ventral nerve-root fascicles emerge, irregularly scattered, out of a greater circumferential area and no true ventro-lateral fissure can be said to exist. The line of emergence of the outermost fascicles is usually taken as an arbitrary boundary between the ventral and lateral districts of the cord, while the dorso-lateral fissure more distinctly maps off the lateral from the dorsal district. An additional fissure, observed most distinctly in the cervical and upper thoracic portions, termed the dorso-paramedian fissure, demarcates the two principal divisions of the dorsal columns, the dorso-median and the dorso-lateral columns. The dorso-paramedian fissure is an exceedingly shallow groove and is best denoted in sections of the cord by its continuance as a connective-tissue (glia) septum into the substance of the dorsal column. An analogous ventro-paramedian fissure is sometimes observable close to the ventral fissure, demarcating the ventral (or direct) pyramidal fasciculus.

Columns of the Cord (funiculi medullae spinalis).—Each half of the spinal cord is thus divided, with respect to its white substance, into three chief columns or funiculi. The dorsal column occupies the area between the dorsal septum and groove and the line of attachment of the dorsal nerve-roots; this column in its turn is generally subdivided into the dorso-median (funiculus gracilis; column of

![Diagram](image_url)
Goll's column and the dorso-lateral (funiculus cuneatus; column of Burdach) by the shallow dorso-paramedian groove and glia-septum referred to above. The ventral column (funiculus anterior) occupies the area between the ventral fissure and the outermost fascicles of the ventral nerve-roots—an arbitrary boundary line. The lateral column (funiculus lateralis) constitutes the remainder of the cord, between the dorsal and ventral nerve-root attachments. Each of these columns is subdivided into its component bundles or fasciculi, best studied in sections of the cord.

**Development of the Spinal Cord.**—The elongated postcranial portion of the neural tube becomes the spinal cord, while the primitive cavity within is preserved
as the central canal of the cord. The metamorphosis of the neuro-epithelial columnar cells has been described (p. 818). The lateral walls thicken considerably, the central slit-like canal widens as the walls bulge outward in an angular manner, and the central tubular gray becomes a fluted column with dorsal and ventral ridges (or horns) enveloped by a rapidly growing mantle of axone bundles which

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<tr>
<th>LOCATION OF THE SEGMENTS FOR</th>
<th>MOTILITY.</th>
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<td>SENSIBILITY.</td>
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Fig. 536.—Explanation of abbreviations: tr. olf., olfactory tract; c. q. l., lateral geniculate body; p. r. cr. A., indicate approximately the location of the reflex centres for the pupillary (p), the respiratory (r), cremasteric (cr.), patellar (pat), and tendo-Achillias (A.) reflexes. The vesical centre lies in the third and fourth sacral segments; the anal centre in the fourth and fifth (represented by circles); the centres for erection, ejaculation, labor pains (?) are probably also situated in this region. In reality, the divisions between the various segments are, of course, not so sharp as they are shown in the diagram, so that a given muscle or cutaneous region derives some of its controlling nerve-roots from the segments lying immediately above and below the principal segment. The sensor segment for any given region is regularly somewhat higher than the corresponding motor segment. (Jakob.)

become myelinic in successive stages. The bulging of the thickening walls in the dorsal and ventral as well as lateral directions produces the ventral fissure and the post-septum.

The segmental nature of the spinal cord has been alluded to before with regard to the segmental derivation of the cerebro-spinal ganglia and the disposition of the out-growing nerve-bundles. There is a further mode of division into longitudinal
systems based upon functional relationships. Two main categories of activity characterize the mechanism of the nervous system and find somatic expression in its architectural plan: First, actions in relation to the external world (somatic—involving skin, muscle, skeleton, etc.); second, internal activities concerned with the processes of nutrition and reproduction (visceral—involving the alimentary tract, circulatory, excretory, and reproductive systems). In each there is a twofold activity on the part of the nerve system: reception of stimuli and motor responses. In the cord (and to some extent in the brain as well) the following functional divisions may be distinguished and located anatomically (Fig. 534):

Somatic sensor elements.
Somatic motor elements.
Visceral sensor elements.
Visceral motor elements.

This functional differentiation of the neural axis into sensor and motor divisions apparently finds organic expression in an important modification of the developing neural tube. Each lateral wall of the neural tube is early demarcated
into a **dorsal** and a **ventral strip** or **lamina** and the slit-like central canal becomes more or less lozenge-shaped on trans-section, owing to the formation of a lateral longitudinal furrow within. The dorsal lamina or zone is preponderatingly sensor in function, while the ventral zone is principally motor in function. This fundamental fact has been of the greatest aid in the correct interpretation of many hitherto obscure facts regarding the mechanism of the nerve system, and will be found to underlie our method of description throughout.

**Muscular Supply from Motor Segments of the Cord.**—This is shown in Fig. 536.

**Internal Structure of the Spinal Cord.**—If a transverse section of the spinal cord be made, it will be seen to consist of white and gray nerve substance. The white substance is made up of myelinated axones; the gray contains the cell-bodies of neurones and non-myelinated axones. The color of the gray substance, so called, varies according to the degree of capillary injection and the age of the individual. It is usually of a faint reddish-gray tinge, the gray preponderating in older persons, but various shades of red, yellow, and light-slate color may be noted.

Nor is the color uniform even in the same section. Around the central canal and at the periphery of the dorsal horn the gray substance is very translucent and is termed, according to its situation, the **gloisa centralis** (gelatinosa centralis) and **gloisa cornualis** (gelatinosa Rolandi or caput glosum). The white substance surrounds the gray column as a variously thickened tunic, closely invested by the pia, which sends numerous delicate, vessel-bearing ingrowths into the substance of the cord. The relative area of the white substance, as seen on section, increases cephalad; the absolute area of both white and gray is largest in the region of the enlargements (Fig. 539).

**Gray Substance of the Cord** (entocinerea; substantia grisea centralis).—A plastic conception of the gray substance of the cord is essential to an understanding of the internal architecture. The gray core must be imagined not alone in the relations in which it is conventionally studied, as exposed in trans-sections, but also as a fluted column having a continuous extent throughout the cord. This gray column is drawn into ventral and dorsal ridges, connected respectively with the ventral and dorsal nerve-roots, while the white substance fills out the
irregularities and completes the nearly cylindrical outline of the cord (Figs. 540 and 541).

On viewing a trans-section, it is seen that the gray substance is so arranged as to present, in each lateral half of the cord, a crescentic or comma-shaped mass, the concavity of which is directed laterad. The two lateral masses are connected by a transverse bar or band of gray substance, termed the gray commissure (commissura cinerea [grisea]), and containing the central canal, which extends the entire length of the cord. The dorsal septum of the cord reaches quite to the gray commissure, there being but a few white commissural fibres in the dorsal zone. Ventrad, however, a lamina of white substance, the commissura ventralis alba, separates the gray commissure from the ventral fissure (Fig. 538).

In trans-sections of the cord it is seen that the lateral crescentic gray masses, united across the middle line by a gray commissure, have the aggregate appearance of the letter H. Each crescentic mass presents projections which are more or less pronounced according to the segment of the cord under consideration. Broadly stated and without reference to special levels, the most marked projections are the dorsal and ventral horns or cornua.

The Dorsal Horn, directed dorso-laterad, is elongated and narrow, and its apex is composed of a translucent V-shaped mass termed the gliosa cornualis (caput gelatinosa Rolandi [caput gliosum would be a better term]).

The attenuated apex of the dorsal cornu approaches the surface of the cord along the line of entrance of the dorsal nerve-roots. The apex of the dorsal horn is wider in the regions of the enlargements and the gliosa is most marked in the higher cervical segments. The base or cervix of the dorsal horn is constricted somewhat except in the thoracic portion, where its greater breadth is due to the presence of the nucleus dorsalis (Clarke's column). The Ventral Horn is shorter, thicker, and more blunt, and is separated from the ventral and lateral surfaces of the cord by a tolerably thick lamina of white
substance. Its margin, in trans-sections, presents a dentate or stellate appearance due to the emergence of fascicles of efferent or ventral root-axones on their way to the ventral surface of the cord.

What is known as the lateral horn projects as a lateral peninsular extension of the central gray nearly on the line of the gray commissure. It is best marked as a triangular projection in the upper thoracic segments. In the cervical enlargement it is merged with the greatly expanded ventral horn, but it again becomes prominent in the upper cervical segments.

The gray substance of the cord is not everywhere sharply demarcated from the white owing to the invasion of myelinic and amyelinic nerve-fibres. Facing the lateral column, in the angle between the dorsal and ventral horns, small fascicles of white fibres are embedded in the gray so that it is broken up in a peculiar basket-work pattern termed the reticula or reticular formation. This gray network is best marked in the cervical region and becomes more abundant in the oblongata.

The mode of arrangement of the gray substance and its amount in proportion to the white vary in different parts of the cord. Thus, the posterior horns are long and narrow in the cervical region; short and narrower in the thoracic; short but wider in the lumbar region. In the cervical region the crescentic portions are small, and the white substance more abundant than in any other region of the cord. In the thoracic region the gray substance is least developed, the white substance being also small in quantity. In the lumbar region the gray substance is more abundant than in any other region of the cord. Toward the lower end of the cord the white substance gradually ceases. The crescentic portions of the gray substance soon blend into a single mass, which forms the only constituent of the extreme point of the cord.

The Gray Commissure which connects the two crescentic masses of gray substance consists of myelinic and amyelinic nerve-fibres and neuroglia. The fibres pass transversely, spreading out at various angles, into the lateral gray masses. In the gray commissure, and extending the whole length of the cord, is a minute channel, the central canal (myelocele; canalis centralis), which is barely visible to the naked eye, but is proportionately larger in some of the lower vertebrates. Cephalad, in the oblongata, it opens out into the fourth ventricle; caudad it is continued for a short distance into the filum, in which it ends blindly. The canal is very minute, less than 0.1 mm., except in the terminal part of the conus, where it expands into a fusiform dilatation, the sinus terminalis (rhombocaele; ventriculus terminalis [Krause]). The central canal is lined by a layer of columnar cells which
are seen to be ciliated in the embryo and are in all respects identical with the endymal cells lining the ventricles of the brain. Surrounding the endymal lining of the central canal and gradually merging into the spongy substance which constitutes the remainder of the gray commissure is a finely granular and reticulated of the central canal and gradually merging into the spongy substance which constitutes the remainder of the gray commissure is a finely granular and reticulated
The gray substance of the cord is composed of (1) the gliosa, which envelops the head of the dorsal horn and which encircles the central canal of the cord; (2) the spongiosa, which forms the crescentic horns (except the heads of the posterior horns and the envelope of the central canal). Further, it may be stated that the gray substance consists of nerve-fibres of variable but smaller average diameter than those of the white column; (3) nerve-cells of various shapes and sizes, with few or many processes; (4) blood-vessels, lymphatic channels, and connective tissue.

The nerve-fibres of the gray substance of the posterior horn are for the most part composed of a dense interlacement of minute fibrils, intermingled with nerves of a larger size. This interlacement is formed partly by the axones and dendrites of the cells of the gray substance, and partly by fibrils which enter the gray substance and which come from various sources.

The nerve-cells of the gray substance are collected into groups as seen on transverse section, but they really form columns of cells placed longitudinally; or else they are found scattered throughout the whole of the gray substance (Fig. 542).

In the ventral horn four main groups of cells may be distinguished which are not wholly represented, however, in all regions of the cord: (1) A ventral group of cells, separable in the cervical and lumbar regions into ventro-medial and ventro-lateral sub-groups; (2) a dorso-medial group, situated in the cervix of the ventral horn, usually demonstrable in the thoracic portion as well as a few contiguous cervical and lumbar segments; (3) a lateral group, separable in the lower cervical and lumbar regions into ventro-lateral and dorso-lateral sub-groups, and supplying the muscles of the extremities; (4) a central group of cells in the lumbar and sacral regions.

In the lateral horn, which is most prominent in the thoracic and upper cervical segments, lies an intermediate group of cells, a long, slender column which is nearly restricted to the thoracic portion of the cord, but is seen to reappear in the upper three cervical and in the third and fourth sacral segments. The axones from these cells probably do not pass out with the ventral nerve-roots, but rather course within the cord to terminate at various levels on the same as well as on the opposite side. A close connection with the sympathetic nerve system, and with vasomotor and sweat-gland nerves, has been suggested.

In the dorsal horn the most conspicuous group of cells is a columniform nucleus commonly termed Clarke’s column (nucleus dorsalis), which extends between the seventh cervical and second (or third) lumbar segments of the cord. The cells are large and the group presents an oval outline in trans-sections, lying in the medial part of the cervix of the dorsal horn. The axones of these cells pass out of the gray into the lateral column of the cord to form the spino-cerebellar tract, and convey tactile impulses to the cerebellum.

Just ventrad of Clarke’s nucleus, and extending through a greater length of the cord, scattered cells constitute the nucleus of Stilling, represented in the oblongata by the accessory cuneate nucleus. Aside from these nuclear columns, the cells of the dorsal horn are not grouped very definitely, and for the purposes of description they are sub-divided according to their location. The cells vary much in form and size and their branched axones pass toward other regions within the gray substance at various levels on the same or on opposite sides, or via the ground-bundles. Many fibres of the dorsal nerve-roots are in relation with the dorsal-horn cells.

The various groups of cells enumerated above are frequently demarcated from neighboring groups by nerve-fibre intervals which may be straight, curved, interlaced, or loop-shaped.
Through the gliosa cornualis pass numerous fine fibrils, chiefly the afferent dorsal nerve-root fibres, but in addition this peculiar, gelatinous, and semitranslucent substance contains numerous small stellate cells; the region is so densely filled with axones and collaterals, as well as neuroglia-cells that until staining-methods became sufficiently developed the importance of this substance remained in dispute. In man the gliosa cornualis shows convolutions feebly imitating those of the olive, and its structure is analogous. Dorsad of the gliosa lies the ultimate zone of the dorsal horn; this gray substance resembles the spongiosa in its essential characters.

The White Substance of the Cord (substantia alba).—The white substance of the cord, consisting chiefly of longitudinally disposed myelinic fibres, with blood-vessels, neuroglia, and connective-tissue septa, forms a thick mantle which invests the central gray column. When stained with carmine, a transverse section of the white substance is seen to be studded all over with minute dots surrounded by unstained circular areas. The dots are the transversely cut axones; the lighter areas are the myelin sheaths. The mass of white substance is closely invested by a sheath of neuroglia immediately beneath the pia. Numerous septa, derived from the pia, but always coated by a thin layer of neuroglia, pass into the white substance to separate the respective bundles of fibres and are often interwoven between individual nerve-fibres, acting as a supporting framework in which they are embedded. In addition to the longitudinal fibres—there are shorter and less numerous transverse fibres collected into the so-called commissural bundle or white commissure.

Longitudinal Fibres.—The longitudinal fibres constitute the conducting tracts. Although a purely anatomical examination fails to reveal the functional relations of these fibre-bundles, the structural alterations which ensue (in accordance with the laws of Waller) in the distal portion of a neurone whose proximal portion has been destroyed, the progressive myelinization of separate tracts in the embryo and infant (as proved by the researches of Meynert and Flechsig), the comparative anatomy method and electro-physiological experimentation have rendered possible the demonstration of the origin and destination of the various conducting systems or tracts with almost mathematic accuracy. While some fibres pursue a lengthy course, serving as conduction paths between the brain-centres and the various spinal centres, others are shorter and serve to associate different spinal levels—in juxtaposition or relatively not far distant. It must be borne in mind that the gray substance, intercalated as it is in the course of the impulses which pass to and fro in the cord, contains the neural elements which are either (a) the source or (b) the destination of these impulses, and thus complete the nerve-cycle requisite for the organization of the functions belonging to the cord. The motor and sensor phenomena, though interacting, depend upon distinct nerve elements.
which, because of their functional relationship, or because of the direction in which they convey impulses, are generally referred to as motor or sensor, efferent or afferent neurones; and in the spinal cord usage has sanctioned the employment of the terms descending and ascending for tracts conveying motor and sensor impulses, respectively. Anatomically speaking, however, it is preferable to describe the tracts with reference to their origins and termini (as cerebro-spinal, spino-thalamic, etc.), when known, or to their topographical relations as studied in trans-sections of the cord.

For the purposes of description it is convenient to classify the longitudinal fibres into three general systems: (1) The cerebro-spinal system of axones forming conduction paths for efferent impulses from the cerebrum to the spinal centres for peripheral organs, and axones for afferent impulses received in the spinal centres from the periphery and conveyed in turn to the cerebrum.

(2) The spino-cerebellar system, consisting of conduction paths, afferent and efferent, between the cerebellum and the spinal centres.

(3) Numberless association systems strictly confined within the cord (or only extending into the oblongata), composed of shorter or longer axones which serve to associate not only different levels of the same spinal segment, but also the different segments, that are in juxtaposition or more remotely situated. These spinal association axones form bundles in close contact with the central gray column and are termed the fasciculi proprii or ground-bundles.

The columns of white substance have already been enumerated (p. 539) as the dorsal, lateral, and ventral columns or funiculi.

In the dorsal column there are described the following tracts:

Ascending:

(1) Fasciculus gracilis (Golli).

(2) Fasciculus cuneatus (Burdachi).

Descending:

(1) Comma tract (Schultze).

(2) Median oval tract (Flechsig).

Associating:

(1) Fasciculus dorsalis proprius.

(2) Dorsal cornu-commissural tract.

(3) Septo-marginal tract (Bruce).

Another tract, usually described as belonging to the lateral column, but functionally more intimately related to the sensor neurone-system of the dorsal column is the fasciculus marginalis (of Spitzka and Lissauer).

The great majority of the axones constituting the dorsal column are the afferent (sensor) axones arising from the spinal ganglion cells, entering the cord by the dorsal roots. These dorsal root-axones bifurcate in the region of the dorsal horn, one branch ascending a little obliquely at first, then vertical, while the other branch takes a similar downward course for a shorter distance (Fig. 544). As additional groups of fibres are contributed by each successive dorsal nerve-root the mass of white substance in the dorsal column accumulates as the cord is ascended, though it must be noted that not all of these afferent fibres traverse the whole of the cord above, but end in relation with cells in the gray substance at various levels. The successive accessions of afferent fibres are disposed in a laminated manner so that the lumbar fibres come to lie lateral to the sacral bundle, the thoracic lateral of the lumbar, and so on as the cord is ascended. A section of the cord at its highest level would therefore traverse a collection of bundles derived from all of the dorsal-nerve roots of the cord, arranged as shown in Fig. 544.

In the upper segments of the cord it is possible to distinguish a division of the dorsal column into two principal fasciculi owing to the presence of a distinct connective-tissue septum which passes into the substance of the dorsal column.
along the dorso-paramedian groove. These fasciculi are termed, according to their position, the dorso-median and dorso-lateral fasciculi or Goll's column and

Burdach's column; in the consideration of the external morphology of the cord, these have already been referred to as the funiculus gracilis and funiculus cuneatus, respectively.
It has been noted that even in the fresh cord, when sectioned, the gracile bundle has a different tinge and stains more deeply with carmine than does the cuneate bundle.

The caudad or descending branches of the bifurcate dorsal-root axones are considerably shorter than the ascending branches. They terminate in the gray substance in relation with its cells and, by numerous collaterals which are shorter or larger and given off at various intervals, serve to associate different levels of the cord. Some of these collaterals cross the median line in the dorsal commissure to come into relation with neurones of the opposite side. Certain of the longer descending branches show a tendency to collect into a feebly marked bundle along the mesal border of the dorso-lateral fasciculus, called because of its outline in trans-sections—as seen in cases of descending degeneration from injury at a higher level—the comma tract of Schultze. A similar bundle, situated along the dorsal septum, best demonstrable in the lumbar cord, and with its fellow of the opposite side of oval outline as seen on section, is called the oval bundle of Flechsig (tractus cervicolumbatis [Edinger]; dorsomediales Sakralfeld [Obersteiner]).

Marginal Tract.—Not all the axones of the dorsal-nerve root enter the dorsal column. Another group elsewhere described passes into the dorsal horn as
THE NERVE SYSTEM

well as toward Clarke's column, while a third group of fibres forms the so-called marginal tract, situated close to or among the entering fibres of the dorsal roots, but frequently described as lying in the lateral column. The tract is demonstrable in all levels and is made up of successive increments of relatively short axones (traversing not more than three or four segments) to end in relation with the cells of the glosa cornualis. It has been assumed that the tract is concerned with the transmission of pain-sense.

Ground-bundle of the Dorsal Column.—A zone of fibres contiguous with the dorsal face of the gray column, and termed the fasciculus dorsalis proprius or dorsal ground-bundle, is composed of axones arising from the smaller cells of the dorsal horn, which, after entering the white substance and bifurcating into ascending and descending branches, come into relation with other levels of the gray column by means of collaterals and terminating in it after a comparatively short course. They are therefore to be regarded purely as association or “longitudinal commissural” fibres. The dorsal cornu-commissural tract (ventrales hinterstrangsbündel [Strümpell]; zone cornucommissurale [Marie]), occupying a triangular interval at the apex of the trans-sected dorsal column, and the septo-marginal tract [of Bruce], in apposition with the post-septum, belong to this category of association bundles. Both tracts are most evident in the lumbar portion of the cord.

In the lateral column the following tracts may be enumerated:

Ascending:

1. Dorso-lateral spino-cerebellar tract (Flechsig).
2. Superficial ventro-lateral spino-cerebellar tract (Gowers).
4. Spino-mesencephalic tract.
5. Spino-olivary tract (Hellweg).

Descending:

1. Crossed pyramidal tract.
2. Rubro-spinal tract.
3. Cerebello-spinal tract (Marchi and Löwenthal).
4. Vestibulo-spinal tract.
5. Olivo-spinal tract.

Associating:

1. Fasciculus lateralis proprius.

The dorso-lateral spino-cerebellar or direct cerebellar tract (of Gratiolet and Flechsig) lies at the periphery, laterad of the crossed pyramidal tract. Its axones arise from the cells of Clarke’s column and ascend uninterruptedly to the oblongata, and thence to the vermis of the cerebellum in its post-peduncle. The tract becomes more massive as the cord is ascended (Fig. 543).

The superficial ventro-lateral spino-cerebellar tract also courses along the periphery, but farther ventrad. The origin of its axones is yet in dispute; they probably arise from cells in the gray column of both sides, in the zone between the dorsal and ventral horns as well as from some of the ventral-horn cells. The destination of the axones of this tract is equally uncertain, but most of the fibres have been traced through the dorso-lateral region of the oblongata and the pontile reticula, whence it turns dorsi-mesad, to enter the cerebellum through the valvula and ending in the dorsal vermis. A lesser portion of the tract has been traced to the quadrigemina, while other groups of axones end in various levels of the gray column.

The spino-thalamic and spino-mesencephalic (tractus spinotectalis) tracts are not gathered into compact bundles, but are rather scattered among the fibres of

1 First described by F. C. Spitzka (in 1885) and Lissauer (1886) and usually bearing the name of the latter.
the lateral column just mesad of the superficial ventro-lateral spino-cerebellar tract (Gowers). The axones of both systems arise from cells in the dorsal horn and its cervix of the opposite side, coursing through the white ventral commissure and ascending the cord, the spino-thalamic fibres ending in the thalamus, the spino-mesencephalic fibres ending in the region of the quadrigemina. The two tracts are collectively called *tractus spino-tecalis et thalamicus*.

The spino-olivary tract (Helweg’s Dreikantenbahn; Bechterew’s Olivenbündel) is found only in the higher segments of the cord, at its periphery and just laterad of the emergence of the ventral nerve-roots.

Its connections and functional direction are uncertain; some investigators have traced its fibres between the olive and certain ventral-horn cells; Obersteiner suggests a relationship with the pyramidal tract. The coincidence, in point of time, of the myelinization of both tracts is significant in this connection.

The crossed pyramidal tract (lateral cerebro-spinal fasciculus) occupies an approximately triangular or oval area in the dorsal portion of the lateral column, just mesad of the direct cerebellar tract, except in the lumbar cord, where it lies at the surface. The axones of this tract arise from the pyramidal cells of the cerebral cortex (motor area) of the opposite side. After having descended through the internal capsule, crusta, pons, to the pyramis of the oblongata, the major portion of the fibres derived from one-half of the brain decussate with those of the other half, crossing the median line to descend in the lateral column of the cord. The fibres which do not decussate constitute the direct pyramidal tract in the ventral column. As the crossed pyramidal tract descends it diminishes in size as its axones become distributed to the ventral horn, where they terminate in contiguity with the ventral motor cells which give rise to the fibres of the ventral (motor) nerve roots. The bundle becomes exhausted as a distinct strand at the level of the fourth sacral segment.

The rubro-spinal, cerebello-spinal, lateral vestibulo-spinal, and olivo-spinal tracts consist of descending axones which are intermingled so that their mutual topographical relations cannot at present be described. Collectively they constitute the *fasciculus intermedius* of Löwenthal and Bechterew (intermedio-lateral tract of Bruce and Campbell) and they lie ventral of the crossed pyramidal tract and mesad of the combined spino-thalamic and spino-mesencephalic tracts.

The rubro-spinal tract (Monakow’s tract; prepyramidal tract) originates in the rubrum (red nucleus in the tegmentum of the mid-brain) of the opposite side and its axones terminate in relation with ventral-horn cells. In their course these fibres are seen to invade the area of the crossed pyramidal tract. The cerebello-spinal tract (Marchi’s tract) is supposed to arise in the cortex of the cerebellar hemispheres; to become distributed to the motor centres in the ventral horn.

The lateral vestibulo-spinal tract arises in the lateral nucleus of the vestibular nerve (Deiters’ nucleus) and by its relations with spinal centres establishes a connection with the equilibratory apparatus.

The olivo-spinal tract, according to Kölliker, is a crossed tract whose axones arise in the olive and terminate in relation with the motor cells of the ventral horn.

Several other descending tracts ending in the spinal cord and arising in higher centres like the quadrigemina, central gray of the mesencephalon, and the cerebellum have been recently described by Held, Boyce, and Bechterew.

**Ground-bundle of the Lateral Column** (*fasciculus lateralis proprius*).—This lies in the concavity of the lateral aspect of the gray column and consists of axones having a purely commissural function. In the regions where the reticula is best marked it is subdivided into a group of smaller bundles by numerous glial septa.
In the ventral column are described the following tracts:

**Descending:**

1. Direct pyramidal tract.
2. Sulco-marginal tract.
3. Ventral vestibulo-spinal tract.

**Associating:**

1. Association-axones between spinal centres and several cranial nerve nuclei.
2. Fasciculus ventralis proprius.

The **direct pyramidal tract** (fasciculus cerebrospinalis ventralis; fasciculus of Türek) is the uncrossed portion of the pyramidal tract below the decussation in the oblongata, and constituting only 10 to 15 per cent. of the fibre system arising in the motor cortex of the same side. It is a small, oblong bundle, as seen on trans-section, lying parallel with the ventral fissure, from which it is separated in the higher segments by the relatively narrow sulco-marginal tract. The tract diminishes in bulk as the cord is descended, to disappear in the thoracic portion of the cord; though, in rare instances, it has been observed to extend throughout the lumbar portion as well. This diminution and eventual disappearance of the tract is due to the successive decussations of its fibres throughout its course, for, with a few exceptions, these cross in the ventral white commissure to come into relation with the ventral-horn cells (motor cells) of the opposite side. This partial longitudinal extension of the pyramidal decussation and consequent formation of an uncrossed, ventrally situated pyramidal tract is peculiar to the primate order of vertebrates.

The **sulco-marginal tract** (tractus tectospinalis) is a thin bundle whose axones arise in the quadrigemina of the opposite side, immediately decussating and descending through the oblongata, to be distributed to various spinal centres in a manner not yet accurately ascertained. The system is assumed to be concerned in the coördination of movements of the head, with optic and acoustic reflexes.

The **ventral vestibulo-spinal tract** (Löwenthal’s tract; anterior marginal fasciculus; ventral cerebello-spinal tract) lies at the periphery of the ventral column, extending, as seen on trans-section, from the ventral-root zone to the ventral fissure. Its axones arise from (1) the lateral (Deiters’) and (2) superior (Beechterew’s) nuclei of the vestibular nerve; (3) from the fastigium of the cerebellum. Their termination about the ventral-horn cells has been traced as far as the sacral region of the cord.

As in the lateral column, and continuous with the like formation, there is in the ventral column an intermediate zone of mixed systems of axones which serve to associate various levels of the cord with ganglionic masses in the oblongata as well as with the cerebellum and quadrigemina. The nuclei of the trigeminus, facial, auditory, glosso-pharyngeal, and vagus nerves, together with the olive and the cerebellum, seem most intimately associated with the spinal centres for movements of the head and neck.

**Ground-bundle of the Ventral Column.**—The white substance of the ventral column contiguous with the central gray is made up of intersegmental axones of association connecting different levels of the cord.

The **ventral white commissure** (commissura ventralis alba) is composed of myelinic fibres which decussate with or cross each other and, on trans-section, are seen to form a narrow band connecting the ventral columns of the two sides. The axones composing it are chiefly (1) those arising from ventral-horn cells, which after crossing the mid-line, course horizontally or cephalad and caudad to come into relation with neurones at the same or at different levels of the gray substance; (2) the decussating axones of the direct pyramidal tract; (3) numerous collaterals from the ventral and lateral column axones. The white commissure is most
massive in the enlargements where the associations of the limb-centres are necessarily greater in number.

**Myelinization of the Axones of the Cord.**—The acquisition of the myelin sheath is not contemporary for all axones in the cord, but is characterized by a regular progression in the myelinization of separate fasciculi. As a rule, those axone systems which are concerned with simpler or intrinsically spinal reflexes become myelinic or "mature" at an earlier stage of fetal development than do those concerned in the more elaborate connections of the cord with the brain. Thus, the efferent and afferent axones, and those of associating neurones, become myelinic in the fifth and sixth months of fetal life, while the pyramidal tracts and the spino-olivary tract (of Helweg) are observed to be the last to mature at the time of birth, in correspondence, apparently, with the inception of the functional use of these tracts. The order of myelinization of the separate fasciculi is indicated in Fig. 546.

![Diagram showing the order of myelinization of the various tracts in the spinal cord (cervical level). The tracts are named on the right side; the Roman numerals on the left side correspond with the enumeration given in the text. H, Helweg's tract; M, marginal tract.](image-url)

**Summary.** **The Gray Substance.**—The gray substance consists, aside from its supporting tissues, of sentient and reacting nerve-cells, with their dendrites and axones, and of the terminals of axones entering from without. These nerve-cells may be classified as follows:

(a) Nerve-cells whose axones pass directly out of the cord. These lie in the ventral horn, are "motor" in function, and their axones form the ventral-nerve roots.

(b) Nerve-cells whose axones pass into the white substance, usually bifurcating into a shorter descending and a longer ascending branch. Two kinds of cells are distinguished:

1. Strand- or tract-cells whose axones (ascending branches) traverse the cord, to come into relation with higher centres in the brain.

2. Association-cells whose axones, after a comparatively brief course in the white substance, reenter the gray substance and serve to coordinate different levels of the cord.

The tract-cells may be further divided into two categories: **homo-lateral** and **contra-lateral tract-cells.** Homo-lateral cells are those whose axones enter the white...
columns of the same side; contra-lateral cells are those whose axones traverse the white ventral commissure to the other side. Tract-cells exist in all parts of the gray substance and are termed, according to their situation: ventral-, lateral-, and dorsal-horn cells. The contra-lateral tract-cells preponderate in the dorsal horn, its cervix, and in the intermediate zone, and, on account of their course, are also called commissural cells.

c) Nerve-cells of Golgi's type II, or cells with short, multi-branched axones.

The motor ventral-horn cells differ, therefore, from the other categories in that they alone send their axones out of the central axis to the periphery. The tract-cells, commissural cells, and the Golgi type II cells are strictly confined to the central axis; the tract-cells serve to coordinate the separate units of the spinal neurone system with higher centres; the association-cells maintain the paths of conduction between higher and lower cell-complexes; while the cells of Golgi's type II are limited to a narrower field of nerve-activity as nerve links in the chaining together of neurones.

White Substance.—The white substance consists essentially of axones the great majority of which are disposed longitudinally. These axones comprise:

a) Axones arising in the cerebral cortex, the gray ganglionic masses in the mid-brain, pons, and cerebellum, and descending to their terminations in different levels of the cord.

b) Axones which, conversely, arise in the gray substance of the cord (tract-cell axones), to terminate in the higher brain-centres.

c) Axones which coordinate different levels of the cord with each other (association-cell axones.)

d) Axones which, arising from the spinal-ganglion cells of the dorsal-nerve roots, enter the cord and ascend in the dorsal columns.

Dissection.—To dissect the cord and its membranes it will be necessary to lay open the whole length of the vertebral canal. For this purpose the muscles must be separated from the vertebral grooves, so as to expose the spinous processes and lamina of the vertebrae; and the latter must be sawed through on each side, close to the roots of the transverse processes, from the third or fourth cervical vertebra above to the sacrum below. The vertebral arches having been displaced by means of a chisel and the separate fragments removed, the dura will be exposed, covered by a plexus of veins and a quantity of loose areolar tissue, often infiltrated with serous fluid. The arches of the upper vertebrae are best divided by means of a strong pair of cutting bone-forceps or by a rachitome.

MEMBRANES OF THE CORD.

The membranes which envelop the spinal cord are three in number. The most external is the dura, a strong fibrous membrane which forms a loose sheath around the cord. The most internal is the pia, a cellulo-vascular membrane which closely invests the entire surface of the cord. Between the two is the arachnoid, a non-vascular membrane which envelops the cord and is connected to the pia by slender filaments of connective tissue.

The Spinal Dura (Dura Spinalis) (Figs. 528, 530, 547, 549).

The spinal dura represents only the meningeal or supporting layer of the cranial dura. The endocranial or endosteal layer ceases at the foramen magnum dorsally, but reaches as low as the third cervical vertebra ventrally; below these levels its place is taken by the periosteum. The dura forms a loose sheath which surrounds the cord and the cauda equina, and is loosely connected with the vertebral periosteum and the ligaments by a quantity of lax areolar tissue and a plexus of veins, the meningo-rachidian veins (plexus venosi vertebrales interni). The
space containing the fat and veins is called the **epidural space** *(cavum epidurale)*. The situation of the veins between the dura and the periosteum of the vertebrae corresponds therefore to that of the cranial sinuses between the endocranial and supporting layers. The dura is attached to the circumference of the foramen magnum and to the axis and third cervical vertebra; it is also fixed to the posterior common ligament, especially near the lower end of the spinal canal, by fibrous slips; it extends below as far as the second or third piece of the sacrum; here it becomes impervious, and, ensheathing the filum terminale, constitutes the **filum durae spinalis** *(Fig. 530)*, and descends to the dorsum of the coccyx, to blend with the periosteum. This part of the dura is called the **coccygeal ligament** *(Fig. 549)*. The dura is much larger than is necessary for its contents, and its size is greater in the cervical and lumbar regions than in the thoracic. Its inner surface is smooth. On each side may be seen the double openings, which transmit the two roots of the corresponding spinal nerve, the fibrous layer of the dura being continued in the form of a tubular prolongation on them as they pass through these apertures. These prolongations of the dura are short in the upper part of the spine, but become gradually longer below, forming a number of tubes of fibrous membrane, which enclose the sacral nerves, and are contained in the vertebral canal.

The chief peculiarities of the dura of the cord, as compared with that investing the brain, are the following:

- The dura of the cord is not closely adherent to the bones of the vertebral canal, and is not, as is the cranial dura, the internal periosteum of the vertebrae. The vertebrae have an independent periosteum.
- It does not send partitions into the fissures of the cord, as the cranial dura sends partitions into certain fissures of the brain.
- Its fibrous laminae do not separate to form venous sinuses, as in the cranium.
- It contains no Pacchionian bodies.
Structure.—The dura consists of white fibrous and elastic tissue arranged in bands or lamellae, which, for the most part, are parallel with one another and have a longitudinal arrangement. Each surface is covered by a layer of endothelial cells. It is sparingly supplied with vessels, and some few nerves have been traced into it.

The Arachnoid (Arachnoidea Spinalis) (Figs. 528, 547).

The arachnoid is exposed by slitting the dura and reflecting that membrane to either side. It is a thin, delicate, tubular membrane which invests the surface of the cord, and is connected to the pia by slender filaments of connective tissue. Above, it is continuous with the cranial arachnoid; on each side it is continued on the various nerves, so as to form a sheath for them as they pass outward to the intervertebral foramina. The outer surface of the arachnoid is in contact with the inner surface of the dura, and the two are, here and there, joined together by isolated connective-tissue trabeculae. These trabeculae are especially numerous on the posterior surface of the cord. For the most part, however, the membranes are not connected together, and the interval between them is named the subdural space (cavum subdurale). The subdural space contains a very small amount of lymph-like fluid. There is no communication between the subdural and the subarachnoid spaces. The subdural space is prolonged outward for a short distance on each emerging nerve and communicates with the lymph tract of the nerve. The inner surface of the arachnoid is separated
THE PIA OF THE CORD

from the pia by a considerable interval, which is called the subarachnoid space (cavum subarachnoideale). The space is largest at the lower part of the spinal canal, and encloses the mass of nerves which forms the cauda equina. Cephalad it is continuous with the cranial subarachnoid space, and communicates with the general ventricular cavity of the brain by means of openings in the pia, in the roof of the fourth ventricle, the metapore or foramen of Majendie and foramina of Key and Retzius. It contains an abundant serous secretion, the cerebrospinal fluid (liquor cerebrospinalis). This secretion is sufficient in amount to expand the arachnoid, and thus to distend completely the whole of the space included in the dura. The subarachnoid space is occupied by trabeculae of delicate endothelial covered connective tissue, connecting the pia on the one hand with the arachnoid on the other. This is named subarachnoid tissue.

In addition to this the space is partially subdivided by a longitudinal membranous partition, the septum posticum or the posterior fenestrated septum (septum subarachnoideale), which serves to connect the arachnoid with the pia, opposite the dorso-median fissure of the spinal cord. It is a partition, but an incomplete and cribriform partition, consists of bundles of white fibrous tissue interlacing with each other, and is coated with endothelium. The dentate ligament (ligamentum denticulatum), which run from the pia to the dura on either side of the cord, divide the subarachnoid space into an anterior and a posterior space (cavum subarachnoideale anterius et posterius), which join like spaces in the cavity of the cranium. The external spinal veins (venae spinales externae) lie in the subarachnoid space.

Structure.—The arachnoid is a delicate membrane made up of closely arranged interlacing bundles of connective tissue in several layers. It contains many elastic fibres, and is covered on each side by endothelial cells. The arachnoid contains neither vessels nor nerves.

The Pia of the Cord (Pia Spinalis).

The pia of the cord is exposed on the removal of the arachnoid (Figs. 547 and 548). It covers the entire surface of the cord, to which it is very intimately adherent, forming its neurilemma, and sending a process downward into its ventral fissure. It also forms a sheath for each of the filaments of the spinal nerves, and invests the nerves themselves. A longitudinal fibrous band extends along the middle line on its ventral surface, called by Haller the linea splendens; and a somewhat similar band, the ligamentum denticulatum, is situated on each side. At the point where the cord terminates the pia becomes contracted, and is continued caudad as a long, slender filament, the filum terminale (Fig. 549), which descends within the sheath of the dura and the arachnoid and through the centre of the mass of nerves forming the cauda equina.

It unites with the dura and arachnoid about the level of the third sacral vertebra, and as the central ligament of the spinal cord, the coccygeal ligament, or the filum durae spinalis the fused membranes extend caudad as far as the base of the coccyx, where they blend with the periosteum. It assists in maintaining the cord in its position during the movements of the trunk. It contains a little gray nerve substance, which may be traced for some distance into its upper part, and is
accompanied by a small artery and vein. At the upper part of the cord the pia presents a grayish, mottled tint, which is owing to yellow or brown pigment-cells scattered among the elastic fibres.

**Structure.**—The pia of the cord is less vascular in structure, but thicker and denser, than the pia of the brain, with which it is continuous. It consists of two layers: an outer, resembling the arachnoid, composed of bundles of connective-tissue fibres, arranged for the most part longitudinally; and an inner (intima pia), consisting of stiff circular bundles of the same tissue, which present peculiar angular bends. It is covered on both surfaces by a layer of endothelium. Between the two layers are a number of cleft-like lymphatic spaces which communicate with the subarachnoid cavity, and a number of blood-vessels which are enclosed in a perivascular sheath, derived from the inner layer of the pia, into which the lymphatic spaces open. The pia contains the anterior spinal artery and its branches, the two posterior spinal arteries, and numerous veins which pass to the external spinal veins. It is also supplied with nerves, which are derived in part from the sympathetic and in part from the cerebro-spinal nerves. These nerves supply the walls of the blood-vessels and enter the cord with the vessels.

The **Dentate Ligament** (*ligamentum denticulatum*) (Figs. 528 and 548) is a narrow, fibrous band, situated on each side of the spinal cord, throughout its entire length, running from the pia to the dura, and separating the ventral from the dorsal roots of the spinal nerves. It has received its name from the serrated appearance which it presents. Its inner border is continuous with the pia at the side of the cord. Its outer border presents a series of triangular, dentated serrations, the points of which are fixed at intervals to the dura. These serrations are twenty-one in number on each side, the first being attached to the dura opposite the margin of the foramen magnum between the vertebral artery and the hypoglossal nerve, and the last near the lower end of the cord. Its use is to support the cord.

**Surgical Anatomy.**—Evidence of value in the diagnosis of meningitis may be obtained by the operation of lumbar puncture, that is, by puncturing the theca of the cord and withdrawing some of the cerebro-spinal fluid, and the operation is regarded by some as curative, under the supposition that the draining away of the cerebro-spinal fluid relieves the patient by diminishing the intracranial pressure. Lumbar puncture may give important diagnostic aid after a head injury by disclosing bloody cerebro-spinal fluid. The operation is performed by inserting a trocar, of the smallest size, below the level of the fourth lumbar vertebra. In an adult the cord terminates at the lower border of the first lumbar vertebra, and in a child opposite the body of the third lumbar vertebra. The canal may be punctured below the fourth vertebra without any risk of injuring its contents. The point of puncture is indicated by laying the child on its side and dropping a perpendicular line from the highest point of the crest of the ilium; this will cross the upper border of the spine of the fourth lumbar vertebra. In a child the puncture is made just below the vertebral spine. In adults one-half an inch to one side of the end of the vertebral spine. However the preliminary puncture is made, the needle penetrates the dura in the middle line. In entering the needle it should be directed upward and forward in a child; upward, forward, and slightly inward in an adult.

**THE BRAIN OR ENCEPHALON.**

The brain is that greatly modified and enlarged portion of the cerebro-spinal axis which, with its membranes, almost completely fills the cavity of the cranium. It is a complex organ in which reside the highest functions—consciousness, ideation, judgment, volition, and intellect—together with the centres of special sense and for the mechanism of life (respiration and circulation), and it is the agent of the will.

**General Appearance and Topography of the Brain.** Corresponding to the varieties of cranial form, the shape of the fresh or the successfully preserved brain
varies from the ovoid to the nearly spherical form, as viewed dorsally. The frontal pole is usually narrower, though more squarely formed; while the parieto-occipital portion is more massive, but more sharply pointed in each half. The outline is often rather that of an irregular pentagon with its angles rounded off. A dorsal view shows only the extensive convex surface of the two great convoluted hemicerebra (cerebral hemispheres) separated by a median cleft, the intercerebral fissure (fissura longitudinalis cerebri). On divaricating the cerebral halves it is seen that the separation is not a total one, for in the depths of the fissure a broad commissural mass of white fibres—the callosum—joins the hemicerebra. Frontad the intercerebral fissure is continued to the ventral or basal aspect of the brain; caudad it passes into the tentorial hiatus (fissura transversa cerebri) or interval, separating the cerebrum from the cerebellum.

In a lateral view the continuity of the spinal cord with the oblongata, then the pons and cerebellum are seen in part, overlapped by the cerebrum. Prominent is the temporal lobe with its rounded pole, separated from the frontal and parietal lobes by a deep cleft, the sylvian fissure, in whose depths—overlapped by the opercula of the adjacent lobes—lies the insula.

A ventral view presents many of the subdivisions of the brain. Here is seen the continuity of the spinal cord, with the short and slightly expanding oblongata lying ventrad of the cerebellum and somewhat buried in its vallecula or depression between the lateral hemispheres, which alone are visible. The cerebellum is a grayish-colored mass of considerable size and easily recognized by its foliated appearance, due to the numerous parallel and closely-set curved fissures. A mass of white fibres, the pons, passes transversely from one cerebellar hemisphere to the other, ventrad of the upper portion of the oblongata. Above the pons are seen two large bundles, the crura, one on either side, diverging to pass into the cerebral halves. The interval between the divergent crura and temporal poles laterad and the orbital portions of the cerebrum frontad contains a number of important structures. Encircling the crura and meeting in the fore-part of the fossa are the optic tracts, decussating in the median plane to form the chiasm and continuing frontad as the optic nerves. The arch of the optic tracts and chiasm and the crura enclose the intercural space, in which may be seen (1) the postperforatum (substantia perforata posterior); (2) the albicantia (corpora albicantia; c. mammillaria; c. candidantia); (3) the tuber (tuber cinereum), and the stalk of the hypophysis. A groove marking the lateral boundary of the fossa along each crus is termed the oculomotor sulcus, as the root-fibres of the oculomotor nerve have their superficial origin therein. The postperforatum is a gray area with numerous minute apertures for the entrance of postperforant branches of the post-cerebral artery. The albicantia are two small, pea-like, white eminences closely set side by side. The tuber is a conical projection between the albicantia and the chiasm, to which the hypophysis (pituitary body), resting in the sella of the sphenoid, is attached. In the removal of the brain from the skull the stalk of the hypophysis is usually torn through and an orifice, the lura, leading to the infundibular recess of the third ventricle, is thus exposed.

In the interval between the optic tract and the orbital surface of each hemicerebrum a small, depressed, triangular area of gray substance leading laterad into the basisylvian fissure and dotted with numerous apertures for the minute basal branches of the medicerebral artery and called the preperforatum.

If the chiasm be drawn somewhat ventrad, a delicate gray lamina, the terma (lamina terminalis; lamina cinerea) is seen attached to the dorsal surface of the chiasm and passing dorsad into the intercerebral cleft to the region of the precommissure.

Parallel to the medial border of the orbital surface of each hemicerebrum lie the olfactory tract and bulb, torn away from the fila olfactoria as these pass through
the cribosa of the ethmoid. The olfactory tract may be traced to its root-area, the **olfactory trigone**, just frontad of the preperforatum.

The superficial origin of nearly all of the **cranial nerves** may be seen upon the basal aspect of the brain (Fig. 551). These nerves, their superficial attachments to the brain, and the foramina of exit in the skull are enumerated in the following table:

**Tabulation of the Cranial Nerves, Their Superficial Attachments to the Brain, and the Foramina of Exit in the Skull.**

<table>
<thead>
<tr>
<th>Nerve.</th>
<th>Superficial &quot;Origin&quot; or Attachment to the Brain.</th>
<th>Foramen of Exit from the Skull.</th>
</tr>
</thead>
<tbody>
<tr>
<td>II. Optic nerve.</td>
<td>Chiasm.</td>
<td>Optic foramen.</td>
</tr>
<tr>
<td>III. Oculomotor nerve</td>
<td>Oculomotor groove along medial border of crus.</td>
<td>Superior orbital fissure.</td>
</tr>
<tr>
<td>IV. Trochlear nerve.</td>
<td>Valvula, laterad of frenulum.</td>
<td>Superior orbital fissure.</td>
</tr>
<tr>
<td>V. Trigeminal nerve.</td>
<td>Prelateral part of ponta.</td>
<td>(a) Ophthalmic ramus, superior orbital fissure.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) Maxillary ramus, foramen rotundum.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(c) Mandibular ramus, foramen ovale.</td>
</tr>
<tr>
<td>VII. Facial nerve.</td>
<td>Postpontile groove (lateral of abducent nerve in preolivary part).</td>
<td>Porus acusticus internus; meatus acusticus internus; facial canal; stylomastoid foramen.</td>
</tr>
<tr>
<td>XI. Accessory nerve.</td>
<td>(a) Encephalic part: Dorso-lateral groove of oblongata.</td>
<td>Jugular foramen.</td>
</tr>
<tr>
<td></td>
<td>(b) Spinal part: Lateral column of spinal cord, between ventral and dorsal roots of cervical nerves as far as the fifth and sixth cervical nerves.</td>
<td></td>
</tr>
<tr>
<td>XII. Hypoglossal nerve.</td>
<td>Pyramido-olivary groove.</td>
<td>Canalis hypoglossi (&quot;anterior condyloid foramen&quot;).</td>
</tr>
</tbody>
</table>

The olfactory, optic, and acoustic nerves are **afferent** or sensory nerves.

The trigeminal, glosso-pharyngeal, and vagus nerves are **mixed nerves**.

The oculomotor, trochlear, abducent, facial, accessory, and hypoglossal nerves are **efferent** or motor nerves.

**Dimensions.**—The sagittal or fronto-occipital diameter of the white male adult brain averages 16 to 17 cm.; the maximum width in the parietal region averages 13 to 14 cm., while the maximum height is about 12.5 cm. The dimensions of the female brain are usually somewhat less. The brains of dolichocephalic
individuals are naturally longer and narrower than those of brachycephalic, and other differences in size and shape are found in conformity with the cranial configuration and other factors.

The Development of the Brain and the Usual Classifications of its Subdivisions.—The cephalic region of the embryonic neural plate is characterized, as already pointed out (p. 816), by a rapid process of expansion and intensity of growth-energy which seems to indicate the higher functional potentiality of what is to become the brain. The fusion of the margins of the neural plate, proceeding rapidly cephalad and caudal from about the cervical region, soon effects the complete closing in of the brain portion of the neural tube and its complete separation from the overlying ectoderm. For a brief period prior to the completion of the tube-formation there exists a minute opening affording communication between the interior of the neural tube and the surrounding amniotic cavity; this temporary passage is called the neonule (Fig. 542), and is morphologically the cephalic end of the tube. Its adult position is probably in the hypophysial region.

The simple neuroblast expands very early in intra-uterine life in a sac-like manner proximal to it and is divided into three dilatations or pouches—the primary

![Diagram of the brain showing the superficial origin of the cranial nerves. The Roman numerals indicate the nerves.](image-url)
The nerve system of the human body is demarcated by two constrictions. The vesicles are designated respectively the Fore-brain (Prosencephalon), Mid-brain (Mesencephalon), and Hind-brain (Rhombencephalon or Metencephalon).

The constriction between mid- and hind-brain has been called the *isthmus rhombencephali* by Prof. His, and he regards it as coordinate with the other segments recognized by him; the region, however, no more deserves a definitive segmental value than would the cephalic constriction even if it were dignified by the term *isthmus prosencephali*. This classification has been found acceptable from every comparative standpoint in brain morphology, but attempts have been made to establish a further segmentation into definite anatomical divisions regarding which opinions and usages differ widely and have proven to be a hindrance rather than an aid to the homologization of brain-structures in the vertebrate series. The difficulties in formul-
ting a satisfactory schema of the segmental divisions of the brain will be overcome, perhaps, only by distinguishing the neuromeres or neural segments conforming to the general segmental plan of the vertebrate body. The existence of a neuromerism that is akin to the metameric or serial segmentation of the body, or to the branchiomerism characterizing the arrangement of the branchial arches, is indicated in several ways, but thus far only the earliest embryonic stages and the disposition of certain of the cranial nerves afford a clue to the definitive segmentation of the brain. According to the most recent researches, as many as eleven, sixteen, and even more neuromeres have been established in various vertebrate brains. The hind-brain alone shows from six to eight such neural segments (Figs. 552 and 553). The whole matter is yet so obscure that confusion will be avoided by restricting our description to the three primary divisions and their derivatives without insisting upon the recognition of further definitive segments proposed by various authors in consequence of preconceived ideas obtained from the complicated adult structure of the brain. At this transitional period the student is, however, obliged to be familiar with the commonly accepted—yet provisional—schemes of segmentation and a comparative view is given in the following table:

**Table showing Comparison of the Segmental Schemas Adopted by**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Partes ventrales.</strong></td>
<td><strong>Partes dorsales.</strong></td>
</tr>
<tr>
<td>VI. <strong>Telencephalon.</strong></td>
<td></td>
</tr>
<tr>
<td>Pars optica hypothalami.</td>
<td>Corpus striatum; rhinencephalon; pallium.</td>
</tr>
<tr>
<td>V. <strong>Diencephalon.</strong></td>
<td></td>
</tr>
<tr>
<td>Pars mammilaris hypothalami.</td>
<td>Thalamus; metathalamus; epithalamus</td>
</tr>
<tr>
<td>IV. <strong>Mesencephalon.</strong></td>
<td></td>
</tr>
<tr>
<td>Pedunculi cerebri.</td>
<td>Corpora quadrigemina.</td>
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<tr>
<td></td>
<td>Brachia conjunctiva; velum medullare anterius.</td>
</tr>
<tr>
<td>III. <strong>Isthmus Rhombencephali.</strong></td>
<td></td>
</tr>
<tr>
<td>Pedunculi cerebri.</td>
<td></td>
</tr>
<tr>
<td>II. <strong>Metencephalon.</strong></td>
<td></td>
</tr>
<tr>
<td>Pons.</td>
<td>Cerebellum.</td>
</tr>
<tr>
<td>I. <strong>Myelencephalon.</strong></td>
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<tr>
<td>Medulla oblongata.</td>
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</table>

**Brief Consideration of the Phases of Development of the Brain-tube.**—

1. **Fore-brain.**—The cephalic or fore-brain vesicle widens and expands most rapidly and attains to a comparatively large size even before the mid- and hind-brain vesicles become markedly defined. A series of remarkable developmental changes ensue in the following order: (a) **Optic vesicles** appear as two diverticula, each budding from either side of the primary fore-brain vesicle, their distal ends growing considerably and coming into contact with the overlying epidermis, while the proximal or attached ends assume a stalk-like shape. The distal
sac-like end becomes invaginated and forms the retina of the eye, while the stalk upon obliteration of its cavity forms the optic nerve. It is necessary to state here that as development proceeds the optic stalks become relatively shifted caudad and form more intimate connections with the thalamus and mid-brain.

(b) A second pair of budding vesicles arises cephalad in the dorsal portion of the fore-brain vesicle and are destined to develop into the ponderous hemicerebra with their great ganglia, growing with great rapidity and exceeding in this respect all other parts of the brain. The growth of these secondary fore-brain vesicles is principally in the distal parts, and in this manner each forms a great pouch whose interior communicates with the primary neural cavity through a small opening, the porta, or foramen of Monro. It must be remembered that in these initial
stages the vesicles are all extremely thin-walled, but later the walls thicken or hypertrophy to a marked degree, so that the neural cavity becomes relatively small.

(c) Meanwhile (in the fourth week) the most cephalic portion of the fore-brain also becomes differentiated. As the enlarging hemispherical vesicles crowd upon the median, slower-growing portion, there is observed, on either side, the development of a groove or furrow, the primary arcuate fissure, which demarcates the olfactory region (rhinencephalon) into a cephalic and a caudal portion. The cephalic portion develops into a blind tubular diverticulum, which grows cephalad to form the olfactory bulb and tract, its central cavity becoming obliterated (persistent in certain other mammals), while the caudal portion forms the roots of the olfactory nerve, the preperforatum and the subcallosal gyre.

(d) At the ventral margin of the hemicerebral or secondary fore-brain vesicle an excessive proliferation of cells results in the production of several ganglionic masses—the basal ganglia, of which the largest are the lenticula and caudatum

(e) The median-cephalic terminal wall intervening between the large hemispherical vesicles persists as a thin and relatively undeveloped lamina, the terma.

(f) The remainder of the fore-brain undergoes great hypertrophy in its lateral walls to form the thalami, while the ventral portion develops moderately to form the hypothalamus, tuber, post-hypophysis, and albicantia. The dorsal wall fails to develop and remains epithelial except at a point immediately adjacent to the quadrigeminal lamina of the mid-brain; here a diverticulum grows out to form the epiphysis (a rudimentary structure in man, but undoubtedly of functional use in ancestral vertebrates).
(q) The cavity of the primary fore-brain vesicle undergoes alterations in form as the secondary metamorphoses of its walls proceed in the course of development.

The hollow cerebral buds so rapidly outstrip all other parts of the brain that their internal cavities, the lateral ventricles, become the most spacious of the ventricular
system. The great hypertrophy of the thalamic ganglia in the lateral walls of the primary fore-brain determine the sagittally placed, slit-like form of the so-called third ventricle. The cavities of the optic and olfactory buds become obliterated.

II. Mid-brain.—The second primary vesicle becomes somewhat later differentiated and takes a less prominent part in the adult brain. Its dorsal wall goes into the formation of four eminences, the quadrigemina, while the lateral and ventral sections grow considerably to form the crura. The neural cavity within the mid-brain persists as the narrow aqueduct joining the third and fourth ventricles.

III. Hind-brain.—The third primary brain-vesicle is demarcated from the mid-brain by a marked constriction to which has been given the term isthmus rhombencephali. The hind-brain is specially characterized by the great expansion of its thinned-out, membranous dorsal wall caudad, while cephalad the dorsal wall becomes very much thickened as the proton or fundament of the cerebellum.

The ventral and lateral parts undergo thickening to form the pons and oblongata.

**Flexures of the Brain-tube.**—The difference in growth-rate of the different parts of the brain-tube and the marked disproportion between the rapid brain-growth and slower head-growth causes the encephalic neural tube to become sharply bent upon itself at certain points. The first flexure to occur is involved in a bending of the entire head and takes place in the region of the mid-brain; this flexure is termed the cephalic flexure. A second bending of the tube occurs at the junction of the spinal cord and hind-brain; this is termed the cervical flexure and is so pronounced in the fifth week of intra-uterine life that the brain-tube and spinal cord form a right angle with each other. A third flexure is produced, in consequence of the other two, in the region of the future pons, and is therefore called the pontile flexure. Subsequently the cervical and pontile flexures are obliterated by a gradual straightening of this portion of the brain axis.
Dorsal and Ventral Laminae or Longitudinal Zones of the Brain.—Quite like the longitudinal division of the developing spinal cord, there is a differentiation of the brain-tube into dorsal and ventral zones, though much less clearly shown. The limiting furrow between the two is not demonstrable in the forebrain; at least it is disputed, on good grounds, that it exists there. It is claimed, even, that three such longitudinal divisions exist on each side (Kupffer) and the formation of the cranial nerves is not quite comparable to the spinal nerves, although there is a fair homology with their dorsal-sensor and ventral-motor functional differentiation, despite their frequent admixture in some cranial nerves or the

![Diagram of brain development stages](image)

**Fig. 560.—Three stages in the development of the oblongata, showing the metamorphosis of the rhomboidal lip.** (Modified after His.)

The total absence of the one category in others. Thus the motor elements do not extend higher than the mid-brain and the dorsal division preponderates in the more highly organized parts of the brain, becoming predominant in the higher vertebrate species—particularly in man.

In its simplest expression the brain is a tube like the rest of the central nervous axis, but a remarkably modified one. There is the same primitive endymal lining throughout its interior; there is likewise a central tubular gray mass of ganglionic tissue which, however, undergoes nuclear differentiation in some portions, atrophies in others, while in certain localities it is crowded away from
the central cavity by the intrusion of white-fibre masses which are chiefly commissural. A total atrophy occurs in a part of the dorsal wall of both fore-brain and hind-brain; partial atrophy is observable in the floor of the third ventricle, near the chiasm, once perhaps the optic centre in the earliest of the ancestral vertebrates, but atrophied in higher forms as the visual tract became secondarily projected in the mid-brain. Great hypertrophy characterizes the growth of the ganglionic gray in the floor of the lateral ventricle (cerebral vesicle), resulting in the formation of nugget-like masses, the caudatum, lenticula, and amygdala. The central gray of the primary fore-brain also undergoes great hypertrophy, but in the lateral walls only, to form the large, compact thalami.

As in the cord, fibre masses develop ectad of the central tubular gray in some localities, while in other regions the ganglionic gray remains at the surface and the white conducting substance is developed on its inner aspect. Thus we have, secondarily, the formation of superficial gray matter as the cortex (or rind) of the cerebrum and cerebellum. The isolation of ganglionic gray masses from the primitive central tubular gray and their differentiation into cell-nests (nidi or nuclei) is also observable in the reticular ganglionic formation of the oblongata and pons as well as in the roof of the mid-brain. Certain aggregations of gray ganglionic tissue are intercalated in the course of fibre strands, receive an admixture of these, and are regarded as terminal, interrupting, or as condensing
stations not unlike some very complex relay telegraph system. The olive, dentatum, rubrum, the nuclei of the gracile and cuneate funiculi, the basketwork intercalations of the reticular and lemniscus fields belong to this intrrafascicular type of ganglionic structures.

The plan of structure of the brain differs, therefore, from the comparatively simple arrangement of the gray and white substance in the spinal cord. In the brain the gray substance is not centrally situated throughout, and there is a tendency to nuclear differentiation of great and small ganglionic masses. These are connected with each other and with the centres in the cord by longitudinal strands of fibres of greater and lesser length, as well as by transverse associating fibres uniting the bilateral nuclei of the same ganglionic category; with the periphery they gain connection through the cranial nerves and (via the spinal cord) the spinal nerves.

In tracing the various structures of the brain from the oblongata to the cerebral cortex we follow anatomically what nature has done in the evolution of the highest type of brain from that of the simplest and most ancient vertebrate. In the oblongata lie the centres which exert a very direct influence over those of the entire cord. The striate bodies and the thalamri form a connecting link between the higher cerebral cortex and the oblongata and cord below. The extensive cerebral cortex, an aggregation of psychic centres and therefore the seat of the will, controls the activities of the fore-brain ganglia (striatum, thalamus) and the cerebellar cortex, and these in turn preside over the functions of lower centres, as in the way of motor responses to external impressions; such reactions may be delayed or immediate according to the exercise of the will-power residing in the cerebral cortex.

This control by the will is intensified the higher we ascend the animal scale; the pyramidal tract, which originates in the cerebral cortex and threads its way to the motor centres of the spinal cord without interruption along the brain-axis, is better developed in man than in any other animal. In the course of evolution the lower or more automatic ganglia and tracts remain relatively about the same in mass as in other mammalia, but the higher, more intellectual ganglia surpass these in growth so that there is an apparent but not real diminution of the automatic systems observed in the human brain.

It has been seen from the foregoing brief accounts of the development of the nervous system that the most prominent feature is the redundant growth of the

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**Fig. 562.**—Scheme showing the connections of the several parts of the brain.
cephalic or brain end of the neural tube. Comparative neuro-anatomic researches have thrown much light upon the probable genesis of this remarkable characteristic. The ancestral vertebrate, built upon the segmental type, was a swimming animal, and its locomotion took place in the direction of its long axis. In its progress through the water the cephalic (or anterior) segments were those which first encountered the foreign objects floating in the same medium. It was for these segments to determine the quality of the objects encountered—whether they were inimical or indifferent or beneficial to its individual ends. The sensory periphery, in consequence of the demands of evolution, underwent specialization in the development of olfactory and gustatory end-organs for testing the quality of the food and of the surrounding medium; optical organs for perceiving rays of light; auditory organs for the appreciation of certain oscillations of the surroundings; while others, strictly tactile in nature, underwent elaboration as such in the development of sensitive antenna or tentacles. Motor contrivances, useful in the quest for food or in encounters with the enemy, were developed in the way of powerful jaws and masticatory muscles. In brief, a remarkable specialization and differentiation of structure attended the development of the head-end and with it the central organ of control kept pace. In the human species we find certain of these structural characteristics in a highly developed condition, while others have dwindled or disappeared in the course of evolution. Thus in the myxinoide fishes and the lamprey the cerebral hemispheres themselves are mere appendages of the olfactory lobes; the sense of smell was probably the most important in lower animals. In the brain of man conditions are reversed and the olfactory system is seen to have dwindled to an extreme degree as compared with the immense size of the cerebrum; this in conformity with the relatively slight use made of the smell-sense in the mental life of man. Other organs of special sense, however, became augmented and these, together with the nerve-mechanisms controlling the vital functions (respiration, circulation), required a more and more elaborate central nervous organ for the harmonious interaction of the several elements. This central organ or brain developed, in bulk and complexity, hand in hand with the increase of the intellectual faculties. Man’s most manifest distinction from other animals has resulted from a remarkable evolutionary growth in brain-size and brain-power; and as the brain is the material organ of mental and moral manifestations, we find in mankind the highest degree of superiority and culture—not only as compared with the nearest related apes, but of the civilized and progressive races as compared with the primitive and unprogressive races.

DESCRIPTIVE ANATOMY OF THE ADULT HUMAN BRAIN.

Morphologically considered, the brain consists of a common trunk (or brain-axis) from which the two cerebral hemispheres crop out like swollen terminal buds, while the cerebellum is an excrescence of the trunk itself. The axially situated brain-axis or "brain-stem" \(^1\) comprises, roughly speaking, the axial parts of all three primary divisions of the brain-tube: (a) oblongata, (b) pons, (c) mid-brain, (d) thalamic division of fore-brain. In this brain-stem lie the majority of the ganglionic masses enumerated above, together with the nerve-tracts uniting the various cell-nests in (presumably) automatic coördination as well as the great nerve-tracts connecting the spinal gray with the cerebral hemispheres, the thalami,

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\(^1\) Also "brain-isthmus." a loosely used term. It may here be remarked that most extant accounts of the anatomy of the brain over-emphasize the distinction of brain-parts from each other. Some authors follow one or another system based upon the theories of the segmentation of the brain-tube; others divide the brain into (a) rhombencephalon or hind-brain and (b) cerebrum, comprising mid- and fore-brain. None of the classifications proposed are, as already pointed out, quite satisfactory. The continuity of the parts can only be interrupted arbitrarily, and such procedure leads to a too narrow conception of brain-structures single and apart rather than serial and connected.
cerebellum, and the ganglia of the oblongata (including the cranial-nerve nuclei), and still other tracts connecting the oblongata with the cerebral hemispheres, the cerebellum, and the special ganglia of the pons and mid-brain.

**Parts Derived from the Hind-brain (Rhombencephalon). External Morphology.**

The Oblongata (Medulla Oblongata; Spinal Bulb; Post-oblongata of Wilder; Myelencephalon).

The oblongata is the continuation cephalad of the spinal cord, the transition lying at the level of the foramen magnum and marked by the decussation of the pyramids. Its cephalic limit is sharply defined ventrad by the rounded margin of the pons, while its dorsal surface is sunk into the cerebellar vallecula. The length of the oblongata along its ventral surface is 20 to 25 mm.; its maximum width at the pontile end is 17 to 18 mm., and half as much at its transition into the spinal cord; its maximum thickness is about 15 mm. Its expansion as it approaches the pons gives it the form of a truncated cone. The ventral surface rests upon the basilar groove of the occipital.

**Fissures.**—The ventral and dorsal fissures of the cord are continued upon the oblongata, making it a bilaterally symmetrical structure. The ventral or ventro-median fissure (*fissura mediana anterior*), at the level of the foramen magnum is interrupted by a number of obliquely intercrossing fibres, called the decussation of the pyramids. Beyond this interruption the ventral fissure passes cephalad to end at the ventro-caudal border of the pons in a recess called the postpontile recess or foramen caecum.
The dorsal or dorso-median fissure (fissura mediana posterior) is of short extent upon the oblongata, for the neural cavity is here expanded into a rhomboideal fossa whose dorsal wall, profoundly atrophied, is represented only by a delicate membranous lamina; the dorsal fissure rapidly becomes shallower as it ascends to cease at the caudal apex of the "fourth ventricle."

Like the spinal cord, the surface of each half of the oblongata is divided into three longitudinal districts by fissures called the ventro-lateral and dorso-lateral fissures. Of these the latter only is a continuation of the fissure of the same name in the spinal cord.

The ventro-lateral fissure (sulcus lateralis anterior) of the oblongata demarcates the ventral column (pyramid) from the lateral column as well as the olive, and the roots of the hypoglossal nerve, arranged in linear order, emerge from this fissure. (The ventro-lateral fissure of the spinal cord becomes obscured as it ascends into the oblongatal region, for cephalad of the emergence of the ventral roots of the first cervical nerve a band of superficial arcuate fibres usually obliterates all traces of the furrow.)

The dorso-lateral fissure (sulcus lateralis posterior) of the oblongata is directly continuous with the same-named fissure of the spinal cord, and the root-bundles of the accessory, vagus, and glosso-pharyngeal nerves are attached along the bottom of this fissure. Unlike the dorsal roots of the spinal nerves, the root-bundles of these three cranial nerves are not all composed of afferent fibres arising in extraneous ganglionic cells and entering the oblongata, for the accessory nerve is purely efferent and the vagus contains both afferent and efferent fibres.

Areas.—The ventro-lateral and dorso-lateral fissures with their rows of nerve-fascicles divide the surface of the oblongata on each side into three districts which appear to be continuous with the three columns of the spinal cord; they are not so in reality, however, owing to the rearrangement of the fibre-tracts and the central ganglionic mass in the myel-oblongatal transition. This portion of the brain-axis is sculptured into several eminences and depressions; of the eminences, some, like the olives, the tubercula cinerea, and the claves are due to the accumulation of gray substance beneath the surface at that point; others, like the pyramids and restes, are due to the prominence at certain points of the surface of the great nerve-tracts.

Areas of the Oblongata.

I. Ventral Area:
   Pyramid.

II. Lateral Area:
   (a) Lateral Tract.
   (b) Olive.

III. Dorsal Area, marked by slight furrows dividing it into:
   (a) Funiculus gracilis.
   (b) Funiculus cuneatus.
   (c) Funiculus lateralis and tuberculum cinereum.

The last three structures mentioned appear to become fused cephalad to continue as the restis; in reality the restis is formed in a different manner.

I. The Pyramids (pyramis medullae oblongatae).—The pyramids constitute the oblongatal portion of the direct cerebro-spinal efferent tracts conveying (voluntary) motor impulses from the precentral cortex, through the internal capsule, crusla, and ventral pons to descend in the crossed and direct pyramidal tracts to the efferent (motor) cell-groups in the ventral horns of the spinal gray. In their external appearance in the oblongata they are moderately constricted at their pontile ends, appear to become somewhat expanded, to again taper as they pass, partly into the ventral columns of the cord, partly, by decussation, into the lateral
columns. The pyramids are separated from each other by the ventral (or ventromedian) fissure except where this is more or less completely obliterated by the decussating bundles. Each pyramid is bounded laterally by a slight furrow, the ventro-lateral or pyramido-olivary groove, in which arise the hypoglossal nerve-roots and which separates the pyramid from the olive. The pontile end of each pyramid is frequently traversed by a band of arched fibres (fibræ arcuatae etales; ponticulus of Arnold (not the ponticulus of Heune), the ecal arcuate fibres.

The Decussation of the Pyramids (decussatio pyramidum) is a term given to the obliquely intercrossing bundles seen at the oblongata-myelon transition. The extent to which this decussation occurs and the degree of its visibility varies in different individuals. While in most cases the majority (90 per cent.) of the fibres cross the median line in this decussation to continue as the crossed or lateral pyramidal tract, it is sometimes observed that a larger share of the fibres pass into the direct or uncrossed pyramidal tract with a corresponding reduction of the crossed tract. Occasionally the decussating bundles are so deeply situated in the ventral fissure as not to be visible.

II. Lateral Area.—The lateral area of the oblongata is continuous with that of the spinal cord and is bounded by the dorso-lateral and ventro-lateral fissures. It is composed of the ventro-lateral spino-cerebellar tract (fasciculus anterolateralis superficialis), the ventro-lateral ground-bundle (fasciculus proprius anterolateralis), and the direct spino-cerebellar tract (fasciculus cerebellospinalis [Flechsig]), while it is invaded from above by the crossed pyramidal tract. The olive is interpolated in the cephalic part of this area.

The Olive (oliva; olivary body) is a prominent, elongated oval mass bulging from the cephalic part of the lateral area of the oblongata, bounded by shallow grooves, of which one, for the hypoglossal nerve-roots (ventro-lateral fissure) separates it from the pyramid, while the other, containing the nerve-fascicles of the vagus, glosso-pharyngeal and accessory nerves, separates the olive from the restis. From the pons it is separated by a shallow groove in which a band of arched fibres is sometimes seen. Numerous white fibres (ectal arcuate fibres) emerging from the ventral fissure and traversing the pyramid loop across the lower parts of the olive to enter the restis. The olive is formed by the olivary nucleus, embedded in a thin layer of white matter.

The olive is about 12 mm. in length and 5 mm. in breadth.

III. Dorsal Area. (a) Funiculus Gracilis.—The funiculus gracilis is the direct continuation of the tract of the same name in the spinal cord. It is a narrow white band placed along the dorso-median fissure, and separated from the funiculus cuneatus by the dorso-paramedian furrow (sulcus intermedius posterior). At the apex of the rhomboidal fossa (fourth ventricle) each funiculus gracilis diverges from the median plane, presenting at this point a club-like enlargement, the clava. The prominence of the funiculus gracilis (and clava) is due to the gray nucleus funiculi gracilis beneath.

(b) Funiculus Cuneatus.—The funiculus cuneatus is the direct continuation of the tract of the same name in the spinal cord. It enlarges as it ascends, exhibiting a slight eminence or enlargement, the cuneate tubercle (tuberculum cinereum), which is marked only in the oblongata of young individuals, and is due to the nucleus funiculi cuneati beneath.

(c) Funiculus Lateralis and Tuberculum Cinereum.—The funiculus lateralis is a longitudinal prominence which gradually enlarges cephalad into a slight tubercle, the tuberculum cinereum (tubereulum Rolandi), marking the approach of the gliosa to the surface so as to form a prominence at a level with the lower border of the olive.

The Restis (corpus restiforme) occupies the upper dorso-lateral area of the oblongata on each side, lying between the floor of the fourth ventricle and the roots.
of the vagus and glosso-pharyngeal nerves. This structure might at first glance appear to be the continuation of the three funiculi just described. But as a matter of fact it is made up of the direct spino-cerebellar tract, a set of ectal arcuate fibres (fibrae arcuatae externae) and a set of ental arcuate fibres (fibrae arcuatae internae). Each rests assists in forming the lower part of the lateral boundaries of the fourth ventricle and then enters the cerebellum as the postpeduncle of that body.

The Pons and Pre-oblongata (Pons Varolii; Protuberantia Annularis).

The pons is a prominent white mass on the ventral aspect of the brain-stem which is interposed between the oblongata and the crura. It is convex from side to side and its fibres, running chiefly in a transverse arched direction, are gathered into rounded, compact strands on either side, to continue as the medipeduncles into the white substance of the corresponding cerebellar hemisphere. The fibre-bundles of the pyramidal tracts thread their way through the pons on either side of the median plane and small aggregations of gray substance (nuclei pontis) are packed in the intervals between the transverse pontile and longitudinal pyramidal fibre-bundles.

The Ventral Surface (pars basilaris pontis).—The ventral surface of the pons is in relation with the basilar process of the occipital and the dorsum sellae of the sphenoid. A shallow mesal groove lies between the eminences produced by the pyramidal tracts in their course through the pons. The groove is called the basilar groove (sulcus basilaris), as the basilar artery is usually accommodated in it; the artery is not, however, a factor in the production of the groove. The large sensor and small motor-root bundles of the trigeminal nerve pierce the mass of the pons near the prepiriform border, and a line drawn from this nerve-
root to that of the facial nerve is usually employed as an arbitrary boundary between the pons proper and the medipeduncle of the cerebellum. The abducent nerve emerges from the postpetontile border (prepyramidal part); the facial and acoustic nerves are attached farther laterad.

While most of the superficial fibre-bundles of the pons are seen to arch transversely, certain small compact bundles1 are seen to extend in an obliquely longitudinal direction from the region of the trigeminal nerve-root to and among the roots of the facial and acoustic nerves.

The Pre-oblongata (pars dorsalis pontis; pars metencephalica medullae oblongatae).—The pre-oblongata is not sharply demarcated from the oblongata or the tegmentum and crusta of the mid-brain and the margins of the pons on the ventral surface afford only arbitrary boundary lines; for in the vertebrate series the pons varies greatly in width and its margins can hardly be accepted as the boundaries of a definitive brain-segment. The dorsal surface of the pre-oblongata is continuous with that of the oblongatal ventricular surface, and its description more properly belongs to a consideration of the anatomy of the fossa rhomboidalis or “floor of the fourth ventricle.”

Fourth Ventricle of the Brain (Ventriculus Quartus).

In a previous section on brain-development it has been pointed out how the growth-changes and differentiations in the hind-brain differ from those of the rest of the neural tube in that there is a marked disproportion in the degree of growth in the dorsal and ventral walls. While the ventral wall thickens greatly throughout to form the pons-oblongata, the dorsal wall hypertrophies in its cephalic portion to form the cerebellum, while caudad thereof the roof atrophies and expands and becomes so attenuated as to be represented merely by a thin epithelial membrane. The outward folding of the walls of the neural tube in this region creates an expansion of the central cavity in the form of a rhomboidal fossa roofed in by the cerebellum and a thin epithelial layer. A time-honored custom enumerates this as the fourth of a system of ventricles of which the other three lie in the forebrain.

A cast of the cavity (Fig. 565) shows it to be irregularly pyramidal, with a lozenge-shaped base and ridge-like apex extending from side to side, corresponding to the acute-angled recessus tecti in the fastigium (“gable roof”) formed by the valvula and velum. Such a cast also indicates the ventral extension of the cavity from the lateral angles of the rhomboidal base in the form of the lateral recesses.

It is customary to describe for the fourth ventricle a roof and a floor, although an

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1 Called the inter-radicular pons tract by E. C. Spitzka (1884) and more recently described as part of the corpus ponto-bulbare by Essick (American Journal of Anatomy, vii, 1).
FOURTH VENTRICLE OF THE BRAIN

examination of a sagittal section of a brain hardened in situ shows the floor to be in a vertical plane in the erect attitude. Caudal the cavity is continuous with the minute central canal of the spinal cord and postoblongata (in part); cephalad it passes into the aqueduct or mesocle. The dorsal wall or "roof" is formed by the valvula, the prepeduncles, metatela, and fastigium of the cerebellum. The ventral wall or "floor" is the rhomboidal fossa occupied by the expanded central gray of the pre- and postoblongatal portions of the hind-brain.

"Floor" of the Fourth Ventricle (fossa rhomboidea).—The "floor" of the fourth ventricle is lozenge-shaped and exhibits regional elevations, depressions, and color differences which are in relation with the deep anatomy of the oblongata and tegmentum (of pre-oblongata). It is divided longitudinally into symmetrical halves by a median groove and each lateral half is subdivided into a larger cephalic and a smaller caudal triangle by white, transverse stria, composed of bundles of myelinic fibres connected with the acoustic tract and appearing to sink beneath the surface near the median groove. The portion occupied by these striae acusticae (striae medullares; striae transversales) is termed by His the pars intermedia as distinguished from the pars superior and pars inferior or frontal and caudal triangles respectively. Much variation is met with in regard to the course and degree of prominence of the striae acusticae (Fig. 566). There may be none visible or as many as twelve distinct bundles; bilateral symmetry is the exception and not infrequently one or more bundles run obliquely cephalo-laterad—the striae oblique (conductor sonorus). This irregularity of the acoustic striae has led to another mode of division of the "floor" for descriptive purposes—each side to be divided into a median and a lateral area, indicated by a more or less well-marked groove, the lateral furrow (sulcus limitans), connecting the superior and inferior (ala cinerea) foveae. This groove probably corresponds to one of the interzonal sulci of the embryonic tube and in a gross way it separates the motor and sensor fields of the "floor." The median area is usually a continuous ridge which is quite accentuated in the cephalic division as the eminentia abducentis, while caudal it becomes narrowed as it approaches the closed part of the oblongata. The convergence of the median and lateral furrows at the caudal apex of the rhomboidal fossa gives the appearance of the point of an ancient writing reed- or quill-pen; hence the term calamus scriptorius.

In the caudal quarter-triangle a middle area is occupied by an elongated triangular field whose depressed apex is directed frontad. A slight oblique ridge, the funiculus separans, composed chiefly of neuroglia, separates the area postrema

![Varieties of fourth ventricle](image-url)
caudal from the *ala cinerea* or *trigonum vagi* of a pronounced grayish color. The apical depression has been termed the *fovea inferior*. Mesally lies a narrow triangular field with its apex directed caudal and with slightly raised surface—the *trigonum hypoglossi*. This area is resolved into two fields by a single or double formation of oblique rugae affording a "feathered" appearance to the lateral field, *area plumiformis*. Laterad of the trigonum vagi lies the caudal portion of the lateral area of the "floor," also called (in part) the *area vestibularis* (*area acustica*) and crossed over its middle by the *stria acusticae* when these are present. The area vestibularis is an irregularly triangular raised surface with its convex base toward the median line, and extending laterally to the attachment of the metatela and into the lateral recess. In the fovea and in certain lower vertebrates the area is more prominent and is designated the *tuberculum acusticum* s. *vestibularis.*

![Diagram](image)

**Fig. 567.—Surface markings and topography of the principal nuclei of the floor of the fourth ventricle.** (Modified from Streeter.)

The "frontal" division of the floor or triangular quarter-field is marked by a depression at about its middle, the *superior fovea*, from which the slight "lateral furrow" runs caudal, and but for the intervention of the strie would reach the inferior fovea. Cephalad of the superior fovea, and continuing some distance along the aqueduct, is the *locus ceruleus*, which owes its color to the refraction of the pigmented cells, the *substantia ferruginea*, by the milky-white endyma. At this altitude, the medial elevation between the superior fovea and the median sulcus is accentuated into a fairly pronounced eminence, the *eminencia abducentis* (*eminencia teres*), overlying the nucleus of the abducent nerve and the genu of the root of the facial nerve. The portion of the median sulcus intervening between the eminencia abducentis is correspondingly depressed to form the *fovea mediana*.

The ventricular features enumerated above correspond in a crude way to the deep structures of the pons-oblongata, and most of the cranial nerve nuclei are held in a rhomboidal frame formed by the pre- and postpeduncles. The surface-markings are only imperfect replicas of the subjacent structures; the various cell-
FOURTH VENTRICLE OF THE BRAIN

nests overlap each other more or less and their relations can best be studied in the projection drawing in Fig. 567.

Membranous Portion of the "Roof" of the Fourth Ventricle.—The caudal extension of the hypertrophied cerebellum hides from view the whole of the rhomboidal fossa, but this structure, as before stated, forms but a part of the actual dorsal wall or "roof." This includes the converging prepeduncles, the valvula intervening between these, the fastigium of the cerebellum, the velum, and the metatela.

The Velum (velum medullare posterior).—The velum is a thin and narrow lamina of white substance, continued lateral as the floroculi of the cerebellum. At its caudal edge, i. e., where nerve-tissue ceases, the endyma or ventricular lining epithelium and the pia over this portion coalesce to form a delicate membrane—the metatela—attached along the caudo-lateral boundary-line of the rhomboidal fossa. Along this attachment there is another intrusion of nerve matter between the endymal and pial layers; this reenforced lamina is usually termed the ligula and may be traced on the clava and cuneate tubercle, thence lateral over the restis to bound the lateral recess. The structure is probably a vestige of the secondary rhomboidal lip and has actually been found to be a part of the ponto-bulbar body referred to above. Another small semilunar lamina of nerve tissue bridges the caudal apex of the fourth ventricle and is called the obex. This structure is often devoid of nerve tissue and is then a mere membranous lamina.

Except in rare instances, the metatela is perforated a short distance from the calamus region. The opening is of variable shape and size; it permits of communication between the ventricular cavity and the subarachnoid space and is termed the metapore (apertura medialis ventriculi quarti) or foramen of Majendie.

Similar apertures at the extremities of the lateral recesses, and called the foramina Luschke (apertura lateralis ventriculi quarti) also permit of a tidal flow of the cerebro-spinal fluid.

The metaplexuses or choroid plexuses of the fourth ventricle are highly vascular infoldings of the metatela, one on either side of the median plane, from each of which shoots extend lateral into the lateral recesses. As the choroid plexuses of the brain are always formed by infoldings or invaginations of the membranous portions of the brain-tube, the endymal continuity is nowhere interrupted.

Internal Structure of the Postoblongata.—While the spinal cord remains a closed tube with centrally situated gray, the oblongata opens out on the dorsal aspect so as to uncover its part of the neural canal as the "floor" of the fourth ventricle. This involves a tilting of the functionally differentiated gray segments and, after a gradual transition in the post-oblongata, the motor gray is to be sought nearest the middle line, the mixed gray just ektad, while the sensor is the outermost of all. Instead of the ventral, lateral, and dorsal horns of each half of the spinal cord, we have an ental, middle, and ectal cornu in each half of the oblongata. The positions alone have changed; the functional relations to nerve-roots having corresponding functions are homologous. Thus the motor hypoglossal nucleus is placed in the mesal part of the ventricular floor, while the terminal nuclei of the afferent vagus, glosso-pharyngeal, and auditory nerves lie in the lateral part.

Another cardinal change in the internal structure of the oblongata, accompanying the preponderating development of the cerebrum and great basal ganglia, is caused by interrupting and decussating fibre systems which seek passage through the brain-stem and encroach more or less on its primitive architecture. While in the spinal cord there is a perfect continuity of the central tubular gray, we find in the oblongata more pronounced peninsular and isolated insular nuclei or ganglionic gray masses.

Pyramidal Decussation (decussatio pyramidum).—An important change in the internal structure is caused by the passage of the fibres of the pyramidal tract as these pass to the same and opposite sides of the cord, the latter category forming
the pyramidal decussation. In consequence of this passage of white (crossed pyramidal) fibres through its substance the ventral gray horn is broken up into a coarse network, while one portion of it, the caput cornu, is entirely separated from the rest; only a small portion of the base of the cornu remains intact close to the ventro-lateral aspect of the central canal. The caput cornu, thus separated, is displaced laterally, and comes to lie close to the caput cornu dorsalis, which has also shifted its position. In consequence of this breaking up of the greater part of the ventral gray cornu by white fibres a coarse network is formed in the anterior and lateral areas of the medulla, which is named the formatio reticularis.

The gliosa (gelatinosa Rolandi) of the dorsal horn is continued into the oblongata, but becomes insignificant, relatively, in the pre-oblongata. The spinal root of the trigeminal nerve is in ectal relation with the gliosa; at higher levels the spinal root of the vestibular nerve intervenes.

**Decussation of the Lemnisci.**—A similar change, dorsad and cephalad of the pyramidal decussation, is caused by the decussation of axone bundles arising in the nuclei of the gracile and cuneate fasciculi (Goll and Burdach). At this level the base of the dorsal gray cornu undergoes change in the form of two thick dorsal peninsular outgrowths which form the nuclei of termination of the axones in the gracile and cuneate fasciculi; externally these gray masses produce the eminences of the clava and cuneate tuberde. The axones from these nuclei stream mesad and cephalad in a series of con-
centric arches, decussating in the raphé with the bundles of the opposite side to form the decussion of the lemnisci or sensor decussion. Cephalad of this decussion the lemnisci are two bundles of fibres coursing on either side of

the raphé between the olives, and just dorsal of the pyramids; their further course toward the cerebrum will be described farther on.

1 Also called "mesal lemnisci" in contradistinction to the "lateral lemnisci"—of different origin.
With the extension of the central gray to form the floor of the fourth ventricle, the caput cornu dorsale is displaced ectad so as to almost reach the surface, where it forms a projection, the funiculus lateralis (Rolandi), which enlarges caphalad into a distinct prominence, the tuberculum cinereum. At a higher level the caput is separated from the surface by the spinal root of the trigeminal nerve and by the ectal arcuate fibres (Fig. 575). The cervix of the cornu becomes broken up into a reticular formation by the decussating fibres. A portion of the base is placed ectad of the nucleus funiculi cuneati and is called the accessory cuneate nucleus, supposed to be a continuation of Clarke’s column.

The Formatio Reticularis (Fig. 575).—The formatio reticularis consists of diffusely scattered gray substance in a meshwork of white fibres. It is far more abundant in the pre- and postoblongata than in the cord. In trans-sections of the postoblongata it is seen to be divided by the hypoglossal nerve-root fascicles into a mesal and a lateral field. In the mesal field the gray substance is scanty and white fibres—principally longitudinal ones—preponderate; this is called the formatio reticularis alba in contradistinction to the lateral grayer reticulated field, the formatio reticularis grisea. Its numerous nerve-cells mostly possess short axones and for the most part exercise associative functions for the constantly active centres of respiration (nuclei of the vagus, phrenic, facial, etc.). Certain axones of longer course are collected into a small compact bundle just ventrad of the ventricular...

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**Diagram 573.** Transverse section of the oblongata at the lower end of the olives. The roof of the fourth ventricle is not represented. (Testut, after Duval.)

**Diagram 574.** Transverse section of the oblongata at the middle of the olives. The roof of the fourth ventricle is not represented. (Testut, after Duval.)
floor and central canal (and aqueduct in the mid-brain), and known as the medial longitudinal fasciculus (*posterior longitudinal bundle*). This tract is in intimate association with the cranial nerve nuclei. The formatio alba is principally made up of this tract and the lemniscus (interolivary stratum).

The Raphé (Fig. 575).—The raphé is situated in the middle line of the oblongata above the decussation of the pyramids. It consists of nerve-fibres intermingled with nerve-cells. The fibres have different directions, which can only be seen in suitable microscopic sections, thus: (1) Some run dorso-ventrad; these are continuous with the superficial arciform fibres. (2) Some are longitudinal; these are derived from the arciform fibres, which on entering the raphé change their direction and become longitudinal. (3) Some are oblique; these are continuous with the deep arciform fibres which pass from the raphé.

The nerve-cells of the raphé are multipolar; some are connected with the dorsolateral fibres, others with the superficial arcuate fibres.

The Restis.—The restis succeeds the gracile and cuneate nuclei in the dorsolateral part of the oblongata. Its fibres converge from various sources and ultimately enter the cerebellum as its postpeduncle. For a description of these fibre systems see the section on the “peduncles of the cerebellum.”

The Nucleus of the Olive or Inferior Olivary Nucleus (*nucleus olivarius inferior*) is a corrugated lamina of gray substance whose extent nearly corresponds to that of the external elevation called the olive. It can be compared to a hollow oval sac or purse, slit on its mesal aspect and the edges of the slit everted. The opening is called the hilum. Numerous fibres stream into the interior through the hilum, while others cut through the lamina to join the fibre-arches of the reticular field and there passing toward the restis.

What are known as accessory olivary nuclei (*nucleii olivarii accessorii*) are smaller detached or semidetached portions of the olivary nucleus named, according to their position, the dorsal and medial accessory olivary nuclei (*nucleus olivarius accessorius dorsalis et medialis*). The root fascicles of the hypoglossal nerve pass between the medial accessory nucleus and the chief olivary nucleus.
The olivary nuclei play an important part as relay stations in cerebellar connections. A considerable mass of fibres, the olivo-cerebellar fibres (fibrae cerebello-olivares), originate in the olivary nucleus of one side to enter the cerebellum along the restis of the opposite side. A much lesser number of fibres, running contrariwise, reach the olivary nuclei from the opposite cerebellar hemispheres—the cerebello-olivary (vestibulo-olivary tract) fibres. The olivary nuclei are also the termini of two important tracts: (1) the spino-olivary tract or Helweg's bundle and (2) the thalamo-olivary tract.

The Arcuate Fibre Systems.—The arcuate fibre systems comprise two sets of fibres according as they course dorsad or ventrad of the olivary nuclei:

1. The Ental Arcuate Fibres comprise the olivo-cerebellar fibres, just described, and a number of commissural systems for the association of the segmental reticular gray ganglia and cranial-nerve nuclei. Others pass cerebralward, others to the cerebellum.

2. The Ectal Arcuate Fibres take origin (a) from the gracile and cuneate nuclei and enter the restis of the same side; (b) from the same-nuclei of the opposite side, decussating in the raphé and sweeping ventrad over the pyramid and olive, forming a thin layer over them and ultimately reaching the restis. Many of these fibres are interrupted, on each side, in the nucleus arcuatus, a thin, isolated lamina of gray matter lying on the ventral aspect of the pyramid.

The nucleus lateralis is seen in the lateral column, (lower part of oblongata) as a diffuse gray mass lying between the gliosa and the olive; it gradually disappears cephalad.

The nucleus intercalatus (of Staderini and Van Gehuchten) forms the elongated, wedge-shaped elevation in the medial triangle of the caudal portion of the ventricular floor called the area plumiformis (p. 880); the nucleus derives its name from its (intercalated) position between the hypoglossal and dorso-vagal nuclei. Its functional connections are not yet precisely known.

A nucleus postremus has been described (J. T. Wilson) as lying subjacent to the area postrema.

The nucleus funiculi teretis lies close to the median sulcus in the altitude of the acoustic stricte, and seems to bear an intimate relation to these.

Summary of the Gray Masses in the Postoblongata:

* Central tubular gray (in "closed" part).
* Gray floor of fourth ventricle (in "open" part).
* Gliosa (or gelatinosa Rolandi).
* Nucleus funiculi gracilis.
* Nucleus funiculi cuneatus.
* Nucleus funiculi cuneati accessorius.
* Nucleus lateralis.
* Nucleus olivaris inferior.
* Nucleus olivaris accessorius dorsalis.
* Nucleus olivaris accessorius medialis.
* Nucleus arcuatus.
  Nucleus nervi hypoglossi.
* Nucleus intercalatus.
* Nucleus postremus.
  Nucleus vagi (alæ cinereæ).
  Nucleus vestibularis (spinal division).
* Nucleus funiculi teretis.
  Nucleus ambiguus.
  Nucleus tractus solitarii.
  Nucleus tractus spinalis n. trigemini.
* Formatio reticularis.
In the foregoing enumeration of the gray masses of the postoblongata, those marked with an asterisk have been described above; the remaining structures relate to the deep connections of the cranial nerves and will be discussed in detail under that head.

**Internal Structure of the Pons and Pre-oblongata.**—Trans-sections of the pons also pass through the pre-oblongata (or tegmental part of the pons). To consider first the internal structure of the pons proper (or pars basilaris pontis): The pons is composed chiefly of (1) transverse fibres arranged in coarse bundles, (2) longitudinal fibres gathered in compact bundles, and (3) diffusely scattered masses of gray substance among the fibre bundles, the nuclei pontis.

The **Transverse Fibres.**—The transverse fibres, corresponding to the large size of the cerebellum, are more abundant in man, relatively, than in any other animal. They form a massive series of bundles coursing ventrad of the brain axis from one cerebellar hemisphere to the other. At the caudal border of the pons they embrace the pyramidal tracts as well, but farther cephalad the transverse pontile fibres are seen to intersect the pyramidal tracts, breaking these up into pyramidal fasciculi; still farther cephalad the pyramidal tracts are wholly embedded in the mass of transverse pontile fibres so that these in turn, with reference to the location of the pyramidal tracts, may be divided into a superficial and a deep set. Laterad they are gathered together to form the medipeduncles (described on p. 901).

The **Longitudinal Fibres.**—The longitudinal fibres consist chiefly of the pyramidal tracts, which are solid strands at their entrance to and exit from the pons, but are broken up into lesser bundles at its middle. A certain number of the pyramidal fibres, as well as other cerebro-pontile fibre-tracts, terminate in relation with the cells of the nuclei pontis, as well as certain of the efferent cranial-nerve nuclei. This fact accounts for the demonstrable diminution in bulk of the pyramidal tract in its course through the pons.

The **Nuclei Pontis.**—The nuclei pontis are small aggregations of gray substance (which in serial sections show them to be continuations of the arcuate nuclei) diffusely scattered among the fibre-systems of the pons proper. They are intercalated in the course (1) of tracts passing from one cerebellar hemisphere to the other and (2) of descending cerebro-pontile tracts. The cells of the pontile nuclei send their axones chiefly to the opposite cerebellar hemisphere and play an important part as links in the complex chain of the neurone systems which make the cerebellum such an important organ of senso-motor coordination.

In the contact-zone of pons proper and the pre-oblongata (or pontile tegmentum) lies a group of transversely decussating fibres with interspersed gray masses with large cells called the **trapezium.** This body will be more fully described in connection with the central auditory paths.

The **Pre-oblongata.**—The pre-oblongata (or tegmental part of the pons) is of much smaller bulk than the pons proper, as seen on trans-sections. On the dorsal surface is spread a layer of gray substance, covered by endyma, which forms the floor of the cephalic part of the fourth ventricle. Beneath this gray substance lies the **formatio reticularis** divided into symmetrical halves by the raphé—continued from the postoblongata. Embedded in the formatio reticularis are various isolated masses of gray substance and various more or less compact fibre-tracts. Among the gray masses are several of the cranial-nerve nuclei, to be described in a separate section, and the following:

The **Superior Olivary Nucleus** (**nucleus olivarius superior**) is a small gray mass or aggregation of several smaller masses situated laterad of the trapezium, intercalated in the path of the trapezial fibres and forming a link in the central acoustic chain (Fig. 579).
The **Nucleus Incertus** (Streeter) is an aggregation of gray substance in the floor of the fourth ventricle near the median sulcus and forming a slight, rounded elevation which extends to the aqueduct. Its functional relations are unknown.

**Fibre-tracts in the Pre-oblongata.**—Among the fibre-tracts in the pre-oblongata the chief ones are (1) the medially lemniscus, (2) the laterally lemniscus, (3) the medially longitudinal bundle, and (4) the prepeduncles of the cerebellum.

The **Medial Lemniscus.**—Each medial lemniscus, in its passage through the pre-oblongata, is gathered into a compact, ribbon-like bundle along the contact-zone of the tegmentum and pons proper, latero-ventrad of the trapezium, some fibres of which traverse it on their way toward the raphé. The medial lemniscus has been described in the postoblongata as occupying the field between raphé and inferior olivary nucleus (the interolivary stratum); in its ascent the medial lemniscus gradually trends laterad so that it almost reaches the surface (Figs. 571 and 573).

The **Lateral Lemniscus.**—The lateral lemniscus is a constituent of the central auditory path and will be described more fully in the sequel. In trans-sections above the level of the trigeminal nuclei the lateral lemniscus is seen as a flattened band spreading over the surface (externally the trigonum lemnisci) ectad of the prepeduncle. Its fibres are interrupted by an intercalated nucleus of the lateral lemniscus.

The **Medial Longitudinal Bundle** *(posterior longitudinal bundle).*—The medially longitudinal bundle maintains its position just ventrad of the central gray, close to the raphé.

The **Cerebellar Prepeduncle.**—The cerebellar prepeduncle, in trans-sections, is seen to be a very compact bundle of crescentic outline with the concavity turned toward the ventricular cavity. Its dorsi-mesal edge is joined to the valvula; its ventral border is sunk into the tegmentum and in its ascent it becomes submerged laterally beneath the lateral lemniscus, dorsally beneath the quadrigeminal plate of the mid-brain.

**Summary of the Gray Masses in the Pre-oblongata:**

Nucleus of Abducent Nerve.
Nucleus of Facial Nerve.
Afferent and Efferent Nucleus of Trigeminal Nerve.
Nucleus of Spinal Root of Trigeminal Nerve.

\[ \{ \text{Cochlear Division} \} \quad \{ \text{Dorsal Nucleus.} \]  
\[ \{ \text{Vestibular Division} \} \quad \{ \text{Ventral Nucleus.} \]  
\[ \{ \text{Medial Nucleus.} \]  
\[ \{ \text{Lateral Nucleus.} \]  
\[ \{ \text{Superior Nucleus.} \]

* Superior Olivary Nucleus.
* Nucleus of Trapezium.
* Reticular Ganglionic Formation.
* Nucleus Incertus.
* Nucleus of Lateral Lemniscus.

Those marked with an asterisk have already been described; the remaining structures relate to the deep connections of several cranial nerves to be described in the succeeding section.

**Central Connections of the Cranial Nerves attached to the Hind-brain.**—Eight of the twelve pairs of cranial nerves are attached to the hind-brain portion of the central axis. Their superficial or apparent origin and the cranial foramina of exit are enumerated in the table on page 889. In coordination with the internal descriptive anatomy of the hind-brain the central connections of these eight cranial nerves must now be considered. They comprise:
### CENTRAL CONNECTIONS OF THE CRANIAL NERVES

<table>
<thead>
<tr>
<th>Purely efferent or motor nerves</th>
<th>Mixed nerves</th>
<th>Purely afferent or sensor nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>XII. Hypoglossal nerve.</td>
<td>VI. Abducent nerve.</td>
<td>VIII. Acoustic nerve.</td>
</tr>
<tr>
<td>XI. Accessory nerve.</td>
<td>X. Vagus nerve.</td>
<td>(a) Cochlear division for hearing</td>
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<tr>
<td>(a) Motor accessory to vagus nerve;</td>
<td></td>
<td>(b) Vestibular division for equilibrium</td>
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<tr>
<td>(b) Motor to trapezius and sternomastoid muscles.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor to muscles of scalp and face.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor to external rectus muscle of eyeball.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senso-motor to respiratory tract and upper part of alimentary tract.</td>
<td></td>
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<tr>
<td>Sensor to tongue (and motor ?) to Stylo-pharyngeus muscle.</td>
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<td></td>
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<tr>
<td>Sensor to face, tongue, teeth; motor to muscles of mastication.</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>(a) Motor to muscles of tongue.</td>
</tr>
</tbody>
</table>

Another nerve which pursues a remarkably aberrant course, becoming associated with three of the above-mentioned cranial nerves, is the *nervus intermedius*, known peripherally as the *chorda tympani*. It is chiefly sensor (taste) in function, but also contains efferent fibres which are excito-glandular for the submaxillary and sublingual salivary glands.

In the hind-brain axis lie certain gray masses which are functionally homologous with the nuclear masses in the different parts of the spinal central gray. These defined nests of nerve-elements, from their relations to the cranial-nerve roots, are called the *cranial-nerve nuclei* or *nidi*. Their analogy to the origins of the spinal nerves extends to the shape and character of their cell-elements and their differentiation into (a) *nuclei of origin* and (b) *nuclei of termination* or *recipient nuclei*.

**The Nuclei of Origin.**—Nuclei of origin or motor nuclei are cell-clusters from which arise the axones of efferent nerves or the efferent components of the mixed nerves. Some of these nuclei are in line with the basal portion of the ventral gray horn in the cord below and are termed, owing to their situation near the mesal plane, the *medial nuclei of origin*. Other nuclei are isolated cell-columns in the line of the *caput cornu ventrale* detached by the decussation of the pyramids, termed, from their position in the tegmental substance, the *lateral nuclei of origin*.

The different nuclei of origin of the efferent cranial nerves are under the dominance of the cerebral cortex by way of the cortico-tegmental (or cortico-bulbar) path—usually included in the pyramidal tract.

**The Nuclei of Termination.**—The nuclei of termination or sensor cranial-nerve nidi are likewise repetitions in structure of the dorsal horn of the spinal gray, but with less regularity and definiteness of position. Thus, while the caput gliosum of the cord is continuous with the nucleus of the spinal root of the trigeminal nerve, other recipient or afferent nuclei are more or less isolated in the tegmental substance, while the two (lateral and ventral) nuclei of the cochlear nerve actually lie on the surface of the brain-stem.

The afferent impulses carried in by the sensor cranial nerves excite impulses in the neurones of the nuclei of termination; their axones enter the tegmental substance as arcuate fibres, cross the mesal plane to join the lemnisci to connect with the thalamus and postgeminum and *via* thalamus and postgeminum with the cerebral cortex.

The location of the various cranial nerve nuclei in the brain-stem may be understood by a reference to the diagrams in Figs. 567, 576, 577, and 578.

**Hypoglossal Nerve.**—The nucleus of origin of the hypoglossal nerve is a rod-like cell-column close to the mesal plane, extending for about 7 mm. in the caudal
portion of the fourth ventricle, while its extraventricular portion extends about 5 mm. caudad of the tip of the calamus. Its efferent axones course ventral between the formatio reticularis alba and grisen, thence between the olivary and medial accessory olivary nuclei, to emerge between pyramid and olive. None of the fibres decussate across the middle line, but the nuclei are coördinated by commissural fibres. Axones from cortical cells (ventral third of pre-central gyre) terminate in relation with the cells of the hypoglossal nucleus.

The hypoglossal nucleus permits of subdivision into groups: (a) a medial and (b) a lateral sub-group. The lateral group innervates the palatoglossus and pharyngoglossus, while the medial nuclear group innervates the remainder of the tongue muscles (lingualis transversus and inferior, genioglossus and hyoglossus).

**The Accessory Nerve.**—The accessory nerve is also a purely motor or efferent nerve whose axones arise from an attenuated nucleus, with large multipolar cells, in direct continuation with the nucleus ambiguus cephalad, and with the dorso-lateral cell-column of the ventral horn of the upper five or six segments of the cord. The oblongatal portion of the nucleus, giving rise to the encephalic root of the accessory nerve, may also be termed the nidus laryngei, for its axones join the vagus nerve to innervate the laryngeal muscles (in contradistinction to the nidus pharyngei or nucleus ambiguus, whose axones join the vagus and glosso-pharyngeal to be distributed to the pharynx). The axones from the spinal nucleus are distributed to the Trapezius and Sterno-mastoid muscles.

The nucleus of the accessory nerve is likewise under the dominion of the cerebral cortex by way of the pyramidal tract, and a reflex arc is completed by afferent axones from the dorsal roots of the spinal nerves.

The **Vagus and Glosso-pharyngeal Nuclei** are usually considered in their aggregate, justified not only by their similarity in origin and central connections, but also by the uncertainty which prevails regarding their peripheral interlacement and complex terminations. Both nerves are in greater part afferent, but also contain efferent axones.

1. **Afferent Portions.**—The afferent axones of the vagus arise from the cells in the jugular ganglion and ganglion nodosum (ganglion of the trunk); the afferent axones of the glossopharyngeal arise from the cells in its ganglion superius and ganglion...
petrosum. The root-fascicles of both nerves enter the oblongata along its dorso-lateral groove and the axones then undergo bifurcation into ascending and descending rami, similar to those of the dorsal roots of the spinal nerves. The ascending rami end in the nucleus alae cinereae (nucleus vagi et glossopharyngei); the descending rami collect to form a compact bundle called the tractus solitarius or trineural fasciculus, and terminating in a gray cell-column called the nucleus of the solitary tract—a caudal prolongation of the nucleus alae cinereae. Both tract and nucleus become attenuated caudal, to disappear in the fourth cervical segment (relation with phrenic nerve nucleus), while cephalad it has been traced as far as the region of the locus ceruleus (relation with trigeminal nerve nuclei?).

From the cells of the nucleus alae cinereae and nucleus tractus solitarii axones pass across the raphé to the contralateral interolivary stratum to join the medial lemniscus, establishing connections with the thalamus and cortex; other axones join the tractus nucleo-cerebellaris.

2. Efferent Portions.—The efferent components of the vagus and glosso-pharyngeal nerves come from two sources: (a) the dorsal efferent (vagal) nucleus and (b) the nucleus ambiguus.

The dorsal efferent nucleus lies ventro-mesad of the principal nucleus alæ cinereae and laterad of the hypoglossal nucleus. The axones from its cells pass obliquely ventro-laterad to enter the root-fascicles of the vagus and to become distributed to

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1 There are other "solitary" fasciculi in the nervous system, and the name "trineural fasciculus" aptly characterizes a tract which has for its object that mutual interchange of functions among the central nuclei of the accessory, vagus, and glosso-pharyngeal nerves.

2 The nucleus of the solitary tract lies to the mesal side of the tract. Another nucleus has been described by Mellus, lying laterad of the tract.
the oesophagus, stomach, trachea, and bronchi. Whether the gloso-pharyngeal nerve receives efferent axones or not is still in debate.

The nucleus ambiguus (nidus pharyngei) is a rod-like mass of large, multipolar cells seen, in trans-sections, lying in the gray, reticular formation midway between olive and trineural fasciculus. The axones arising from its cells run dorsi-mesad at first, then turn abruptly ectad to join the vagus (and gloso-pharyngeal?) nerve-root fascicles, becoming distributed to the pharyngeal muscles, oesophagus, crico-thyroid and laryngeal muscles.

The Acoustic Nerve.—The acoustic nerve consists of a cochlear and a vestibular division; the former is concerned with the sense of hearing, the latter with the sense of equilibrium.

1. The Cochlear or true auditory nerve arises in the bipolar cells of the cochlear spiral ganglion; its axones terminate in (a) the dorsal nucleus (tuberculum acusticum), a pyriform mass on the dorso-lateral aspect of the restis, and (b) the ventral nucleus, somewhat detached from the former.

From the dorsal nucleus cells arise the axones which compose the striae acusticae, myelinic fibre-bundles traversing the ventricular surface to near the median sulcus, dipping into the tegmental substance, crossing to the opposite side in the raphé, and eventually joining the lateral lemniscus to end in the postgeminum and postgeniculum.

From the ventral nucleus cells arise the axones which course transversely to form the trapezium at the contact-zone of the pons proper and tegmentum. Additional axones from cells in the superior olives of both sides and in the trapezium itself increase the bulk of this tract; some of the primary axones end in relation with

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**Fig. 578.**—Primary terminal nuclei of the afferent (sensor) cranial nerves schematically represented in a supposedly transparent brain-stem, lateral view. The optic and olfactory centres are omitted.
These axone-groups form the contralateral lemniscus lateralis, which contains the intercalated nucleus of the lateral lemniscus as a relay station, to be continued to the postgeminum and postgeniculum and thence to the cortical auditory “centre” in the supertemporal gyr.

2. The Vestibular Nerve axones arise in the bipolar vestibular ganglion cells (G. of Scarpa), enter the brain-stem, and bifurcate into ascending and descending rami, which terminate as follows: The ascending rami end in the medial nucleus (Schwalbe’s); the descending rami end in the spinal vestibular nucleus, which extends down to the gracile and cuneate nuclear level; another group of axones ends in the lateral nucleus (nucleus magnocellularis) (Deiters’); while a fourth and last group ends in the superior nucleus (Bechterew’s). From the cells of all these nuclei of termination axones proceed toward the cortex, dentatum, and fastigatum of the cerebellum, as part of the nucleo-cerebellar tract, to the nuclei of the abducent, trochlear, trigeminal, and oculomotor nerves by collaterals from axones in the medial longitudinal bundle, to the thalamus, and to the ventral-horn nuclei of the spinal cord along the tractus vestibulospinalis. The far-reaching and complex connections of the vestibular nerve with the cerebellum and the centres for eye-muscles and the spinal centres for bodily movements make this cranial nerve a most interesting subject for the active research now going on.

The Facial Nerve.—The facial nerve proper is to be distinguished from its so-called sensor root, or pars intermedia, or nervus intermedius.

The axones of the efferent facial nerve arise from cells forming the facial nucleus in the ventro-lateral region of the reticular formation, in line with the nucleus ambiguus or nidus pharyngei, a little over 4 mm. from the ventricular floor. These axones converge toward the ventricular floor to form a compact bundle which curves over the abducent nucleus from behind (caudad), overlying it like a horse-shoe over a ball (genu facialis internum); not as a straight but as a bent horseshoe, bent so that its cephalic branch is directed more laterad than its caudal branch.

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**Fig. 579.—Diagram of the central auditory tract (system of the second order).**

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After having encircled the abducens nucleus, the facial root passes ventro-laterad, passing its own nucleus ectad, and emerging in the postoblongatal groove (recessus facialis).

Pyramidal fibres from the precentral cortex place this nucleus under the influence of the will; it also receives fibres from the trigeminal and acoustic central systems.

The *nervus intermedius* is a mixed nerve, containing afferent (taste) fibres and efferent (excito-glandular or secretory) fibres. With respect to its afferent component it may be regarded as an aberrant portion of the glossopharyngeal nerve.

1. **Afferent Portion.**—These axones arise, from the cells of the *geniculate ganglion*, implanted upon the genu facialis externum, and terminate in a nuclear extension cephalad of the *nucleus tractus solitarii*. They probably convey gustatory sense impulses from the tip of the tongue and the pillars of the soft palate.

2. **Efferent Portion.**—A nucleus of origin for the excito-glandular elements has been described as a group of cells extending beneath the ventricular floor from the level of the facial nucleus to that of the motor trigeminal nerve, close to the raphé and called the *nucleus salivatorius*.

Peripherally we shall study this nerve as the *chorda tympani*. The mixed nature of the nervus intermedius and of the geniculate ganglion makes it probable that they combine the elements of a sympathetic and a spinal ganglion; the nerve, at least, contains both vegetative and sensorial elements.

The *Abducent Nerve.*—The abducent nerve is a small motor nerve supplying the External Rectus muscle of the eyeball. Its nucleus of origin, with large, multipolar cells, lies close to the median plane beneath the eminentia abducentis. The axones from these cells pass ventrad through the tegmentum and trapezium, and laterad of the pyramidal tract, to emerge in the postoblongatal groove. The nuclei are brought under the dominion of the cerebral cortex by pyramidal fibres of the opposite side. They are likewise brought into intimate relation with the trigeminal, acoustic, and opposite oculomotor nerve nuclei.

The *Trigeminal Nerve.*—The trigeminal is relatively enormous and has correspondingly extensive central connections, including nuclei in the mid-brain, pre- and post-oblongata, and spinal cord. It is a mixed senso-motor nerve and the afferent and efferent divisions must be considered separately.

1. **Afferent Portion.**—The axones of the afferent or sensor root arise in the cells of the large semilunar (Gasserian) ganglion. As in the dorsal roots of the spinal nerves, these axones bifurcate, on entering the brain-axis, into ascending and descending rami. These terminate in a cephalic nuclear extension of the caput glossum of the cord; the ascending rami terminate in the so-called sensor nucleus of the trigeminus, the descending rami in the nucleus of the spinal tract of the trigeminus, which extends as far as the second cervical segment of the cord. The sensor nucleus, at the level of the entrance of the nerve, is quite massive, becoming attenuated cephalad. The spinal tract, in its descent, likewise decreases rapidly as it gives off its terminal axones to the nucleus of the tract. The cells of these terminal nuclei send out axones which cross the median plane, giving off collaterals to the facial nucleus, to join the medial lemniscus to reach the thalamus, and, via thalamus, the somesthetic cerebral cortex. Other axones are distributed (a) to the motor or efferent nucleus of the trigeminus and (b) to the motor or efferent cranial-nerve nuclei.

2. **Efferent Portion.**—The efferent or motor component of the trigeminal nerve consists of axones arising from cells in two nidi: (a) the principal nucleus in the dorso-lateral part of the pre-oblongatal tegmentum, dorso-mesad of the sensor nucleus; (b) a small, slender, so-called mesencephalic root-nucleus (*nucleus radicis descendentis nervi trigemini*) extending cephalad of the region of the locus ceruleus to lie along the aqueduct in the mid-brain. The fibres from the principal
nucleus supply the muscles of mastication. The distribution of the fibres from the mesencephalic root is not precisely known. Kölliker suggests that they may supply the Tensor veli palatini, Tensor tympani, Mylo-hyoid and anterior belly of the Digastric.

Like other motor nuclei, these efferent divisions of the trigeminal are under the dominion of the cerebral cortex via pyramidal fibres.

The Cerebellum.—The cerebellum occupies the greater part of the posterior or cerebellar part of the skull and is the largest portion of the hind-brain. It is overlapped by the occipital lobes of the cerebrum, being separated from these by the tentorium. It lies dorsal of the pons-oblongata and partly embraces this portion of the brain-stem. It is composed of a white central core with scattered gray masses, and a surface layer of gray substance that is of darker hue than the cerebral cortex.

The cerebellum is convoluted on a plan entirely different from that of the cerebrum. Each primary fold is folded by secondary and these in turn by tertiary folds, so that on sagittal section a cypress-leaf appearance is noted, the arbor vitae cerebelli. The interior or medullary white substance follows all these branchings and sub-branchings, forming a skeleton of the minute folds which are called folia. These folia are demarcated on the surface by numerous curved and more or less parallel fissures of various depths.

![The Cerebellum](image)

Fig. 580.—Upper surface of the cerebellum. (Schäfer.)

The cerebellum is connected to the brain-stem by three pairs of peduncles and by vestigial portions of the primitive dorsal wall of the brain-tube. Among the latter the medullary vela or laminae are most important; they are the valvula (superior medullary velum) and the velum (inferior medullary velum), which enter into the formation of the “roof” of the fourth ventricle.

The rounded margin of the cerebellum demarcates two surfaces looking respectively “upward” and “downward,” or cephalic and caudal surfaces. Both are convex, the inferior or caudal surface more so than the upper or cephalic. The inferior surface shows a deep median depression, the vallecula, into which the oblongata is sunk. The ventral margin is widely notched to partly embrace the brain-stem (pre-oblongata and quadrigemina); a dorsal notch (incisura cerebelli posterior), which is smaller and narrower and lodges the falcula, separates the hemispheres as these project beyond the postvermis.

The cerebellum is arbitrarily sub-divided into a medial segment, the vermis or worm, from its annulated appearance, and two lateral portions, commonly called...
the cerebellar "hemispheres" or pileums. The vermis may, according to the aspect in which it is viewed, be divided into the prevermis on the upper or cephalic surface, and the postvermis on the inferior or caudal aspect. The prevermis is hardly distinguished from the adjacent sloping surfaces of the hemispheres; occasionally a slight furrow exists on either side. Ordinarily the term is to be restricted to the high median elevation usually called the monticulus cerebelli. The postvermis is more distinctly bounded by a deep fissure, the sulcus valleculae, on each side, separating it from the corresponding lateral hemisphere.

Among the many fissures which traverse the surface of the cerebellum, one is particularly conspicuous as a deep elef which may be traced along the dorso-lateral margin from the dorsal notch to the point of entrance of the cerebellar peduncles. This is the peduncular sulcus or great horizontal sulcus (sulcus horizontalis cerebelli), and it divides the cerebellum into a cephalic and caudal or upper and lower part. The sulcus is usually quite deep in the hemispheral portion, but it frequently fails to traverse the vermis. Other deep fissures demarcate the lobes or major sub-divisions of the intricately convoluted surface of the cerebellum.

Conventionally the lobes and fissures or sulci are described upon the "upper and "lower" surfaces respectively, and this mode of description is briefly adhered to here. A better idea of the topographical relations of the lobes and sulci in the vermis and the hemispheres may be gained from a study of the divisions of the cerebellum as it extended in one plane as well as on sagittal sections through the mesal and lateral planes.

**Lobes and Fissures of the Cerebellum.**—The surface of the cerebellum is traversed by eight more or less curved and deep fissures demarcating nine lobar sub-divisions. Distinctive names are given to the portions of each lobe in the hemispheres as contrasted with that in the vermis, although often without warrant, as the two are quite continuous and merit no such distinction. This burdensome nomenclature seems so firmly rooted in descriptive anatomy that the various terms must be repeated here. The arrangement of the fissures and lobes will be understood by reference to the following schema, in which the structures are named from "before backward," or cephalo-caudad:
The **Lingula** (lingula cerebelli) is a tongue-shaped process of the vermis lying in the ventral cerebellar notch, ventrad of the central lobe, and is partially or completely concealed by it. It consists of 5, 6, or 7 lamellae lying upon and connected with the dorsum of the valvula. At either side the lingula gradually shades off, being prolonged only for a short distance toward the region of the peduncles as the vincula lingulae.

The **Central Lobe** (lobulus centralis) is a small median mass situated in the ventral notch, dorsad of and overlapping the lingula. Its lateral, wing-like prolongation is called the **ala lobuli centralis**.

The **Culminal Lobe** (lobulus monticuli) is much larger than the two lobes just described and constitutes, with the succeeding lobe (the clival lobe), the bulk of the prevermis and "upper" surface of the cerebellum. It partly overlaps the central lobe. Its lateral extensions are also termed the **anterior crescentic lobes**.

1 The anterior and posterior crescentic lobes are often called the pars anterior and pars posterior respectively of the "lobulus quadrangularis."

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**Fig. 582.—Diagram showing fissures on under surface of the cerebellum:**

- **F**, flocculus
- **U**, uvula
- **Py**, pyramid
- **Am**, amygdala
- **Bivent.**, biventral lobe

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57
The Clival Lobe is of considerable size, separated from the culminal lobe by the preclival fissure and from the cacuminal lobe by the postclival fissure. Its lateral extensions are also termed the posterior crescentic lobes.

The anterior and posterior crescentic lobes of either side have been described by some writers as the pars anterior and pars posterior of the quadrate lobe or lobulus quadrangularis.

The Cacuminal Lobe (folium vermis; superior semilunar lobe) is a short, narrow band at the dorsal margin of the vermis, which expands in either hemisphere into a lobe of considerable size, of semilunar shape, and bounded caudad by the peduncular fissure.

The Tuberal Lobe is of small size in the region of the postvermis, but laterally spreads out into the large inferior semilunar (lobulus semilunaris inferior) and gracile lobes demarcated by the intervening postgracile fissure. These lobes comprise at least two-thirds of the “inferior” surface of the cerebellar hemispheres.

The Gracile Lobe is often divided by an intragracile fissure into pre- and postgracile lobes.

The Pyramidal Lobe is a conical projection, forming the largest prominence of the postvermis. It is continued laterad into the hemisphere as the biventral lobe (lobulus biventer); the demarcation between the latter and the pyramis proper is accentuated by the deep sulcus valleculae.

The Uvular Lobe (uvula vermis) occupies a considerable portion of the postvermis as the uvula, while its lateral extension in either hemisphere, the tonsilla or amygdala (tonsilla cerebelli), is a rounded mass lying in a deep fossa between the uvula and biventral lobe. (This fossa was termed, by the older anatomists, the nidus avis or “bird’s nest” [Reil and Vieq d’Azyr].) The junction of uvula and tonsilla is an attenuated isthmus marked by a few shallow furrows and termed the furrowed band.

The Nodular Lobe comprises the nodulus (nodulus vermis) (in the postvermis) and the flocculus (floeculi secondarii) of each side, connected by a delicate lamina of white matter, the velum. Each flocculus lies adjacent to the ventro-lateral surface of the peduncular mass, extending into the ventral extremity of the pedun-
cular fissure. The flocculi of the two sides are connected with each other by a band of white matter, termed the velum (posterior medullary velum) in its medial portion, while its lateral expansions toward the flocculi are termed the peduncles of the flocculi.

**The Internal Structure of the Cerebellum.**—In any section of the cerebellum we may recognize the interior white substance, corpus medullare (medullary body), and the peripheral gray cortex. The white substance in each lateral hemisphere is more bulky than in the median vermis, while the cortex is of more uniform thickness throughout. In a sagittal section in the mesal plane the central white core is seen to divide into two main branches, preramus and postramus; these main branches divide and subdivide into a series of medullary laminae surmounted by the foliated cortex, and presenting the characteristic appearance known as the arbor vitae cerebelli.

**Isolated Gray Masses or Nuclei of the Cerebellum.**—Embedded in the white matter of the cerebellum are several gray masses. They are four in number on each side:

1. **Dentatum or dentate nucleus.**
2. **Embolus or nucleus emboliformis.**
3. **Globulus or nucleus globosus.**
4. **Fastigatum or nucleus fastigii.**
The dentatum is the largest and best studied of the cerebellar nuclei. It is located in the mesal part of the corresponding cerebellar hemisphere, in the direct prolongation of the prepedunculus, which appears to enter it. It consists of a folded lamina of gray matter convoluted like the similar nucleus of the olive, and opens cephalo-mesad where its hilum (hilus nuclei dentati) permits of the entrance and exit of fibres from various sources.

The embolus is a small mass of gray substance, elongated cephalo-caudad, and placed entad of the dentatum, partly covering its hilum.

The globulus consists of several small round or oval masses connected with each other and lying entad of the preceding.

The fastigatum (nucleus of the "roof") is second in size to the dentatum, situated close to the mesal plane directly dorsad of the fourth ventricle, or in the fastigium of the cerebellum, and within the postvermis. The nuclei of opposite sides approach each other so nearly as almost to fuse.

The Cerebellar Peduncles.—Three pairs of peduncles constitute the chief avenues for the entrance and emergence of the fibres composing the white substance of the cerebellum and connecting adjacent parts of the brain-stem therewith. The peduncles are, on each side, the prepeduncle, medipeduncle, and postpeduncle.

The Postpeduncle (corpus restiforme) is the continuation of the restis of the oblongata. It contains both afferent and efferent fibres, connecting the cerebellar cortex with structures situated caudad: (1) The dorsal or direct spino-cerebellar tract, composed of axones arising in Clarke's column (spinal cord) and terminating in the cortex of the prevermis on both sides of the median line, but chiefly on the opposite side. (2) The olivo-cerebellar tract, composed of axones arising in the (inferior) olivary nuclei—principally from the contralateral or opposite olive, and terminating in the cortex of the prevermis and adjacent hemispheral portions, as well as in the dentatum. (3) External arcuate fibres from the homo-lateral and contralateral nuclei of the gracile and cuneate funiculi. (4) The nucleo-cerebellar
tract, composed of axones from the recipient nuclei of certain cranial nerves (vestibular, trigeminal). (5) The cerebello-spinal (descending) tract, terminating in relation with the ventral-horn cells at various levels of the spinal cord.

The Medipeduncles (brachia pontis) are the largest of the three pairs. They consist of a mass of curved fibres comprising the pons and entering either cerebellar hemisphere between the parted lips of the ventral end of the peduncular fissure, just ectad of the postpeduncle. Each peduncle contains axones coursing in opposite directions and in large part may be considered as purely commissural fibres. Some of the axones terminate, however, in the nuclei pontis to convey impulses so the cells therein; these in turn send their axones (tractus pontocerebellares) into the opposite medipeduncle, and therefore constitute interrupted commissural systems. A few fibre-systems in the medipeduncles establish relations with certain other structures in the brain-stem, notably the nuclei of the oculomotor, trochlear, and abducent cranial nerves.

The Prepeduncles (brachia conjunctiva) emerge cephalad from the cerebellum entad of the medipeduncles. As they extend cephalad they converge to form the lateral boundaries of the fourth ventricle and partly roofing it in. On trans-section they appear of oval outline, somewhat concave toward the cavity of the ventricle. The valvula, a thin lamina of white substance, spans the interval between the converging prepeduncles, and thus completes the roofing-in of the cephalic portion of the fourth ventricle.

The prepeduncles consist almost wholly of axones arising from the cells of the dentatum, the ectal part of the fastigium of the same side, and mesal part of the fastigium of the opposite side. In their course, converging cephalad, these bundles pass into the tegmentum of the mid-brain ventrad of the quadrigemina, and decussate almost wholly. The fibres of each peduncle terminate in the rubrum (red nucleus) of the opposite side, although a few continue to enter the thalamus.

This system of fibres is also called the tractus cerebello-tegmentalis, and axones of inverse functional direction have been included therein.

The Ventral spino-cerebellar tract (Gowers' tract) is in relation with the prepeduncle and valvula. Unlike the dorsal or direct spino-cerebellar tract, it does not enter the cerebellum along the postpeduncle. Its fibres pass farther cephalad, through the reticular formation of the pre- and post-oblongata, to become reflected dorso-caudad at the level of the isthmus of the hind-brain, and entering the valvula, proceed with the prepeduncle into the cerebellum.

The Medullary Vela.—These are two thin, relatively undeveloped laminae of white substance, representatives of the mid-dorsal wall of the brain-tube adjacent to the cerebellar proton, and in the adult brain appear as prolongations of the white central core of the cerebellum. They are the valvula (anterior or superior medullary velum; valve of Vieussens) and the velum (posterior or inferior medullary velum).

The Valvula is a thin lamina of white substance spanning the interval between the converging prepeduncles, and with these assisting in the formation of the "roof" of the fourth ventricle. Caudad it is continuous with the white substance of the cerebellum, while on its dorsal surface lie the five to seven folia of the lingula.
Cephalad it narrows as the quadrigemina are approached, and a slight median ridge, the frenulum, descends upon the dorsal surface of its apical portion from between the postgemina; on either side of the frenulum may be seen the superficial root of the trochlear nerve. The majority of the fibres in the valvula are longitudinal; as already described (p. 901), the ventral spino-cerebellar tract reaches the cerebellum along the valvula.

The Velum is a still thinner lamina of white substance which bears the same relations to the nodulus that the valvula presents to the lingula. Laterad it extends to the flocculus of either side. The velum ends in a free crescentic edge and its endynal and pial coverings continue as a fused, delicate membrane, the metatela.

The valvula and velum enter the cerebellum at an acute angle, forming the peaked roof (fastigium), while the tent-like recess is called the recessus tecti.

The Fibres Proper of the Cerebellum.—The fibre proprius of the cerebellum are of two kinds: (1) commissural fibres, which cross the middle line to connect the opposite halves of the cerebellum, some at the anterior part and others at the posterior part of the vermis; (2) association fibres, which are homo-lateral fibres connecting adjacent laminae with each other.

Microscopic Appearance of the Cerebellar Cortex.—The cerebellar cortex, on section, presents two marked layers: an outer, of a pale-gray color, the molecular layer, and an inner, of a rusty-brown tint, the granular layer. At the contact line of these two layers, but more within the molecular than the granular, are found the characteristic nerve-elements of the cerebellum, the flask-shaped Purkinje nerve-cells.

The Molecular or Ectal Layer consists of cells and delicate fibrillae embedded in a neuroglial network. The cells are small and are characterized by the course of their branching axones which run parallel with the surface of the folium, give off numerous collaterals which pass in a vertical direction toward the cell-bodies of the Purkinjean elements and embrace these in a basket-like network. Hence these cells are called basket-cells (Fig. 587).

The Purkinjean Cells are flask-shaped, and form a stratum at the junction of the molecular and granular layers, their bases directed toward the latter. Each cell gives off an axone entad, while ectad it gives off numerous dichotomously branching dendrites covering a very large field of the molecular layer. The axone, after giving off several collaterals which pass toward different parts of the granular layer, becomes myelinic not far from the cell-body and passes into the white substance to establish connections with other folia within the cerebellum or with more distant brain-structures.

The Granular or Ental Layer is characterized by containing numerous small nerve-cells or granules of a reddish-brown color, together with many nerve-fibrils. Most of the cells are nearly spherical and provided with short dendrites, which spread out in a spider-like manner in the granular layer. Their axones pass outward into the molecular layer, and, bifurcating at right angles, run horizontally for some distance. In the outer part of the granular layer are also to be observed some larger cells, of the type termed Golgi cells (Fig. 587). Their axones undergo frequent division as soon as they leave the nerve-cells, and pass into the granular layer, while their dendrites ramify chiefly in the molecular layer.

Finally, in the gray substance of the cerebellar cortex fibres are to be seen which come from the white centre and penetrate the cortex. The cell origin of these fibres is unknown, though it is believed that it is probably in the gray substance of the spinal cord. Some of these fibres end in the granular layer, by dividing into numerous branches, on which are to be seen peculiar moss-like appendages; hence they have been termed by Ramón y Cajal the moss-fibres (Fig. 587); they form an arborescence around the cells of the granular layer. Other fibres derived from the medullary centre can be traced into the molecular layer, where their
branches cling around the dendrites of Purkinje’s cells, and hence they have been named the clinging or tendril fibres (Fig. 587).

The cerebellum is an important senso-motor organ, transmuting sensor impressions into motor impulses under the dominance of the cerebral centres. Its connections with other brain portions and the spinal cord are established by the peduncular fibres. It is essentially an apparatus for the coördination of movements and the orientation of the body and its parts in space. These functions depend principally upon the reception of sensor impulses from (1) the vestibular nerve and (2) the spino-cerebellar (ascending) tracts. Motor impulses pass along (1) the cerebello-spinal (descending) tracts to the ventral-horn nuclei of the cervical cord; (2) the tractus rubro-spinalis, which arises in the rubrum (red nucleus)—an intercalated ganglionic mass connected with the cerebellar cortex by the prepeduncles, or tractus cerebello-tegmentales. The tractus rubro-spinalis is a tract for voluntary motor impulses next in importance to the pyramidal tract.

Weight of the Cerebellum.—Its average weight in the male is 165 grams and 155 grams in the female. It attains its maximum between the twenty-fifth and
nine-ty-fifth years, its increase in weight after the fourteenth year being relatively greater in the female than in the male. The proportion between the cerebellum and the cerebrum is as 1 to 7.5; among eminent men it is 1 to 8.5. In the newborn the ratio is as 1 to 20.

The Mid-brain (Mesencephalon).

The mid-brain is the short and constricted portion of the brain which lies in the opening of the tentorium cerebelli (incisura tentorii) and which connects the pons with the inter-brain and hemispheres, and hence it is frequently called the isthmus cerebri. It is developed from the second brain-vesicle, the cavity of which becomes the aqueduct. It comprises the crura cerebri, the quadrigemina, the geniculate bodies, and the aqueduct. Its two surfaces are ventral and dorsal. They are free, but concealed: the ventral surface by the apices of the temporal lobes which overlap it; the dorsal, by the overhanging cerebral hemispheres. The ventral surface, when exposed by drawing aside the temporal lobes, is seen to consist of two cylindrical bundles of white substance, which emerge from the pons and diverge as they pass forward and outward to enter the inner and under part of either hemisphere. They are the crura cerebri, and between them is a triangular area, the intercru-ral space; near the point of divergence of the crura the roots of the third nerve are seen to emerge in several bundles from a groove, the sulcus oculomotorius (sulcus nervi oculomotorii) (Fig. 551). The dorsal surface is not visible until a considerable portion of the cerebral hemispheres and other overlying structures have been removed. It then presents four rounded eminences placed in pairs, two cephalad and two caudad, and separated from one another by a crucial

![Diagram of the brainstem](image-url)
THE MID-BRAIN

905
depression. These are termed the quadrigemina (tubercula quadrigemina) (Fig. 588). The ventral and dorsal surfaces meet on the side of the mid-brain, and are separated from each other by a furrow, the lateral groove (sulcus lateralis mesencephali), which runs caudo-cephalad (Fig. 588).

External Morphology.—Dorsal Surface.—The quadrigemina are four rounded eminences placed in pairs separated by a flat median groove and a more sharply cut transverse furrow. The cephalic pair, the pregemina (superior colliculi; the nates of older authors), are the larger and the epiphysis rests in the flattened depression between them. The pregemina are oval, their long diameter being directed cephalo-lateral, and are of a yellowish-gray color. The postgemina (colliculi inferiores; the testes of older authors) are hemispherical in form, and lighter in color than the preceding. The lamina quadrigemina, comprising the whole of the dorsal wall of the mid-brain, extends from the root-region (postcomissure) of the epiphysis to the cephalic end of the valvula.

Each pre- and postgeminum is continued latero-ventrad in prominent white bands, the brachia. The band from the pregeminum is termed the prebrachium; that from the postgeminum is called the postbrachium.

The Prebrachium (brachium quadrigeminum superius) proceeds cephalo-ventrad between the overhanging pulvinar and a light-gray eminence, the postgeniculum. In reality it is a continuation of a part of the optic tract. The Postbrachium (brachium quadrigeminum inferior) proceeds in a similar direction to disappear beneath the postgeniculum.

Of the two geniculate bodies, on either side, the pregeniculum belongs rather to the thalamus, while the postgeniculum may properly be considered here among the structures of the mid-brain.

The Postgeniculum (corpus geniculatum mediale s. internale) is a small oval eminence on the lateral surface of the mid-brain in which the mesal root of the optic tract appears to terminate. The postbrachium likewise appears to run into this body; as a matter of fact, so far as is known, the postgeniculum is (1) a way-station for auditory impulses in their course toward the cerebrum; (2) the origin and terminus for the arched comissure of Gudden (infracommissure; commissura inferior [Gudeni]), by means of which circuitous path, through the chiasm, and along the mesal root of optic tract, the postgenicula of the two sides are connected.

The quadrigeminal lamina is continuous caudal with the cerebellar prepeduncles and the intervening valvula. A slight, median, ridge-like projection, the frenulum valvule, descends from between the postgemina onto the valvula; on either side of the frenulum emerge the slender trochlear nerves.

The Crura constitute the bulk of this portion of the brain-stem. Upon the ventral aspect of the brain they appear as two large, white, rope-like strands emerging from the pons and diverging to either cerebral hemisphere, becoming embraced by the optic tracts. Each crus is composed of a dorsal tegmental part—a continuation of the tegmentum of the hind-brain—and a ventral crusta or pes. These parts are demarcated from each other on the external surface by the oculomotor sulcus ventrad (which looks into the intercerebral space) and the sulcus lateralis mesencephali on the lateral aspect. The lateral surface shows dorsally the cerebellar prepeduncle dipping into the substance of the mid-brain, while between it and the crista is a small triangular field of oblique fibre-strands, not always well defined, called the trigonum lemnisci because the lateral lemniscus tends to reach the surface of the brain-stem at this situation (Fig. 588).

The surface of the crura shows a rope-like twist in the course of its fibre-bundles. Oblique or transverse fasciculi are sometimes seen upon the surface, two of which are fairly constant. They are (1) the taenia pontis, and (2) Gudden's tractus peduncularis transversas (cimbia).
The Taenia Pontis, as Horsley has shown, takes origin contralaterally in the gray substance continuous with the "interpeduncular ganglion," but ventral to it. The tenia then passes over the lateral lemniscus and cerebellar prepeduncle to the dentatum and fastigatum.

The Cimbia¹ or Tractus Peduncularis Transversus may he traced from the pregeminum and postgeminulum over the surface of the crus to near the ventro-meson, disappearing from view in the oculomotor sulcus.

**Internal Structures of the Mid-brain.**—If a cross-section be made through the mesencephalon it will be seen that each lateral half is divided into two unequal portions by a lamina of deeply pigmented gray substance, named the substantia nigra (intercalatum; ganglion of Soemmering). The postero-superior portion of the crus is named the tegmentum, and the antero-inferior the crusta or pes. The substantia nigra is curved on section with its concavity upward, and extends from the lateral groove externally to the oculomotor sulcus internally. The two crusts are in contact in front of the pons, from which point they diverge from each other, but the two halves of the tegmentum are joined to each other in the mesal

¹ In architecture—a band or fillet about a column. Also called fasciculus arciformis pedis.
plane by a forward prolongation of the raphé or median septum of the pons. Laterally the tegmenta are free, but dorsally they blend with the quadrigemina.

Traversing the mid-brain in the median plane and nearer the dorsal surface is the aqueduct, surrounded by the central tubular gray, which in this brain-segment has retained the comparatively primitive arrangement of the embryonic brain-tube.

The Aqueduct (Mesocele) and Central Gray Aqueduct.—The aqueduct is a narrow canal connecting the third with the fourth ventricle, and demarcating the lamina quadrigemina dorsal from the tegmental zone. Its shape on trans-section varies at different levels, being T-shaped caudal, oval or quadrangular along its middle, and triangular cephalad. It is lined by the endyma (columnar ciliated epithelium) and surrounded by the central aqueduct gray. The central gray is separated dorsally from the quadrigemina by the stratum lemnisci; ventrad near the median plane lie the medial longitudinal bundles. Within the gray substance lie certain well-defined cell-clusters, the nuclei of origin of the oculomotor and trochlear nerves and the mesencephalic root of the trigeminal nerve. These will be described in detail later.

The Substantia Nigra or Intercalatum.—The substantia nigra is a crescentic layer of deeply pigmented gray substance interpolated between the crus and the tegmentum. Mesad it nearly touches its fellow of the opposite side, being separated by the rudimentary ganglionic gray (the postperforatum) in the intercrural space. Its ventral face sends numerous ramifying prolongations among the fasciculi of the crus. It extends from the cephalic border of the pons to the subthalamic region, while its lateral edge reaches the surface along the lateral sulcus. Its cells are medium-sized, multipolar, their bodies approaching the fusiform, or angular in outline. The cells are characterized by a pigment (marked only in man) which varies from a pale brown in the young to an absolute blackness in the very aged. The axones arising from the cells proceed in various directions toward the tegmentum and crus, but their exact course is not known. Experimental excitation of this ganglionic mass elicits movements of deglutition accompanied by respiratory changes. Mellus has found in the monkey that a portion of the pyramidal tracts is interrupted in the substantia nigra.

The Quadrigemina.—The quadrigemina are largely composed of gray substance, but the pre- and postgemina differ distinctly in structure.

The Pregeminum presents a true cortical type, which is more evident in the optic lobes of lower vertebrates. In man the thin, outermost white layer—the stratum zonale—is an expansion of the optic tract. Beneath this lies a gray nucleus, with numerous small cells—the stratum cinereum—a cup-like layer of crescentic outline on trans-section. The succeeding ental layer is a white stratum, also derived from the optic tract—the stratum opticum. Between this and the underlying stratum lemnisci is a second gray layer, less defined because of the diffuse interlacing of white fibres.

Each pregemum is one of a series of primary centres of vision related more to eye-muscle reflexes resulting from optic and auditory stimuli than to actual light and color perception. Fibres from the retina, for the most part, form the stratum zonale and end in the ganglionic gray; others enter into the formation of the stratum opticum. Return fibres from the occipital cortex also enter the stratum opticum. The retinal and occipital fibres determine the formation of the prebrachium. Other fibres reach the pregemum through the lateral and modal lemnisci—from both sides—to end in relation with the deeper cells of the stratum cinereum. The connections of the pregemum with the cochlear centres afforded by the lateral lemniscus establishes the so-called optic-acoustic reflex path.

The Postgemina are more homogeneous in texture, comprising a pair of compact ganglia which on trans-section have the shape of biconvex lenses, encapsulated by white substance. The cells are small, multipolar, and very numerous, embedded
in a fine molecular groundwork. The white stratum zonale is principally derived from the fibres of the lateral lemniscus, which terminate in the central gray of the postgenminum as well as in the postgeniculium. The axones of the cells in the postgeninum course cephalad in the postbrachium, dip beneath the postgeninum into the tegmentum and proceed to the thalamus. The postgeminina are important links in the chain of the auditory neurone system, and are special localities for the reflexion of auditory impulses.

The Tegmentum.—The tegmentum of the mid-brain is continuous with the like formations in the hind-brain stem and consists of longitudinal fibre-bundles intersected by transverse arched fibre-systems with great substance irregularly scattered in the interstices, composing the formatio reticularis. In its ventral portion, on either side, and at the level of the pregeninum, lies a gray ganglionic mass, the rubrum or red nucleus. (nucleus tegmenti; nucleus ruber).

The Rubrum or Red Nucleus, so termed from its reddish tinge in the fresh brain, which it owes to the pigmentation of its cells as well as to its great vascularity, is found subjacent to the pregeninina in those section-levels where the substantia nigra has its greatest expansion. In trans-sections its outline is irregularly circular; in sagittal sections an elongated oval. The rubrum is the end-station for the majority of the decussated cerebellar prepeduncule fibres, for fibres from the cerebral cortex, and from the stratum. These fibre-bundles form for the nucleus a' capsule which is thicker on its ectal surface. From the cells of each rubrum arise axones which pass (1) to thalamus and cerebral cortex (links in the cerebello-cortical neurone-chain), and (2) axones which descend into the spinal cord to form the tractus rubrospinalis (Monakow's)—a continuation of an indirect motor path from the cerebral cortex to peripheral motor nerve. The tracts arising from the red nuclei of the two sides decussate with each other and descend in the tegmentum.

In the intercruical space lies a primitive gray ganglionic mass, the postperforatim. Cephalad of the pons, in the median line, lies a cluster of cells, the interpeduncular ganglion (Gudden). The fasciculus retroflexus (Meynert), whose fibres arise in the habenal ganglion, descends to end in the interpeduncular ganglion.

The principal longitudinal fibre-tracts in the tegmentum of the mid-brain are (1) the medial longitudinal fasciculus, (2) lateral lemniscus, (3) medial lemniscus, (4) the decussating cerebellar prepeduncules, (5) the decussating rubro-spinal tracts, and (6) the central segmental tracts.

The Medial Longitudinal Bundle lies on each side of the median plane, lying ventrad of the central aqueduct gray in the mid-brain and continuous throughout the brain-stem in its formatio reticularis. It is the continuation and the equivalent, but in a more differentiated form, of the ventral basis bundle of the spinal cord. It is formed by association neurones and acts as an associating agent with regard to many cranial and spinal-nerve centres for the performance of certain definite functions. Its neurones receive impulses from afferent elements and transmit them to motor or efferent elements. It particularly brings into relation the sensor cranial-nerve nuclei and the quadrigemina with the motor nerves of the eye (III, IV, and VI), of the face (VII), and of the trunk. A special nucleus for the bundle is described as being situated in the gray floor of the third ventricle, at its junction with the aqueduct. The axones from the cells of this nucleus cross to the opposite side through the postcommissure (Fig. 591).

The Lateral Lemniscus, we have learned, is a continuation of the auditory path in its course to the cerebral cortex. Its formation is described on p. 888. In the mid-brain the fibres of the lateral lemniscus course through the lateral part of the tegmentum, near the surface, and most of them end in the postgeninmal gray nucleus and in the postgeniculium. A few fibres are carried into the pregeninum.

The Medial Lemniscus, or principal conduction path for sensor impulses from the trunk and extremities, and already discussed in the preceding (p. 888), ascends
in the tegmentum of the mid-brain in the contact-zone with the crusta. In its ascent it is deflected slightly dorso-laterad by the red nucleus. The lateral border of the ribbon-like bundle is in contact with the lateral lemniscus, and forms an angle with it, as seen on trans-sections (Figs. 589 and 590).

Many of the fibres of the medial lemniscus terminate in the pregemum; the remainder proceed to the thalamus.

The Prepeduncles of the Cerebellum sink into the mid-brain tegmentum in a cephalo-ventral direction, the two prepeduncles converging and their fibres undergoing a complete decussation (Werneck's commissure) subjacent to the post-gemina. The crossed fibres end, for the most part, in the rubrum of each side; others circumvent the nucleus, forming a white capsule for it which is thicker on its ental surface, and proceed to the thalamus.

The Tractus Rubrospinalis (Monakow's) is composed of axones arising in the red nucleus, decussating with those of the opposite tract, and descending in
the tegmentum to the lateral intermedial fasciculus of the cord, to terminate in relation with ventral-horn cells.

The Central Tegmental Tract (olivary fasciculus) probably arises in the inferior olivary nucleus and ascends in the tegmentum. In the pre-oblongata it is best seen in trans-sections as a compact longitudinal bundle along the dorsi-mesal aspect of the superior olive. Cephalad it is said to end in the lenticula.

Fountain Decussation. — A dense decussation may be found in the space between the two red nuclei. The fibres composing the decussating bundles arise from cells in the pregramina and central aqueduct gray. After having crossed the middle line they descend, join the medial longitudinal fasciculus, and give off collaterals to, or terminate in the nuclei of the eye-muscle nerves.

The Crusta or Pes.—The crusta or pes is somewhat crescentic in outline on section and is composed of longitudinal fibre-bundles—the continuation of the internal capsule—divisible into three sectors. The middle sector comprises three-fifths of the cross-section area of the crusta, and comprises the pyramidal tract on its way from the cerebral cortex (motor area) to cranial and spinal centres below. The ectal sector, or lateral one-fifth, comprises the temporo-pontile tract; its axones arise from cortical cells in the temporal lobe and end in fine terminal arborizations in relation with cells of the nuclei pontis. The ental sector, or mesal one-fifth of the crusta, comprises the fronto-pontile tract; its axones arise from cells in the cortex of the frontal lobe and terminate in the nuclei pontis.

The Pyramidal Tract is a direct “voluntary” motor tract; the two cortico-pontile tracts enumerated above are links in a chain of neurones which constitute an indirect motor tract. The series may be shown in the following order: Cortico-pontile tract; nuclei pontis; cerebello-cortex; dentatum; prepeduncle; rubrum; tractus rubrospinalis; spinal gray; spinal nerve; muscle.

Summary of the Gray Masses in the Mid-brain.

* Central aqueduct gray
  (a) Oculomotor n. nucleus
  (b) Trochlear n. nucleus
  Nucleus radicis descendentis nervi trigemini
  * Nucleus of medial longitudinal bundle and postcommissure
  * Formatio reticularis
  * Substantia nigra (intercalatum)
  * Rubrum (red nucleus)
  * Stratum cinereum pregemini
  * Nucleus postgemini
  * “Interpeduncular” ganglion.

Structures marked with an asterisk have been considered in the preceding description. The central connections of the oculomotor, trochlear, and trigeminal nerves may now be described.

Deep Origin of Cranial Nerves Arising in the Mid-brain.—The mesencephalic root of the trigeminal nerve has been described on p. 894.

The Trochlear-nerve Nucleus.—The trochlear-nerve nucleus is situated in the level of the cephalic half of the postgeminum. It is a small oval mass of gray substance in the ventral part of the central aqueduct gray. The cells are large, sometimes stellate in appearance. The root fibres pursue a peculiar course; they accumulate in the latero-ventral angle of the aqueduct gray, run caudad, gradually rising dorsal, and suddenly turn mesad to undergo a complete decus-

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1 Decussatio fontinalis, so called because of the resemblance of the scattering strands to the jets of a fountain.
2 Türck's bundle; not to be confused with Türck's column in the cord.
ation with the root of the opposite side in the valula, emerging laterad of the frenulum, or at the inner border of the prepuduncle.

The nucleus is placed under the dominion of the cerebral cortex by pyramidal fibres, and it is associated with other nuclei in the brain-stem by the medial longitudinal bundle.

The Oculomotor-nerve Nucleus.—The oculomotor-nerve nucleus is a group of cell-clusters in the ventral portion of the aqueduct gray, subjacent to the pregeminum, and extending cephalad to become lost in the gray wall of the third ventricle at the slope formed by the opening out of the aqueduct. Its nerve-elements are arranged in definite groups. The most cephalic of these is composed of smaller elements, closely crowded and embedded in deeply staining molecular ground-substance. In a flat-wise section of the brain-stem the outline of this nucleus resembles an inverted L or the tip of a boat-hook; the axones from the cells of this nucleus (of Edinger and Westphal) supply the ciliary muscle and sphincter iridis (pupillary motion). The main nucleus, composed of several sub-groups, lies caudo-laterad of the preceding, and is composed of larger cell-elements.

The root-fibre bundles from this nuclear group pass ventrad, breaking through the medial longitudinal fasciculus, separating like the strands of a horse's tail by the interference of the red nucleus, to become gathered into more compact bundles between the mesal edge of the substantia nigra and intercruhal region, and emerging by eight to twelve fascicules which compose the trunk of the oculomotor nerve.

The origin of each nerve is not limited to the nuclei of its side; a part is decussated and the decussated origin is related to the innervation of the Internal Rectus. By means of association neurones in the medial longitudinal fasciculus the oculomotor and abducent nuclei of one side are brought into relation, affording an organic basis for the synergism existing between the Internal and External Recti muscles in the conjugated lateral eye-movements.

The paradox of the facial nerve supplying muscles under the reflex dominion of the retina (orbicularis oculi) instead of the oculomotor may be explained by the assumed existence of fibres emerging from the oculomotor nucleus, entering the medial longitudinal fasciculus and joining the root of the facial.

Parts Derived from the Fore-brain.

The Fore-brain or Prosencephalon includes those portions of the brain which are derived from the cephalic one of the three primary brain-vesicles. It includes, according to prevailing schemas, a thalamic portion (the thalamencephalon or diencephalon) and the telencephalon. The two divisions constitute a structural continuity and exhibit a mutual dependency so close that the arbitrary distinction now in vogue tends to mislead. The relations of "diencephalon" and "telencephalon" are further complicated by the intimate fusion of the sides of the former (thalami) with the floors of the latter (caudata); this caudatothalamic fusion, in the adult brain, gives rise to some difficulty in distinguishing the two segments. The internal capsule which intervenes between thalamus and lenticula also intervenes between lenticula and caudatum, both telencephalic parts.

External Morphology.—The diencephalon or thalamencephalon comprises the thalami, the epiphysis and habenae, the pregeniculums, and the pars mammillaris hypothalami. (Other classifications include also the pars optica, with tuber, chiasm, and hypophysis. It is also defined as so much of the fore-brain as does not enter into the formation of the cerebral hemispheres.) Caudal it is continuous with the mid-brain, cephalad with the cerebral hemispheres. Its primitive cavity becomes metamorphosed in the adult into the third ventricle or diaelese as the lateral walls hypertrophy to form the thalami. Its ventral surface is the relatively
insignificant gray lamina in the intercrural space. Its dorsal surface is concealed from view by the massive hemispheres and their great commissure, the callosum, and by the fornix. Its actual roof, separating it from the overlapping cerebral parts, is a delicate membranous fold, the diatela or velum interpositum.

The Thalami.†—The thalami constitute the bulk of this portion of the brain. They are large ovoid masses of gray substance so named by the ancients after their resemblance to a pair of couches. Each thalamus is smaller frontad than caudad and the caudal ends are more widely separated from each other. The mesal or ventricular surface is largely free, except for an area, of variable size, by which the two thalami are fused in 90 per cent. of brains. This thalamic fusion is also called the medicomissure. This surface is covered by endyma and of smooth contour. Its dorsal limit is marked by an endymal ridge, usually torn through in dissection, the ripa² or tænia thalami, fortified by a subjacent narrow band of fibres called the stria medullaris, which may be traced to the habenal nucleus and habenal commissure (or “stalk” of the epiphysis). Caudad lies a depressed triangular area—the trigonum habenae, situated cephalad of the preglomerinum.

The dorsal surface is usually described as being free, but only a narrow ectal portion can be so described, the endyma of the lateral ventricle being slightly reflected upon it (the lamina affixa) before entering into the formation of the paraplexus. The rest of the dorsal surface is not lined by endyma, but is in contact with the pial fold called the velum interpositum. This surface is of a whitish color owing to a thin layer of white fibres, the stratum zonale. A faint oblique groove crosses this surface in a caudo-lateral direction, corresponding to the ectal

† Thalamos, bed or couch; bed-chamber.
² The name ripa was proposed by Wilder for the line formed by the rupture of the endyma along the lines of its reflection from entocelian (ventricular) surfaces.
edge of the fornix. Laterad it is demarcated from the caudatum by a groove which is occupied by a slender band of fibres and the striatal vein, called the *tania semicircularis* or *stria terminalis*. The surface is not of even contour throughout, usually showing three eminences (in addition to the pulvinar) corresponding to the main nuclear aggregations within the thalamus, viz.:

- Tuberculum anterius.
- Tuberculum medialis.
- Tuberculum lateralis.

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**The Tuberculum Anterius.**—The tuberculum anterius forms a marked bulging frontal extremity, which helps to form the boundary of the *porta* (*foramen of Monro*) or aperture of communication between lateral and third ventricles.

The caudal extremity of the thalamus is a prominent, bolster-like projection which overhangs the brachia of the quadrigemina and is called the *pulvinar*. A smaller oval prominence, situated ventro-laterad of the pulvinar, is termed the *pregeniculum* (*corpus geniculatum externum*)—a partial end-station for the optic tract.
The lateral surface of the thalamus is in contact with the internal capsule—that
great concentration of fibre-tracts coursing to and from cerebral centres and
forming the crusca below. To this white stratum the thalamus itself contributes
fibres destined to reach the cortex, and in turn it receives fibres from the cortex.
These thalamo-cortical and cortico-thalamic sets of fibres constitute the thalamic
radiation, forming a more or less distinct reticulated capsular zone (external
medullary lamina; stratum reticulatum) for the thalamus.

The ventral surface is in contact with the sub-thalamic tegmental substance
and continuous with the central gray of the third ventricle lining its sides and floor.

Internal Structure of the Thalamus and its Connections.—The thalamus is composed
of gray substance, with large multipolar cells, which is sub-divided into a
number of distinct nuclei; twenty such have been described; three are universally
recognized. They are separated from each other by a white layer (lamina medul-
laris interna) which runs parallel to the wall of the third ventricle for its greater
length; caudally it runs mesad, overlapped by the eetal nucleus, and numerous
sub-laminae run into it. Frontad the internal medullary lamina sub-divides into
two branches, thus permitting the intrusion of the nucleus anterius between the
two main nuclei (medial and lateral).

The nucleus anterior lies fronto-dorsad; in it terminate the axones of the fasciculus
thalamomammillaris (fasciculus albicantothalami—bundle of Vicq d’Azyr). The nucleus medialis is lined mesad by the central gray of the third ventricle and is
usually fused with its fellow of the opposite side (medicomissure). A special
spheroidal cell-cluster in this nucleus is called the centrum medianum (Luys).
The nucleus lateralis is the largest of the three, extending the entire length of
the thalamus and including the pulvinar. A special semilunar cluster of cells in the
ventral portion of this nucleus is called the nucleus semilunaris (Flechsig).

The Connections of the Thalamus.—The thalamus is a ganglion interposed
between the sensor tracts in the tegmentum and the cerebral cortex, as well as
an important link in the optic path. It also gives rise to motor tracts con-
cerned with instinctive movements of an emotional nature. It is a relay station
for the various tracts which convey sensations of touch, temperature, and pain
from the body, extremities, head, and neck, of muscle-sense, and of the special
senses. It transmits these impulses to, and, reciprocally, receives impulses from
the cerebral cortex. As an “emotional” centre it is also under the inhibitory
influence of the cerebral cortex, which, if the emotion be not too strong, prevents
its external manifestation.

The thalamo-cortical and cortico-thalamic fibres, with the internal capsule, enter
into the corona radiata or fan-like formation of the white substance of the cerebral
hemisphere. Although there is no anatomic sub-division into distinct groups of
these fibres as they stream to and from the thalamus, it is customary to distinguish
a frontal, a parietal, an occipital, and a ventral stalk. The frontal and parietal
stalks, as their names indicate, pass between thalamus and fronto-parietal cortex,
as well as to the lenticular and caudatum. The occipital stalk is composed of
fibres passing in both directions between the pulvinar and occipital cortex, con-
stituting the so-called optic radiation. The ventral stalk comprises the ansa
lenticularis (thalamolenticular) and the ansa peduncularis (thalamotemporal and
thalamoinsular). They will be described in detail farther on.

The Fregeniculum is an intercalar ganglion proper to the optic nerve, derived
from the thalamus. On section it is seen to be characterized by the regular
alternation of deeply gray and white lamine. The latter are thicker and com-
poosed of fibres which enter the pregeniculum from the optic tract and optic radia-
tion. The nerve-cells in the gray substance are large, multipolar, and pigmented.

[Note.—The pregeniculum and the more isolated postgeniculum are gener-
ally included under the head of metathalamus.]
The *Hypothalamic Tegmental Substance*, continuous with the mid-brain tegmentum, is interpolated between the ventral face of the thalamus, the red nucleus, and a continuation of the substantia nigra known as the *corpus hypothalamicus* or *body of Luys*. Through the hypothalamic tegmentum stream the fibres of the *medial lemniscus*, of the *cerebellar prepdenduncle*, and from the red nucleus, to end in relation with thalamic cells. The corpus hypothalamicus is a grayish-brown, lentiform mass which lies in the ideal continuation frontad of the lateral part of the substantia nigra, and, like it, situated between pes and tegmentum. It is made up of fine myelinated fibres crowded in great profusion and confusion, with numerous delicate, coiled capillaries and sparse, multipolar, more or less pigmented, nerve elements of moderate size. The outline of the body is defined by a white capsule, some of the fibres of which are seen to decussate in the floor of the third ventricle, with those of the opposite side dorso-caudal of the albeantia.

The *Epiphysis* (*corpus pineale*) (Figs. 592, 593).—The epiphysis (*pineal body*, from its shape resembling a fir-cone—*pinus*) is a small, reddish-gray body placed between the caudal ends of the thalami and occupying the depression between the two pregressina. It is covered by the velum interpositum, which intervenes between it and the splenium of the callosum. It is an outgrowth which is not regarded as an important neural ingredient of the human brain and is generally believed to be a rudimentary relic, representing a cyclopean eye\(^1\) of some extinct ancestral vertebrate, homologous with the parietal organ, resembling a mollusean eye of a living species of lizard (the *Hatteria* of Australia). Its attached base is a hollow peduncle divisible into a dorsal and ventral part by the intrusion of the *epiphealseal recess* (*recessus pinealis*) of the third ventricle. The *dorsal stalk* continues on either side and upon each thalamus as the stria medullaris; it is reinforced by commissural fibres joining the habenae of the two sides; hence another name for the dorsal stalk is the *habenal commissure* (*supracommissure* of Osborn). The *ventral stalk* is folded over another commissural band—the *postcommissure*.

Structure.—The epiphysis, or pineal gland, consists of a number of follicles, lined by epithelium, and connected together by ingrowths of connective tissue. The follicles contain a transparent, viscid fluid, and a quantity of sabulous matter named *brain sand* (*acerbus cerebrii*), composed of phosphate and carbonate of lime, phosphate of magnesia and ammonia, with a little animal matter. These concretions are almost constant in their existence, and are present at all periods of life.

In the interval between the epiphysis and the caudal end of the thalamus lies a small triangular depression (sometimes an elevation) known as the *trigonum habenae*, marking the position of the *nidus* or *ganglion habenae*, a group of small angular cells. The axones from these cells are collected ventrad into the *fasciculus retroflexus* (Meynert), which courses through the tegmentum mesad of the red nucleus to end in the *interpeduncular ganglion* (Gudden) in the postperforatum. In addition to this fasciculus, the habenae is the reunion point for two other sets of fibres: (1) the *stria medullaris* and (2) the *habena proper* or *habenal commissure*. The stria medullaris (p. 912) is made up of axones arising from two sources: (1) cells in the hippocampus (*via fornix*) and (2) cells in the ganglion opticum basale. These join near the fornix column (anterior pillar of fornix) and run caudad on the mesal thalamic surface, to end in the habenal ganglion of the same side and, by crossing in the dorsal stalk of the epiphysis form the habenal commissure, ending in the corresponding nidus habenae of the opposite side.

Postcommissure.—The postcommissure is a round band of white fibres crossing from side to side in the ventral stalk of the epiphysis bridging the aqueduct at

\(^1\) Although most vertebrates show a single epiphysis or parietal organ, it is double in the lamprey and certain reptiles; the two epiphyses lie one in front of the other—not side by side (although probably paired organs originally). The frontal organ sends its fibres into the habenal nucleus; the caudal organ to the region of the postcommissure (tectum opticum).
its continuation into the third ventricle. The postcommis sure shares relation with both fore- and mid-brain structures and is formed of decussating fibres which may be enumerated in the following systems: (a) fibres arising in the special nucleus (described on p. 908) for the medial longitudinal bundle; (b) fibres connecting the two thalami; (c) fibres connecting the habenal nidi; (d) fibres connecting the pregmina.

[Note.—The habenae, epiphysis, and postcommis sure are generally included under the head of epithalamus.]

The Postperforatum (locus perforatus posticus).—The postperforatum has been described on p. 861. It marks the situation of the “interpeduncular ganglion,” small in man, but very large in rodent brains. From the cells in this primitive gray lamina arise the fibre-tracts already described as the tænia pontis (p. 906), and often visible at the point of emergence from the gray substance of the intercrural space.

The Albicantia (Fig. 592).—The albicantia or mammillaria are two symmetrical, small, round, white protuberances situated side by side in the intercrural space cephalad of the postperforatum, at a point where the floor of the third ventricle rapidly decreases in thickness to form the tuber. The color of each albian is white, owing to a superficial stratum of fibres derived from the fornix. Within lie three nuclear masses; two medial, constituting the main mass, and a smaller lateral nucleus applied against the former, so as to represent a crescent on cross-section.

The fibres of the fornix terminate in the albi cans. From its cells arise two fasciculi which have a common neurone origin. Cajal discovered, and Kölliker confirmed the fact, that the axones from the medial nucleus cells bifurcate; one set of limbs passes fronto-dorsad to form the fasciculus thalamomamillaris (bundle of Vteq d’Azyr), which ends in the nucleus anterius of the thalamus, while the other set of limbs of the primary axones passes caudal to form the fasciculus pedunculomamillaris in the mid-brain tegmentum; its destination is doubtful. The axones from the lateral nucleus join the latter bundle.

[Note.—The postperforatum and the albicantia are generally included under the head of the Pars Mammillaris Hypothalami.]

Third Ventricle (ventriculus tertius) (Fig. 592).—The third ventricle is the adult representative of the cavity of the primary fore-brain vesicle, but only so much of it as is not carried laterad, on either side, in the rapidly growing, eventually huge cerebral hemisphere buds to form the lateral ventricles. It is a narrow, cleft-like interval between the two thalami and hypothalamic gray, limited frontad by the terma, continuous caudad with the aqueduct and laterad, through the porta, with the lateral ventricles. Its roof is destitute of nerve tissue and is formed by a delicate, fused endymal and pial layer, invaginated on either side of the median plane by paraplexuses. The pial layer is one of the constituents of the fold known as the velum. The floor of the ventricle is formed by structures already described on the basal aspect in the intercrural space, viz., the tuber, albicantia, and postperforatum, as well as the chiasm and a portion of the tegmentum of the crura. Much of the floor, it may be noted, is formed by the primitive, undifferentiated central gray; and although the optic vesicle developed from its ventro-cephalic portion, the caudal shifting of central optic connections to thalamus and mid-brain has made this portion of the neural tube wall comparatively insignificant. The lateral walls are formed, in part by the thalami, in part by the hypothalamic gray ventral extension. The fornix may be seen, shining through a thin lamina of gray substance and the endyma, coursing caudo-ventrad to the albicans. A slight furrow, the aulix or sulcus of Monro, may sometimes be traced from the aqueduct to the porta, curving ventrad of a bridge-like fusion of the two thalami—the medicommission. (The latter term is inappropriate, as no
commissural fibres appear to pass from one thalamus to the other in this "thalamic fusion;" it is absent in about 10 per cent. of brains examined.)

The cephalic wall is formed by the terma, the rudimentary median-cephalic wall of the neural tube. The terma is attached to the dorsum of the chiasm; dorsally it is reënforced by the precommissure.

As seen in mesial section or as shown by a cast of the ventricle (Fig. 592) it is seen to be of irregular outline. Frontal is the optic recess, dorsad of the chiasm; caudad thereof is the infundibular recess in the tuber. The epiphyseal recess is seen between the habenal commissure and the postcommissure. Dorsad of the epiphysis is a diverticular recess of variable extent (recessus suprapinealis).

If the segmentation of the fore-brain into two divisions be adopted ultimately, it will be necessary to allot one portion of the third ventricle (between the thalami) to the diencephalon (hence diac(e)le), and the rest to the telencephalon (the medial cavity of which is termed the aula by Wilder).

In anticipation of the description of the cerebral hemispheres we may consider here the remaining structures in the floor of the third ventricle, usually included under the head of the pars optica hypothalami of the telencephalon, in order to lead up to a description of the cerebral connections of the optic tract.

External Morphology of the Optic Portion of the Hypothalamus.—This includes the tuber and hypophysis, the terma, the chiasm, and the optic tracts.

The Tuber (tuber cinereum) (Fig. 592).—The tuber is a thin-walled conical projection in the interceral space cephalad of the albicantia. Its apical portion is attenuated to form the stalk of the hypophysis; this is generally termed the infundibulum, while the cavity of the funnel-shaped diverticulum is called the infundibular recess of the third ventricle. The gray lamina composing the tuber is continuous with the central ventricular gray, and therefore with the terma.

The Hypophysis.—The hypophysis is a structure of two-fold origin, giving rise to a division into a prehypophysis and a posthypophysis. The posthypophysis alone is of neural origin, developing as a ventral diverticulum from the primitive neural tube. The prehypophysis develops from the stomodeum, or primitive buccal cavity, as a tubular diverticulum (Rathke's), which eventually loses its connection with the oral tissues to become included within the cranial cavity and intimately attached to the neural bud. Both pre- and posthypophysis are therefore of ectodermal origin and have developed from a conjunction of surface tissues which have migrated from opposed (ventral and dorsal) parts through the head! The prehypophysis is much the larger and somewhat embraces the posthypophysis; the two are inseparable, however, and together occupy the fossa hypophyseos of the sphenoid.

The two parts of the hypophysis are as distinct in structure as they are in embryonic origin. The posthypophysis consists of a mass of neuroglia, connective tissue, and bloodvessels; the structure of the prehypophysis is distinctly glandular, resembling that of the parathyroid bodies. It is surmised that the latter is the functional part of the hypophysis—concerned with the internal secretions, and usually involved in the pathological form of giantism called acromegaly.

The Terma (lamina terminalis s. cinerea) (Fig. 592).—The terma is a thin, easily torn lamina between the chiasm and the precommissure, limited laterally by the closely approximated hemicerebra, and constituting the primitive, undifferentiated cephalic boundary of the original neural tube.

The Optic Tract and its Central Connections.—In the section on the development of the brain it was learned that the optic nerve is not a peripheral nerve; it is rather a central brain tract extruded from the neural tube. Evidence is at hand that in ancestral vertebrates the general cutaneous sensor system was also capable

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1 Occasionally the channel persists as the cranio-pharyngeal canal.
of light perception. With the recession of the neural tube from the surface and in company with the morphological differentiation of the head-end, a light-perceiving pair of organs arose as a special development. The distal end of the optic brain-vesicle becomes the retina, in structure like the brain-wall, whose cell-axones carry afferent impulses to the brain. Although the optic fibres enter the ventral wall of the brain, the retina is originally derived from the dorso-lateral (sensor) wall of the second neuromere (Fig. 558). The parietal organs, also light-perceiving, likewise developed as paired dorsal buds farther caudad, eventually to atrophy, as the more frontal optic organs better subserved the purposes of the organism.

The remarkable and as yet unexplained fact regarding the optic apparatus is that the afferent fibres from the retinal cells pass into the ventral wall to cross to the opposite side, forming a decussation which is total, or nearly so, in vertebrates below the mammals; the more laterally placed the eyes are the more nearly total is the decussation.1

Although the optic vesicle is a diverticulum of the fore-brain in its cephalic portion, the optic tract in its central connections becomes intimately related with the pregeniculum and pulvinar, with the pregeminum of the mid-brain, and with the occipital cortex of the cerebrum. Some of these central structures are way-stations in reflex-paths; the occipital cortex alone is the actual visual centre, though visual perceptions are here brought into association with tactile, auditory, and other impulses.

1 Possibly the reflex contraction of the muscles on one side of the body in the ancestral vertebrate followed the perception of a menacing object by the eye of the opposite side; hence the advantage of a decussation.
Chiasm.—From the retina of each eye the so-called optic nerves converge to partially decussate at the base of the brain to form the chiasm, a white quadrangular plate which presses in the primitive central gray floor of the third ventricle, as previously described. Approximately one-third of the fibres of each optic nerve do not cross to the opposite side. The chiasm is further reinforced by the infracommissure (of Gudden) and other lesser fibre-tracts (commissura superior [Meynert] and commissura ansata [Kölliker]). The fibres in the chiasm are so complexly interwoven that only through exhaustive experimental, developmental, and pathologic studies has it been possible to understand its structure. Broadly stated, the fibres from the medial (or nasal) halves of the retina decussate in toto, while those from the lateral (or temporal) halves do not cross. Leaving the chiasm, the crossed medial and uncrossed lateral fibres form the slightly flattened optic tracts coursing caudo-lateral, embracing the crura cerebri and dividing in the neighborhood of the pregeniculum into two "roots," a mesal and a lateral root. The mesal root is in reality not a part of the true optic path; it is a separate fascicular representation of the infracommissure of Gudden, composed of fibres forming a reciprocal bond of union (commissural) between the postgeniculums of the two sides and coursing through the chiasm (Fig. 594). The lateral root of the optic tract is the true visual path, composed of (a) the uncrossed fibres from the lateral half of the retina of the same side and (b) the crossed fibres from the mesal half of the retina of the opposite side. The fibres of the lateral root are distributed to the primary or lower optic centres as follows: (1) Most fibres end in the pregeniculum; (2) a lesser number end in the pulvinar; (3) the remainder end in the nucleus of the pregeniculum.

The pregeniculum and pulvinar are ganglionic way-stations or internodes in which visual impulses are reflected, in large part, to the visual cortex in the occipital lobe; the pregenium, on the other hand, plays no part in the conduction of impulses perceived as light or color; it presides rather over the eye-muscle reflexes to visual stimuli, and in its turn is under the dominion of the higher cortical centre. Reflex impulses are sent to oblongatal and spinal centres along axones entering into the formation of the medial longitudinal bundle. The axones of corticifugal neurones proceed to the nucleus of the pregeneculum along the optic radiation.

The connections of the pregeniculum and pulvinar with the higher cortical centre of vision are established by neurones, the cells of which lie in the two ganglia just mentioned, and whose axones stream in an arched, more or less compact bundle in the white matter of the hemiserebra toward the occipital cortex. Another system of neurones, whose cells lie in the cortex, sends its axones in the reverse direction (corticifugal) to the two lower centres. The cerebral tract thus formed between primary and secondary (cortical) centres is called the optic radiation, to be studied more fully in the sequel. The components of the optic path are delineated schematically in Fig. 594.

The Cerebral Hemispheres.

External Morphology.—Of all the component parts of the brain, the cerebral hemispheres form the largest part, and their preponderance and remarkable specialization underlie the extraordinary manifestations of the intellect so highly amplified in man.

The term cerebrum, often employed loosely as embracing several brain-parts,
is here intended to include the brain-mantle and the olfactory lobe—equivalent to the telencephalon of His, with the exception of the pars optica hypothalami. As already indicated in the section on brain-development, there has occurred, in the evolutionary history of man's vertebrate ancestry, a progressive increase of the secondary fore-brain, with concomitant reduction of the rhinencephalon, or smell-brain—the most archaic portion because of the important relations of the smell-sense to the life history of the earliest vertebrates.\(^1\)

In a mesal view of a hemisected brain (Fig. 595) may be seen the various parts of the brain-stem and the cerebellum overlapped by the preponderantly greater cerebrum. Among the many notable features exposed to view in this brain-section are certain fibre-masses, commissures, extending across the meson, and therefore divided by the knife in this preparation. Of the commissures pertaining to the cerebrum one is conspicuous for its size and firm consistency. This great fore-brain commissure is the callosum already mentioned as being demonstrable in the depths of the intercerebral cleft on divaricating the lips of this fissure. The callosum constitutes a massive system of association fibres for the bilateral coordination of corresponding cortical parts. It is thickened caudally, forming the splenium of the callosum; frontad it bends on itself ventro-caudad to form the genu ("knee"), including an interval, between the two limbs, which is flanked on both sides by a thin lamina (hemiseptum) and bounded ventrad by the fornix, constituting a closed cavity, the pseudocele (or "fifth ventricle"). The recurved ventral part of the genu tapers into a thinner, beak-shaped part, the rostrum. The rostrum is joined to the terma, frontad of the precommissure, by a thin lamina, the copula (lamina rostralis; lamina baseos alba).

\(^1\) For a more thorough discussion on the natural subdivision of the fore-brain, based upon comparative morphology, see the paper by G. Elliott Smith, *Journal of Anatomy and Physiology*, 1901.
An arched structure composed of longitudinal fibre-bundles comes to view ventrad of the junction of the splenium with the body of the callosum, proceeds fronto-ventrad with its convexity frontad, to sink from view in the substance of the hypothalamic gray at a point just caudal of the precommissure. This white arched bundle is the fornix. Between it and the callosum, rostrum, and copula stretches a thin, translucent lamina of nerve-tissue—the hemiseptum. The hemisepta of the two sides together have usually been termed the septum pellucidum, while the enclosed narrow cavity is called the pseudocele or fifth ventricle. The subjacent parts revealed in this section have already been described; the morphology and internal relations of the callosum, fornix, and hemiseptum will be described at a later stage.

The cerebral hemispheres together, as viewed from above or dorsally, appear as two symmetrical masses in close apposition, conforming in outline to that of the cranial cavity, which they so nearly fill. The frontal extremities or poles are massive and rounded, preponderatingly so in comparison with the brains of any related primate species. The occipital poles are each more pointed, but expand frontad into the widest part of the cerebrum—the parietal lobes. The cerebral hemispheres or, briefly, the hemicerebra are partially separated from each other by the intercerebral cleft or fissure (fissura longitudinalis cerebri), into which fits
a fold of the dura—the **falk**. By means of a large commissural band of white fibres—the **callosum**—the cerebral halves are joined together in the depths of the intercerebral cleft. All adjacent parts of the brain are overlapped by the ponderous cerebrum so as to entirely conceal the thalamic portion and the mid-brain, while the occipital lobes overlap the cerebellum with the intervening tentorium—another fold of the dura. Further description will be restricted to each hemicerebrum.

**Configuration of Each Hemicerebrum.**—Each hemicerebrum presents an *outer convex surface* (*facies convessa cerebri*), applied to the corresponding half of the cranial vault; a *mesal flattened surface* (*facies medialis cerebri*), which lies in a sagittal plane, applied to the corresponding surface of the opposite hemicerebrum, with the intercerebral cleft intervening, and for the most part in contact with the falk; and a *basal or ventral surface*, of irregular form, resting frontad upon the floors of the anterior and middle cranial fossae, and caudad upon the tentorium.

Prominent in the lateral and ventral views is the blunt projection of the temporal pole, while at the ventro-lateral border, nearer the occipital pole, is a slightly marked indentation usually called the **pre-occipital notch**. The deep vallecular depression between the orbital surface and the temporal pole accommodates the great wing of the sphenoid.

More or less distinct borders demarcate the surfaces. The arched **dorsi-mesal border** intervenes between the mesal and the convex surfaces; a straight **mesorbital border** intervenes between the orbital and mesal surfaces of the frontal lobe; a **ventro-lateral border** separates the tentorial surface from the lateral, convex surface of the occipital and temporal lobes; while an obtuse border—the **mesoventral or internal occipital border** separates the tentorial from the mesal surfaces.

**Cerebral Fissures and Gyres.**—The surface of each hemicerebrum presents alternating depressions or **fissures** which demarcate gyral elevations—the **convolutions** or **gyres**.¹ The fissures vary in depth from that of a mere shallow groove to as much as 30 mm., and may attain a length of 15 cm. They are more or less

¹ Consistent with the use of the English *lobe* and *lobes* (for *lobus* and *lobi*), the English *gyrus* and *gyres* are preferable to *gyrus* and *gyri*. The term *fissure* is here uniformly employed for all anfractuosities of the surface, though *sulcus* (pl. *sulci*) is quite as generally used; sometimes both terms are indiscriminately mixed.
THE CEREBRAL HEMISPHERES

sinuous and ramified. They mark the surface with fairly approximate uniformity, that is, one rarely finds an un fissured surface more than 15 to 20 mm. in width. Numerous functional and mechanical influences must be credited with bringing about the complex foldings of the cerebral surface, principally (a) resistance of the cranium to the expanding brain or "mechanical packing;" (b) differences of growth-rate in different parts of the cortical surface; (c) differences of growth-rate of different fibre-bundles retarding cortical expansion along the fissure-lines and elongating to help in the formation of the gyres. The obvious result, whatever the influences may be, is an expansion of the cerebral cortex to an enormous degree, so that, instead of having a surface-area of only 60,000 sq. mm. (if unconvoluted), the average adult cerebrum has a cortical area of 200,000 sq. mm. or more. Furthermore, the vascular pia, closely investing the surface and dipping into every fissure, is expanded in a like manner, affording an ample and uniform supply of blood for the entire cerebral cortex.

The cerebral vesicle of the foetal brain presents a smooth surface during the first half of intrauterine life, except for the depressed sylvian fossa at the site of the future insula—destined to become buried in the depths of the sylvian elefant formed by the apposition of the more energetically growing contiguous parts of the cerebral mantle. Some of the cerebral fissures develop early as infoldings of the comparatively thin wall of the vesicle, and hence produce corresponding projections into the cerebral cavity; these are termed the total or complete fissures. The remaining fissures are only linear depressions of the surface not involving the entire thickness of the wall—the partial or incomplete fissures. The complete fissures and their correlative projections into the cerebral cavity (lateral ventricle) are:

<table>
<thead>
<tr>
<th>Fissure</th>
<th>Internal Eminence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hippocampal fissure</td>
<td>Hippocampus</td>
</tr>
<tr>
<td>Calcarine fissure</td>
<td>Callear</td>
</tr>
<tr>
<td>Collateral fissure</td>
<td>Collateral eminence</td>
</tr>
<tr>
<td>Occipital fissure</td>
<td>Occipital eminence</td>
</tr>
</tbody>
</table>

Among the remaining cerebral fissures, of which over fifty have been recognized and named, some are constant in representation in all normal brains, while others are of variable occurrence in different individual specimens. The constant fissures are those which regularly exist as interlobar and intergyral boundary lines forming a common pattern for all normal brains, but these, like all cerebral fissures, are subject to many individual variations as to course, depth, length, mode of branching, and Anastomosis with neighboring fissures or manner of interruption by gyral isthmuses. The range of individual variations is so great that no two brains can be said to be exactly alike; in fact, one may find numberless stages of complexity in the cerebral surface configuration from the simply fissured brains of mentally inferior individuals and races to the complexly fissured and more highly organized brains of vigorous thinkers and talented geniuses among the highly intellectual races of man.

Cerebral Lobes and Fissures.—The cerebral surface is divided into five principal areas called lobes, demarcated by certain constant fissures which are more or less conspicuous, and were therefore selected by the older anatomists as arbitrary boundary lines; these are termed the interlobar fissures.

The lobes are: (1) the frontal; (2) the parietal; (3) the temporal; (4) the occipital; (5) the insula. The inter-lobar fissures are: (1) the sylvian; (2) the central; (3) the occipital; (4) the calcarine; (5) the circuminsular. A series of fissures demarcating

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1 The so-called transitory fissures of older descriptions may be neglected, since the researches of Retzius, Hochstetter, and Mall have shown these to be in reality artifacts due to postmortem swelling.
the rhinencephalon from the pallium or cerebral mantle proper will be considered at a later stage.

The Interlobar Fissures. The Sylvian Fissure and its Rami (fissura cerebri lateralis [Sylvii]).—This fissure is a well-marked cleft on the base and side of the hemicerebrum. Traced laterad from the region of the preperforatum, it begins as a deep depression between the orbital surface of the frontal lobe and the temporal pole, corresponding to the bony ridge formed by the lesser wing of the sphenoid and extending to the convex surface. This portion of the fissure is termed the basisylvian fissure or vallecula sylvii, as far as the sylvian point. The sylvian point marks the conjunction of the main portion of the sylvian fissure with its basisylvian part as well as one or two rami. These rami are: (1) the presylvian ramus; (2) the subsylvian ramus.

Fig. 598.—Cerebral fissures and gyres viewed dorsally.

The Presylvian Ramus usually proceeds dorsad, slightly inclined frontad, for a distance of 2 to 3 cm. into the subfrontal gyre.

The Subsylvian Ramus (anterior horizontal limb) extends frontad for a distance of 1.5 to 2. cm., parallel to the orbito-frontal (superciliary) margin.

These two rami often spring as shorter branches from a common stem and both may be replaced by a single unbranched limb.

The sylvian fissure proper is the most conspicuous part. It extends from the sylvian point in a caudal direction, inclined slightly dorsad, on the lateral surface of the cerebrum for a distance averaging 6 cm. It separates the temporal lobe
wholly from the frontal and partly from the parietal lobe. It usually ends in an upturned manner, in the parietal lobe, the change of direction being often more abrupt than gradual; this terminal piece receives the name of epiylvian ramus. Occasionally a short ramus is sent ventrad into the supertemporal gyre and is called the hypo.sylvian ramus.

The sylvian fissure ranges in depth from 15 mm. or less at the presylvian point to 25 or 30 mm. at the postsylvian point, correlative with the contour of the insula, which lies in its depths. If the lips of the sylvian fissure be divaricated the insula is revealed as a cortical district, of tetrahedral form, which is normally completely concealed by overlapping portions of the hemicerebrum called the opercula. These are four in number: (1) the operculum proper, (2) the preoperculum, (3) the suboperculum, and (4) the postoperculum.

The operculum (frontoparietal operculum) is composed of the adjacent portions of the ventral border of the frontal and parietal lobes, the sylvian fissure intervening between it and the postoperculum, which is the overlapping part of the temporal lobe. The pre-operculum is a small triangular portion embraced by the presylvian and subsylvian rami, and is also called the pars triangularis or Broca's cap. The suboperculum (orbital operculum) is small, demarcated by the subsylvian ramus, and for the most part on the orbital face of the frontal lobe, projecting slightly over the frontal part of the insula, with its margin separated from the temporal pole by the basylvian cleft.

The overlapping opercula are demarcated from the insula by the circumsylvian fissure (sulcus circularis Reilii).

Development of the Insula and the Sylvian Cleft.—The insular cortical district is topographically correlative with the great gray ganglia of the cerebral hemisphere, particularly the lenticular, from whose ectal surface the insular cortex is but little removed. As will be learned at a later stage, few if any projection fibres pass to and from the insula; its function is almost wholly associative for adjacent parts of the cerebral mantle. The insula therefore becomes buried beneath the more energetically growing and bulging parts immediately around it. There is at first a slight fossa (observable in the tenth to twelfth week) which, as development proceeds, and as the overhanging operculum encroach upon the insula, becomes more deeply situated as a cleft-like depression until at birth the fossa has become a fissure, with the insula perhaps slightly exposed near its cephalic extremity, where the incomplete apposition of the opercula leaves a triangular space. This

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Fig. 599.—Central fissure fully opened up, so as to exhibit the interlocking gyres.
space is usually obliterated in childhood, but is commonly met with in certain races (negro, Australian) and in brains showing developmental defects or arrest. The mechanics of the formation of the surface outline of the sylvian fissure by the apposition of the growing and plastic opercula may be understood by a reference to Fig. 604.  

The Central Fissure (fissura of Rolando [sulcus centralis]).—The central fissure is situated at about the middle of the convex surface, and, coursing obliquely latero-frontad, divides this surface into approximately equal parts, intervening between the frontal and parietal lobes. It may be traced from a point at or near the dorsi-mesal border, about 1 cm. caudad of the mid-point of the occipito-frontal arc. It then runs sinuously latero-frontad to within a short distance of the sylvian fissure, about 2 cm. caudad of the sylvian point; its line of general direction makes an angle of about 70 degrees with the median line (Rolandic angle). If measured along its sinuosities, its length averages 10.5 cm. Its curved course may be analyzed into five alternate curves (sometimes more or less), of which three are convex frontad and two caudad. It is rarely very much branched and does not often anastomose with neighboring fissures. Its dorsal end bears a constant relation to the caudal limb of the para-central, frontad of which it can be found as a hook-like curve. If the lips of the central fissure be divaricated, interdigitating sub-gyres are commonly seen in its depths. These interlocking gyres are often fused to a greater or lesser degree, and a total interruption of the fissure has, in rare instances, been observed. The central fissure develops at about the end of the fifth month of intrauterine life, not as a single integer, but as the result of the union of two segments: a short dorsal and a longer ventral segment. As development proceeds these segments eventually unite end to end, and at the site of this union a vadum (or shallow uprising of the floor of the fissure) or even a complete isthmus may be demonstrated in the adult brain. Only three cases of bilateral interruption are on record.  

The Occipital Fissure (fissura occipitalis).—The occipital fissure is a deep cleft across the dorsi-mesal border trans-secting the occipito-frontal arc at about 5 cm. from the occipital pole, and extending upon both the mesal and the convex surfaces. On the meson it attains a length of 3 to 3.5 cm. (to its junction with the calcarine fissure) while its lateral extent is shorter (2 to 2.5 cm.). It is quite deep throughout and usually shows a number of interdigitating sub-gyres.  

The Calcarine Fissure (fissura calcarina).—The calcarine fissure is a slightly arched fissure which is usually joined with the occipital fissure at the apex of the cuneus and extends caudal to the occipital pole, ending in a bifurcation. The fissure is composed of two integers which may be partially or completely separated (by a vadum or an isthmus); the caudal segment may then be distinguished as the post-calcarine fissure.  

The occipital and calcarine fissures join to form a Y-shaped junction; the two limbs of the Y embrace the cuneus, while the stem is continued as the occipito-calcarine stem for a distance of about 3 cm. This fissural stem is allotted to the occipital fissure by some and to the calcarine fissure by other authors. As there is no greater frequency of confluence with one as against the other, so far as present statistics go, it is preferable to assign no special relationship for this stem to one or the other principal fissure.  

I. Frontal Lobe. Fissures of the Frontal Lobe. 1. Lateral Surface.—The lateral surface is bounded by the dorsi-mesal arched border, by the fronto-orbital (or superciliary) border, by the sylvian fissure (in part), and by the central fissure. The principal fissures making this surface demarcate four gyres: (1) the precentral, (2) superfrontal, (3) medifrontal, and (4) subfrontal gyres. The fissures are: (1) the precentral, (2) superfrontal, and (3) subfrontal fissures. In addition must be described certain fissures which are intragryral and of more or less constant occurrence.
The Precentral Fissural Complex (sulcus precentralis).—Two fissural integers which are sometimes joined extend more or less parallel with the central fissure. The mesally situated piece is usually of zygal (yoke-shaped) shape or triradiate, and usually anastomoses with the superfrontal fissure. From its position it is termed the supercentral or superior precentral fissure (sulcus precentralis superior). The laterally situated piece is of longer extent, sometimes straight or slightly sinuous, sometimes arched like an inverted L, or T-shaped. It usually anastomoses with the subfrontal fissure. The two precentral segments demarcate the precentral gyre from the remaining three gyres of the lateral surface of the frontal lobe.

The Superfrontal Fissure (sulcus frontalis superior) usually springs from the supercentral and pursues a sinuous course frontad, to become lost, as a rule, in the zigzag or transverse ramifications of the prefrontal region. It is usually quite ramified and often anastomoses with other fissures. It demarcates the superfrontal from the medifrontal gyre.

The Subfrontal Fissure (sulcus frontalis inferior) is most often confluent with the precentral, less often with the supercentral fissure. It proceeds frontad in an arched course, to end either in a bifurcation or by anastomosing with other fissures (radiate fissures, orbito-frontal fissures, or medifrontal fissures). The subfrontal fissure demarcates the medifrontal from the subfrontal gyre.

Both the superfrontal and medifrontal gyres are characterized by a more or less pronounced longitudinal subdivision by less constant fissural segments. They are: (1) the paramesal fissure (sulcus paramedialis) occupying an intermediate position between the superfrontal fissure and the dorsi-mesal border, in the superfrontal gyre, more often composed of a series of short segments which become lost in the more complex configuration of the prefrontal region; (2) the medifrontal fissure (sulcus frontalis medius) situated in the prefrontal part of the medifrontal gyre, rarely extending throughout, and usually ending cephalad in a widely spread bifurcation which constitutes the orbito-frontal fissure when independent. The medifrontal fissure is usually very much ramified and frequently anastomoses with neighboring fissures. The fissure is a characteristic of human and anthropoid brains only.

![Diagram of the cerebral hemispheres](image-url)
By the occurrence of either or both paramesal and medifrontal fissures, the ordinary three-tier type of frontal lobe is converted into a four-tier and five-tier type; the latter more often in the brains of the more highly intellectual—a feature which is concomitant with the comparatively late phyletic and embryonic development of the two secondary fissures described.

Other, less important, fissures are: (1) the inflected fissure (fissura inflecta), incising the dorsi-mesal border between the central fissure and the cephalic limb of the paracentral; (2) the radiate fissure, near the lateral orbito-frontal border; (3) the trans-precentral, a short oblique piece ventrad of the central and usually dipping into the sylvian cleft, and (4) the diagonal fissure between the presylvian ramus and the ventral end of the central, and often confluent with the precentral (Fig. 600)

2. MESAL SURFACE.—The mesal surface of the frontal surface lobe is bounded by the dorsi-mesal border, the mesorbital border, and the callosal fissure. An arcuate fissure or system of fissures intermediate between the dorsi-mesal margin and the callosal fissure divides this surface into the superfrontal gyre, mesal aspect, and the callosal gyre. The name "calloso-marginal" was usually applied to this fissure, but an examination of many brains reveals a certain integrality of fissural parts which are not always connected. One constant segment from its relations with the central fissure is called the paracentral fissure, composed of a main stem with a cephalic and a caudal limb, embracing the paracentral gyre. Frontad thereof extends the supercallosal fissure, often in two segments, running a concentric course between the arched dorsi-mesal border and the genu of the callosum. The supercallosal may be confluent with the paracentral. The supercallosal is, as a rule, quite ramified, its branches transcribing the superfrotal gyre. In the prefrontal region and ventrad of the genu of the callosum lie one or two fissures, more or less parallel to the mesorbital border, and called, respectively, the rostral and subrostral fissures (sulci rostrales) .

3. ORBITAL SURFACE.—The orbital surface of the frontal lobe is constantly marked by a straight fissure, the olfactory fissure (sulci olfactorius), which runs parallel to the mesorbital border and is occupied by the olfactory bulb and tract. It is about 5 cm. in length and demarcates the mesorbital gyre from the remaining orbital gyres. This orbital surface is marked by a fissural system (sulci orbitales)
that is usually of zygal type, H-shaped or K-shaped, quadriradiate, or, rarely, triradiate. When the transverse element is sufficiently pronounced it merits the name of transorbital fissure, demarcating the preorbital from the postorbital gyral field.

Gyres of the Frontal Lobe (lobus frontalis). 1. Lateral Surface.—The precentral gyre (gyrus centralis anterior), one of the chief motor areas of the cerebral cortex, is a moderately sinuous gyre extending from the dorsi-mesal border to the sylvian fissure and demarcated by the central and the precentral fissures (supercentral + precentral).

The superfrontal gyre is limited laterally by the superfrontal fissure, while it is continuous over the dorsi-mesal border with its mesal surface. It merges insensibly with the medifrontal gyre in the prefrontal region, while it may be partially subdivided by the paramesal fissure.

The medifrontal gyre (gyrus frontalis medius) is broader than the preceding, demarcated by the superfrontal and subfrontal fissures, and often marked by the medifrontal fissure in its prefrontal portion.

The subfrontal gyre (gyrus frontalis inferior) is limited by the subfrontal fissure and the basisylvian + sylvian proper. It is traversed by the presylvian and subsylvian rami, embracing the pre-operculum or pars triangularis. The gyre is of historic importance since Broca, in 1861, declared it to be the seat of speech control. (See Cerebral Localization.)

There being no fissure at this border, it is improper to give the mesal surface of this gyre a different name (i.e., "marginal gyrus" of the authors).

Fig. 602.—Fissures and gyres of the basal surface of the cerebrum.

The cerebral hemispheres.
2. Mesal Surface.—On the mesal surface of the frontal lobe and embracing the dorsal end of the central fissure lies an oval lobule or gyre called the paracentral gyre (lobulus paracentralis), limited by the paracentral fissure with its caudal and cephalic limbs. Frontal thereof extends the large arched mesal surface of the superfrontal gyre ( gyrus frontalis superior), limited by the supercallosal fissure. Between the latter fissure and the callosal fissure, concentrically situated with respect to the superfrontal, lies the callosal gyre (the “ gyrus formicatus” of the authors).

Frontal these two gyres arch around the genu of the callosum, to become merged through the disappearance of the intervening supercallosal fissure, and the rostral fissures alone mark this surface.

3. Orbital Surface.—The olfactory fissure and the mesorbital border bound the mesorbital gyre ( gyrus rectus). The remaining orbital surface is not regularly divisible on account of the great variability of the orbital fissures; when the transorbital fissure is pronounced, a pre- and postorbital gyre may be distinguished.

The postorbital limbus is a formation occasionally met with on the orbital surface. It consists of a curved, welt-shaped eminence demarcated by an incisure created by the lesser wing of the sphenoid, and due, apparently, to the intrusion of the postorbital portion into the middle fossa.

II. Parietal Lobe ( lopus parietalis). Fissures of the Parietal Lobe. 1. Lateral Surface.—The lateral surface is bounded by the dorsi-mesial border, by the central fissure, and by a part of the sylvian fissure; it is only partially demarcated from the occipital lobe by the occipital fissure, and merges gradually into the temporal lobe.

The principal fissures marking its surface consist of a group of integral segments showing various degrees of confluence in different individuals and formerly known in the aggregate as the intraparietal sulcus of Turner (sulcus intraparietalis). Two of the fissural segments present much the same parallelism to the central fissure which was noted for the precentral group, and hence these are termed the postcentral fissural complex.

The postcentral fissural complex ( sulcus postcentralis) comprises a longer mesal and a shorter lateral (and ventral) segment, which are confluent in about 75 per cent. of brains and then very much resemble in length, continuity, and course the central fissure. This appearance has given rise to reports of alleged duplication of the central; an analysis of the relations of the dorsal ends of the fissures in question with the caudal limb of the paracentral removes all doubt.

The postcentral fissure (proper) is the longer mesal (and dorsal) segment. Its dorsal end is frequently bifurcated and sometimes embraces the dorsal extension of the caudal limb of the paracentral. The subcentral fissure constitutes the shorter latero-ventral segment.

The parietal fissure is usually a slightly arched fissure inclining meso-caudal, sometimes independent but more often confluent, with one or both of the postcentral segments just described. It demarcates the parietal gyre from the subparietal district.

The paroccipital fissure, in whole or in part, probably represents a part of the simian exoccipital or “ Affenspalte,” isolated by the upgrowth of gyral protos which are totally submerged in the ape brain, but rose to the surface concomitantly with the rise in functional dignity of cortical areas so important in the human brain. The fissure is almost invariably of zygal shape, its stem directed sagittally, its ends bifurcated. Its confluence with the parietal fissure seems to be subject to some morphologic law; continuity is the rule on the left side (77 per cent.), and occurs less often on the right. The combination of continuity on the right and separation on the left is a rare one (6 per cent.).
Less constant fissures are the transparietal, in the parietal lobe and the inter-
medial (Fig. 600). In the subparietal district terminate the upturned ends of
the sylvian (i. e., episylvian ramus) of the supertemporal and the meditempo-
rall fissures.

2. Mesal Surface.—The mesal surface of the parietal lobe is equivalent to
the quadrangular precuneus, limited by the paracentral and occipital fissures,
while ventrad it is imperfectly separated from the callosal gyre by the precuneal
fissure (postlimbic sulcus), usually of zygal or triradiate form and occasionally
confuent with the paracentral.

Gyres of the Parietal Lobe. 1. Lateral Surface.—The postcentral gyre (gyrus
centralis posterior) is one of the chief somesthetic areas of the cortex. It is a long,
more or less sinuous convolution extending obliquely from the dorsi-mesal border
to the sylvian fissure and demarcated by the central and the postcentral + sub-
central fissures.

The parietal gyre (gyrus parietalis) lies between the dorsi-mesal border and the
parietal fissure, bounded cephalad by the postcentral, caudad partly by the
occipital fissure, the transition to occipital lobe being maintained by the arched
par occipital gyre.

The subparietal district or lobule (lobulus parietalis inferior) is divided into
three convolutions which arch around the upturned ends of the sylvian, super-
temporal, and meditemporal, and merge insensibly with the adjacent temporo-
occipital gyres. The marginal (supramarginal) gyre arches over the extremity
of the episylvian ramus and is connected frontad with the postcentral gyre, ventrad
with the supertemporal gyre. The angular gyre (gyrus angularis) arches over the
upturned extremity of the supertemporal fissure, and its limbs fuse with the super-
temporal and meditemporal gyres. The postparietal gyre is not always clearly
defined; it arches around the upturned end of the meditemporal or its representa-
tive segment; mesally it is bounded by the par occipital fissure. Variable inter-
medial fissures sometimes help to define the angular gyre from its two neighbors.

2. Mesal Surface.—The mesal surface of the parietal lobe has already
been described as equivalent to the precuneus, from its position in “front” of the
cuneus or quadrate lobe from its general shape. It is sometimes marked by a
mesal extension of the transparietal fissure or by intraprecuneal fissures.

III. Occipital Lobe (lobus occipitalis). Fissures of the Occipital Lobe. 1. Lat-
eral Surface.—The lateral surface of the occipital lobe is imperfectly demarcated
from the adjacent parietal and temporal lobes in most brains. The sharply defined
exoccipital fissure or “Affenspalte” of other primates has, in the ancestry of man,
been reduced to a series of fissural segments by the upgrowth of submerged cortical
parts. The par occipital fissure, we have already learned, probably represents
one of the gaps in the series; another may be the sulcus lunatus (Elliott Smith),
usually termed the lateral occipital by the authors; lastly, a fissure sometimes called
the inferior occipital (suboccipital), and usually embraced, on the occipital pole,
by the bifurcate limbs of the postcalcarine, may complete the series. Further
researches are necessary to elucidate the morphology of this region.

2. Mesal Surface.—The mesal surface is equivalent to the wedge-shaped
region embraced by the occipital and calcarine fissures, and called the cuneus.
A fairly constant cuneal fissure traverses its surface parallel to the calcarine.

If it is ever determined that the morphological boundary of the occipital lobe is
as outlined above, the lobe is practically excluded from the basal surface of the
hemicerebrum.

IV. Temporal Lobe (lobus temporalis). Fissures of the Temporal Lobe. 1. Lat-
eral Surface.—The lateral surface of the temporal lobe is bounded by the
basisylvian and sylvian fissures and by the ventro-lateral border; caudally it
merges into the adjacent parietal and occipital lobes.
The supertemporal fissure (sulcus temporalis superior) is a deep, long (10 to 12 cm.), and usually continuous fissure which begins near the temporal pole, proceeds ventrad of but parallel with the sylvian, to become upturned in the parietal lobe and embraced by the arched angular gyre.

The meditemporal fissure (sulcus temporalis medius) is rarely continuous; more often it is represented by a series of segments, two, three, or four in number, the caudal segment running more vertically into the parietal lobe to be embraced by the postparietal gyre. The meditemporal fissural segments run nearly parallel with the supertemporal and demarcate the meditemporal from the subtemporal gyre.

2. Tentorial or Ventral Surface.—Close to the ventro-lateral margin and more or less parallel with it runs the subtemporal fissure (sulcus temporalis inferior), extending from near the temporal to near the occipital pole. It is rarely continuous, being usually broken up into two or more segments. It demarcates the subtemporal from the subcollateral gyre.

The collateral fissure (fissura collateralis) is a well-marked long (8 to 12 cm.) and deep fissure extending from near the occipital to near the temporal pole. Caudally it demarcates the subcalcarine gyre from the subcollateral; frontad it intervenes between the latter gyre and the hippocampal gyre. Its middle part is correlative with the collateral eminence. On the ventro-mesal aspect of the temporal lobe and near its pole, cephalad of the uncus is a moderately marked fissure or groove called, because of its topographic relation to the amygdala—a gray, ganglionic mass—the amygdaline fissure (fissura ectorkinalis s. posthinalis) or incisura temporalis.

3. Dorsal or Opercular Surface.—The dorsal or opercular surface of the temporal lobe enters into the formation of the sylvian cleft. It is but slightly marked by a few oblique or transverse furrows (trans temporal fissures) demarcating slightly elevated transtemporal gyres.

Gyres of the Temporal Lobe.—The five principal fissures named subdivide the lobe into five gyres. On the lateral surface lie the supertemporal, meditemporal, and subtemporal gyres (gg. temporalis superior, medius et inferior); on the tentorial surface are the subcalcarine (gyrus lingualis), subcollateral (gyrus fusiformis; g. occipitotemporalis) and part of the subtemporal.

The hippocampal gyre (gyrus hippocampi), formerly included in the "limbic lobe," but morphologically belonging to the neopallium, occupies the dorsi-mesal part of the ventral surface of the temporal lobe. The longer or shorter extension of the occipito-calcarine stem partially (forming the isthmus gyri hippocampi) interrupts its continuity with the callosal gyre. It is demarcated by the collateral fissure (in part) and the hippocampal fissure, broadens out toward the temporal pole, and appears to become bent upon itself dorsally to form the uncinate gyre (uncus). As will be learned in the sequel, the hippocampal gyre is demarcated.
from the uncus proper by the intervention of the frenulum Giacomini—an extension of the narrow, gray, dentate gyre.

Near the temporal pole it is demarcated from the subcollateral gyre by the fissura rhinica, or postrhinal fissure; this fissure is not infrequently confluent with the collateral.

The surface of the hippocampal gyre, particularly in the zone along the hippocampal fissure, is of a more whitish color than is characteristic of other cerebral gyres; this is due to a white reticular stratum of fibres, the substantia reticularis alba (Arnold). The convex, broader part of the gyre is marked by numerous small, wart-like eminences, resembling the skin of an amphibian, and called by Retzius the verrucae gyri hippocampi. Just ventrad of the uncinate portion, or the terminus of the hippocampal fissure, lies a groove marking the impression of the free edge of the tentorium.

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**The Insula (Central Lobe or Island of Reil)** (Figs. 603, 604, 605).—The insula lies deeply in the sylvian cleft and can only be seen when the lips of that cleft are widely separated, since it is overlapped by the opercula already described. With the opercula removed, the insula presents a tetrahedral shape with its apex or pole directed ventro-cephalad. Its borders are sharply outlined by the circum-insular fissure except in the depths of the basisylvian cleft, where the insular cortex is continuous with the gray substance of the preperforatum—the threshold or limen insulae (belonging to the rhinencephalon). An oblique transinsular or central insular fissure divides this district into a larger preinsula and a smaller postinsula. The postinsula is usually a single long gyre (gyrus longus insulae), while the preinsula is subdivided by shallow fissures into three, four, or five shorter preinsular gyres built upon a radiate plan, converging in the region of the insular pole. As already hinted, the insula represents an area of the brain-mantle whose growth did not

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1 Called by Wilder, on account of its correlation with the amygdala, the amygdaline fissure. Schwalbe calls it (in part) the incisura temporais.
keep pace with that of the surrounding parts; hence its submergence by them. The close apposition of the insular region to the subjacent basal ganglia, and the failure of development of great masses of projection fibres so prominent elsewhere, were doubtless factors therein. The insular cortex is uninterruptedly continuous with the rest of the cortex, but it has become specialized into the purest association centre in the cerebrum, and we shall learn of its intimate relations to the faculty of speech at a later stage.

The Rhinencephalon or Olfactory Lobe (lobus olfactorius) (Figs. 606, 607, 609).—The grouping of the parts constituting the central olfactory structures under the term “rhinencephalon” as distinguished from the rest of the forebrain (pallium) was first clearly made by Turner and proved by His to be embryologically well founded and by Edinger to agree with phylogenetic development. More light has been thrown upon the subject recently by Retzius and Elliott Smith. The sense of smell, while highly useful in the quest for food in earlier and lower forms of vertebrates, is relatively little used in the mental life of man. The enormous preponderance of the cerebral mantle and the concomitant atrophy of the rhinencephalon in the human brain afford one of the most striking contrasts in brain morphology. This relatively feeble development in bulk of the olfactory apparatus in the human brain by no means renders its description simple. In fact, not until its development in lower macrosmatic animals was studied could anatomists form even an approximately clear conception of the seemingly disjointed remnants in the human brain of an olfactory apparatus so relatively huge in lower animals. The great expansion of the cerebral hemispheres and of the great commissure which connects them (the callosum) has been an important factor in widely displacing primitively connected parts. The developmental history must be sought for in the writings of Edinger, Retzius, and Elliott Smith.

The Rhinencephalon comprises:
1. Peripheral parts
2. Central or Cortical parts.

A comprehensive term for the peripheral part is lobus olfactorius, divisible into pre- and postolfactory parts.

Preolfactory lobe
1. Bulbus olfactorius.
2. Tractus olfactorius.
3. Tuberculum olfactorium and trigonum.
4. Area parolfactoria (Broca).
5. Stria (gyrus) olfactorius medialis.
6. Stria (gyrus) olfactorius intermedialis.
7. Stria (gyrus) olfactorius lateralis.
9. Gyrus subcallosus and Broca’s diagonal band.

Postolfactory lobe

The Preolfactory Division.—The olfactory bulb and tract form a long and slender band with a bulbous extremity situated on the basal aspect of the frontal lobe and constituting a rudimentary remnant of a relatively large diverticulum, developed from the sensor ectoderm close to the border of the neural plate before it becomes converted into the neural tube and situated on either side of the neuropore at the extreme frontal end. Although hollow at first, the cavity (rhinocoele) soon becomes obliterated.

The olfactory bulb (bulbus olfactorius) is an oval mass of reddish-gray color, which rests on the cribiform plate of the ethmoid and is received in the olfactory fissure on the orbital surface of the frontal lobe. It receives the numerous olfactory nerves (fila olfactoria) from the nasal mucous membrane. The olfactory
tract (tractus olfactorius) is a band of white substance, of prismatic outline on section, its apical ridge fitting into the olfactory fissure. Toward its root-region it is somewhat narrowed.

The medial and lateral olfactory gyres are also termed the medial and lateral roots of the tract, and diverge in the region of the trigonum. The olfactory tubercle (tuberculum olfactorium) is best seen if the bulb and tract be lifted away from the olfactory fissure; the tubercle appears as a small pyramidal elevation, its apex buried in the olfactory fissure, its irregularly triangular base forming the trigonum olfactorium, a small gray area frontad of the preperforatum. This area is marked by ridge-like elevations which appear like radiating roots of the tract, and named, according to their position, the medial, intermediate, and lateral roots, striae or gyres. The lateral olfactory stria or gyre is continuous with the limen insulae in the depths of the basisylvian cleft, and thence passes to the uncus to end in the gyrus ambiens and gyrus semilunaris. The sharp turn made at the limen insulae is called the angulus lateralis. The medial olfactory stria or gyre, a narrow gyral band, proceeds mesad and merges with the adjacent cerebral surface; its extension on the mesal surface is known as the parolfactory area (Broca) limited frontad by the anterior parolfactory sulcus (sulcus parolfactorius anterior) and separated from the subcallosal gyre by the posterior parolfactory sulcus (sulcus parolfactorius posterior).

The intermediate stria is not always very distinct; when present it may be traced from the proximal end of the olfactory tract for a short distance over the gray field of the trigonum, to plunge into the gray of the preperforatum.

Postolfactory Division.—The preperforatum (anterior perforated substance) occupies an irregular quadrate field between the olfactory trigone and the optic chiasm and tract. A more or less marked groove (sulcus parolfactorius posterior), which is identical with the fissura prima (His) of the embryo, separates the trigonum from the preperforatum. Its frontal part, much perforated, is of a darker

![Diagram](image-url)
The cortical and central parts of the rhinencephalon comprise:

1. The hippocampus.¹
2. The uncus.
3. Gyrus dentatus.

Cortical

4. Fasciola.
5. Indusium, medial and lateral longitudinal striae upon the callosum.
7. Gyri subcallosi.
8. Fornix and fimbria.

Central

10. Part of precommissure.
11. Part of hemiseptums.

Central or Cortical Parts of the Rhinencephalon.—Following the suggestion made by Broca in 1878, it has been customary to designate these various parts by the comprehensive term: limbic lobe. Broca’s notion of the limbic lobe in man was founded upon attempts to homologize the human cerebral configurations with those found in lower animals. More recent researches have proved that Broca’s “limbic lobe” included parts belonging to the neopallium and not to the rhinencephalon. The term is therefore inappropriate in a morphologic sense.

The hippocampus is the submerged, peculiarly folded margin of the cerebral

¹ Not to be confounded with the hippocampal gyr of the pallium.
hemisphere produced by the hippocampal fissure. Its architecture can best be understood by referring to a frontal section (Fig. 608). It is seen that the whole cerebral marginal wall is pushed into the ventricular cavity (medicornu) as a fold caused by the intrusion of the hippocampal fissure. A secondary fold—not produced by a fissure, however—constitutes the gyrus dentatus. Superimposed lies a prominent white band—the fimbria—composed of axones from the hippocampal cells, assisting in the formation of a white lamina, subjacent to the endyma of the ventricle, and called the alveus. The whole formation is characteristic of this region and from its fancied resemblance to a ram’s horn—a symbol used on the temple of Jupiter Ammon—the name of cornu ammonis has been given; the name hippocampus was applied because of a fancied resemblance to the marine animal of the same name. The ventricular relations and internal structure of the hippocampus will be given farther on (p. 947).

The uncus, with the atrophied lateral olfactory stria, is all that remains in the human brain of the relatively large pyriform lobe of lower forms. It appears to be a hook-like retroflexion of the hippocampal gyre which is partially encircled by the gyrus dentatus. Morphologically speaking, it is only the apical portion, or that which lies caudad of the dentate gyre which is the true uncus (the gyrus intralimbicus of Retzius); the remainder is neopallial and a part of the hippocampal gyre. The uncinate or intralimbic gyre may be traced caudad in the depths of the fimbrio-dentate fissure, along the dentate gyre, the dentato-fascicular

\[\text{Fig. 608. — Trans-section of the hippocampal gyrus. (Edinger.)}\]

1 Frequently, but incorrectly, given as Ammon’s Horn.
groove intervening, to be continued as the fasciola (gyrus fasciolaris of Retzius) over the splenium of the callosum.

If the hippocampal gyre be depressed for the purpose of examining the depths of the hippocampal fissure, there is revealed a narrow, gray band whose surface is scored by numerous incisures and whose edge is notched at frequent intervals. This corrugated band is the dentate gyre or fascia dentata. Partly overlapping it, but farther laterad, lies a white band—the fimbria—extending caudad from the uncus to become continued as the fornix.

The dentate gyre is demarcated from the hippocampal gyre by the hippocampal fissure, from the fimbria by the fimbriodentate fissure, in whose depths lies the narrow continuation of the uncus or gyrus intralimbicus—the fasciola. Extending caudad, and for the most part parallel with the fimbria, it loses its corrugated appearance on approaching the splenium, then fuses with the fasciola, parting company with the fimbria (which now becomes fornix), to be continued upon the callosum as a thin, broad plate of gray matter—the indusium or gyrus epicallosus. At the uncus the dentate gyre makes an abrupt turn to appear upon the mesal surface, out of the depths of the hippocampal fissure, and encircles the neck of the uncus, forming the frenulum Giacomini. Beyond this point it can be traced, in rare instances, to the gyrus semilunaris.

The gyri Andreae Retzii are rudimentary gyral formations consisting of small, rounded, oval or spirally corrugated eminences situated ventral of the splenium in the angular interval between the dentate and the hippocampal gyres. Structurally they have been shown to belong to the hippocampal formation.

The indusium (gyrus epicallosus s. supracallosus), considered to be a vestige of the hippocampus, is a thin strip of gray substance superimposed upon the callosum and raised into two paired ridges by longitudinal fibre-bundles which constitute the mesal and lateral longitudinal striae. The indusium and its striae are continued cephalad into the gyrus subcallosus; perhaps, also, into the parolfactory area (Fig. 607).

The central connections of the rhinencephalon will be considered in the description of the internal configuration of the hemisphere. (See Fornix, Precommissure, etc.)

Internal Configuration.—Each hemicerebrum contains a cavity, the lateral ventricle or paracelle, an extension of the primitive neural cavity carried outward, its contours modified by the developmental changes in the growth-history of the secondary fore-brain vesicle. This central cavity is surrounded by the thick, convoluted walls of nerve-tissue which make up the bulky cerebral hemispheres. The cerebral tissue, as elsewhere in the central axis, is made up of gray and white substance. Two well-marked types of gray substance are recognizable: (a) the cortical, so named because its situation upon an interior white centre, invites comparison with the rind (cortex) of a fruit; (b) the massive ganglionic or nugget-like masses not dissimilar from the thalamus already described, comprising, in this division of the brain, the caudatum, lenticula, and amygdala. The white substance fills out the entire space intervening between the cortex, the cavity of the lateral ventricle and the great basal ganglia, and is composed of myelinic axones which connect the elements of the cortex with other parts of the nerve system, or with other regions of the cortex of the same or the opposite hemicerebrum.

If a brain, resting upon its basal surface, be sliced by successive horizontal sections from above, the peripheral gray and internal white are brought into view. The more superficial sections reveal relatively more gray than white substance; deeper sections show a reverse condition and a section immediately dorsad of the

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1 The mesal striae are also called Striae Lancii; the lateral stria, Tenia tecti.
callosum reveals, in each hemicerebrum, a very extensive semioval field of white substance, the centrum semiovale, surrounded on all sides by a narrow, convoluted margin of gray substance, the cortex. A close examination of the cut surface, in a fresh and normal brain, shows it to be studded with numerous minute red dots (punta vasculosa) produced by the escape of blood from divided blood-vessels.

The Cortex.—The cortex, as revealed in such a section, is not of uniform thickness throughout; different regions show different cortical thicknesses. In general, the cortex is somewhat thicker at the summit of a gyre than in the depths of an adjoining fissure, and it is thicker upon the convex than upon the mesal or basal surfaces. The maximum thickness is observed in the cortex of the central gyres and the insula; the minimum at the frontal and occipital poles, notably the latter. Not only is the cortex not of uniform thickness, but it is not of homogeneous structure as seen with the naked eye. An alternation of gray and white stripes is discernible, particularly in the occipital cortex, where a white band runs parallel with the cortical surface between two gray strata; this white stripe, first described by Gennari and usually bearing his name, is also called the band of Vicq d’Azyr.

![Diagram of the brain](image)

Fig. 609.—Mesial view of a partly dissected hemicerebrum, to show the relations of fimbria, fasciola, dentate gyre, and uncus.

The preponderance of white substance over gray substance in the cerebrum is a human characteristic concomitant with the relative increase of the association cortex, in turn demanding a more intricate interconnection of the many nerve-cells by a multitude of association neurones. These coördinating fibre-systems are as truly representative of the complexity of man’s thought apparatus as the number of interconnecting wires within a telephone “central” station is indicative of the amplitude of connections possible in that system. The proportions of gray and white substance are expressed in the following tabulation:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Cortex</th>
<th>Ganglia</th>
<th>White substance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>33 per cent.</td>
</tr>
<tr>
<td>Gray substance</td>
<td></td>
<td></td>
<td>6 per cent.</td>
</tr>
<tr>
<td>White substance</td>
<td></td>
<td></td>
<td>61 per cent.</td>
</tr>
</tbody>
</table>

The removal, by successive slices, of the dorsal parts of the cerebrum soon brings into view the large expanse of transverse myelinic fibres, the callosum, which connects the two hemispheres.

The Callosum (corpus callosum; trabes cerebri; commissura maxima).—The callosum is a thick stratum of transversely directed nerve-fibres, by which
almost every part of one hemicerebrum is connected with the corresponding part of the other hemicerebrum (Figs. 610 and 611). The axones composing it arise from the small pyramidal or the polymorphous cells of the cerebral cortex, or they may be collaterals from the long association or even the projection neurones. They pass in both directions and within the centrum semiovale radiate in various directions (radiatio callosi) between the fibres of the corona radiata to terminate in the layer of small pyramidal cells of the cortex, thus forming a great transverse commissural system, and at the same time roofing in the greater part of the lateral ventricle in each half. A portion of the dorsal surface is free for a width of about 1 cm. on either side of the mesal plane, partly covered by the indusium and overlapped by the callosal gyres of the two sides, a fold of pia intervening.

The radiating mass of fibres may, for convenience of description, be subdivided into a pars frontalis, a pars parietalis, and a pars occipitotemporalis. The frontal and occipito-temporal portions are compressed or thickened mesally because the fibres cannot pass directly across, but curve, respectively, frontad and caudad in each hemicerebrum to form two tong-like bundles, the preforceps (forceps anterior s. minor) and postforceps (forceps posterior s. major). The pars parietalis constitutes the greater part of the "body" of the callosum. The fibres traversing the body (truncus corporis callosi) and the adjacent part of the splenium curve round the postcornu and trigonum ventriculi of the lateral ventricle, to form a thin but definite white stratum, the tapetum, in the roof and ecal wall of these parts of the cavity.

The transverse direction of the fibres is rendered apparent in a dorsal view of the exposed callosum in the form of the stria transverse. These are but little obscured by a thin, gray lamina—the indusium—which is thickened longitudinally by two symmetrically situated fibre-strands, the mesal (striae lancisii) and lateral longitudinal striae (teniae tectae), already mentioned as rudiments of the rhinencephalon.

The best conception of the size and form of the callosum is obtained from a view of a mesal section. It is then seen to be a long, thick, somewhat flattened arch which bends sharply upon itself frontad to form the genu (genu corporis callosi) while its caudal end is rounded and somewhat folded closely upon itself to form the splenium. The callosum ranges in length from 7 to 10 cm., its cross-section area from 5 to 10 sq. cm., being longer and larger in heavier brains and in those of the highly intellectual as compared with smaller and less highly efficient brains. It extends to within 4 cm. of the frontal pole and to within 6 cm. of the occipital pole. The thickness of the "body" averages 5 mm., of the splenium

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Fig. 610.—Diagram of coronal section of cerebrum to show course of fibres of callosum. (Testut.)
Fig. 611.—Diagram of horizontal section of cerebrum to show course of fibres of callosum. (Testut.)
9 mm. or more, while the maximum thickness of the genu is about 13 to 15 mm. The reflected portion or rostrum (rostrum corporis callosi) gradually tapers into a very thin lamina, the copula (lamina basoea alba), which in turn joins the terma frontad of the precommissure.

The splenium (spleenium corporis callosi) projects as a rounded welt over the mid-brain, but is separated from it by a pial fold—the velum interpositum. Further frontad the fornix becomes fused to the ventral surface of the callosum for a short distance, to again leave in its more arched course toward the albicans. Two thin laminae, one on either side of the median plane, but closely applied to each other and frequently partially fused, occupy the interval between callosum and the fornix of each side. The laminae together are termed the septum lucidum of the authors, each one being called a hemiseptum; the enclosed cavity is called the pseudocele or fifth ventricle, though not derived from the original neural cavity.

**Development.**—The callosum develops as a mass of commissural fibres which grow from side to side in the terma (lamina terminalis). The terma serves as a matrix for several commissural systems, viz., the hippocampal or fornicommissure and the precommissure, in addition to the callosum. The last develops rapidly in higher mammalian brains, thrusts aside the hippocampal margin of the pallium so that it atrophies in large part, and stretches out within its sharply bent arch a portion of the precommissural wall of each cerebral vesicle. It thus withdraws a part of the intercerebral cleft, eventually enclosing it entirely as the pseudocele. The stages of development are shown schematically in Fig. 612 and its development in the human embryo is shown in Fig. 613. The callosum is most fully developed in man and does not appear below the marsupials. Its growth kept pace with the preponderatingly greater development of the neopallium in higher forms, and it may be looked upon as an index of the elaboration of at least one division of the association systems—those concerned with bilateral coördinations.

**The Lateral Ventrices.**—An incision through the callosum, on either side of the median plane, will expose two large, irregular, symmetrically situated cavities, the lateral ventricles (paracæles), extending through a great part of each hemi-cerebrum. Each lateral ventricle communicates with the third ventricle through a small opening, the pora or foramen of Monro, situated between the fornico-lum (anterior pillar of fornix) and frontal end of thalamus. The cavity is lined throughout by endyma; it is narrow in some and wide in other localities, and contains cerebro-spinal fluid.

The shape of the ventricle is best understood by reference to a cast of its interior and its location within the cerebrum may be appreciated by a study of Figs. 614 and 615. Conventionally the paracæle or lateral ventricle is described as being composed of a body or cella and three horn-like extensions or cornua. Viewed laterally its contour corresponds to that of the cerebral hemisphere and its cornua project toward the three poles, viz., frontal, occipital, and temporal.
Fig. 613.—Brains of human embryos; mesal aspects of median sagittal section show the development of the callosum: A, fourth month; B, fifth month; C, sixth month; D, seventh month.
The body \((pars\ centralis\ ventriculi\ lateralis)\) or cella of the lateral ventricle is defined as that portion whichextends from the porta to the region of the splenium. Itsfrontal prolongation is called the precornu. Near the splenium thecavity may be traced ventro-laterad into a capacious part \((trigonum\ ventriculi)\), fromwhich the postcornu and medicornu are prolonged, respectively, toward theoccipital and temporal poles.

The Precornu \((cornu\ anterius)\) passes frontad, inclined slightly ventro-laterad. Its floor is the head \((caput)\) of the caudatum, forming a rounded incline slopingmesad toward a trench-like recess floored by the rostrum of the callosum. Its roof is the preforceps of the callosum. Its mesal wall is formed by a portion of the hemiseptum. Laterally it is limited by the apposition, at an acute angle, of callosum and caudatum. Its apex reaches the ventricular surface of the genu of the callosum. The general outline of the ventricle, in a frontal section, is triangular (Fig. 625).

![Diagram](https://example.com/diagram.png)

**Fig. 614.**—Showing the ventricular system of the brain as a solid cast as if seen through a transparent brain.

The body of the cavity is curved with its convexity dorsad; its outline in transsections varies from the triangular to a mere slit which slopes slightly meso-ventrad. It is wholly roofed in by the callosum \((pars\ frontoparietalis)\). Its floor is formed by the following structures named in order from its ectal toward its ental limit: (1) caudatum; (2) a groove which marks the line of coalescence of caudatum and thalamus and lodges the tectual vein and a narrow fibre-strand—the taenia semicircularis, beneath the endyma; (3) a reflexion of the endyma onto a narrow area of the thalamus; (4) the paraplexus or choroid plexus of the lateral ventricle; (5) the thin, sharp (fimbriated) edge of the fornix. The caudatum narrows rapidly as it passes caudad. The taenia semicircularis, lying along the ental border of the ventricular surface of the caudatum, is a small band of white fibres arching from the amygdala (near the temporal pole to the preperforatum. The entrance of a part of the thalamus into the formation of the floor of the paracelle is apparent enough, but morphologically it should be strictly excluded there-
from. The thalamus is in no way formed from the parietes of the secondary fore-brain vesicle (telencephalon), for it is, in fact, excluded by a layer of endyma (lamina affixa) reflected onto, and often separable from, the surface of the thalamus, so that it appears as a constituent of the floor because of the transparency of the endymal sheet. The paraplexus is a richly vascular invagination over which the endyma is continuous to again become reflected onto the fornix along its

sharp edge. A reference to Fig. 608, showing the topographical relations of these structures in a frontal section, may be of assistance.

The cavity is thence continued ventro-lateral in a bold sweep to become expanded as an obliquely pyramidal space of a somewhat triangular outline on section, and placed subjacent to the parietal lobe—the trigonum ventriculi. A conspicuous feature in its floor is the collateral eminence, correlated with the
collateral fissure. From the trigonum, the most capacious part of the paracelc, the cavity is prolonged in opposite directions as the medicornu and postcornu.

The Medicornu (cornu inferius) is a prolongation of the ventricular cavity, from its trigone toward the temporal pole, which pursues a curved course with its convexity directed ventro-laterad (Figs. 614 and 615), corresponding to the curved contour of the temporal lobe, and situated at a depth of about 3 cm. from its lateral surface as well as from the temporal pole. The roof is formed by (a) the tapetum of the callosum; (b) the cauda (tail) of the caudatum; (c) the tænia semi-circularis. The medial wall is principally composed of the hippocampus, a prominent welt-like eminence bulging into the cavity, largely filling it, and produced by the hippocampal fissure. The hippocampus nearly conceals from view the actual floor, which is of variable extent in different brains and usually marked by an extension of the collateral eminence previously described. Surmounting the corrugated hippocampal formation and projecting slightly into the cavity, is the fimbria, and from its sharp edge the ventricular endyma is reflected upon the invaginated paraplexus. The paraplexus of the medicornu is more voluminous than that of the body of the ventricle, and must be lifted in order to expose the whole of the ventricular aspect of the hippocampus.

At the apex of the medicornu the roof presents a more or less pronounced bulging, the amygdaloid tubercle, due to the presence of the amygdala, a small mass of ganglionic gray from which the tænia semicircularis arises and in which the caudatum apparently ends.

The Postcornu is a shorter diverticulum which passes toward the occipital pole in a gently curved course, with its convexity directed laterad. It is not very capacious, usually slit-like on section, and tapers to a point within 2 or 3 cm. of the occipital pole. Its roof, slanting latero-ventrad, is formed by the tapetum of the
callosum. On the inner or mesal wall two elongated bulgings may be observed. The upper or dorsal elevation, called the occipital bulb or bulb of the cornu (bulbus cornu posterioris; callosal eminence [Wilder]), is formed by the compact arched postforceps of the callosum as it curves around the very deep occipital fissure. The occipital bulb is not always well marked. Ventral of it lies a more constant limbus or welt-like elevation, the calcar (calcar avis; hippocampus minor), a projection produced by the infolding of the cerebral wall along the calcarine fissure. The paraplexus does not enter the postcornu.

The Choroid Fissure or Rima (rima transversa cerebri magna; fissure of Bichat) is not a true fissure, and only becomes one when the (paraplexus) choroid plexus of the lateral ventricle is torn from its connections. The rima is nevertheless a gap between the diencephalic part and the overlapping and recurved telencephalon produced by the extension of the secondary fore-brain vesicle in an arcuate manner which Hill described by the phrase "rotation of the great fore-brain." It is along this arcuate and fissure-like gap that the richly vascular (pial) paraplexus invaginates the atrophied parietae of the secondary fore-brain to form the paraplexus which is everywhere covered by endyma. The rima extends from the porta to near the tip of the mediocornu in an arcuate course and endymal reflections everywhere close in this gap except at the porta (Fig. 617). The manner in which this is accomplished may best be understood by a study of trans-section showing the endymal reflections from the ventricular wall onto the invaginated paraplexus. The caudato-thalamic fusion and the intrusion of the great fibre-masses constituting the cerebral crura play their parts in complicating the relations in brains of higher type.

The Paraplexus and Velum.—The paraplexus is a highly vascular, fringe-like structure composed of pia which is invaginated into the paracele along the rima, or gap between hemicerebrum and diencephalon. The portion of the paraplexus protruding into the "body" of the paracele is the fringed vascular border—a triangular fold of pia—the velum interpositum (tela chorioidea superior), which, as its name implies, is interposed between the relatively small primary fore-brain and the enormous overlapping secondary fore-brain, and is produced by the overgrowth of the latter onto the former. Inasmuch as the nerve-tissue in the roof of the third ventricle atrophies totally, the ventral fold of the pia comes into contact with the endyma of that ventricle and here permits a similar vascular invagination in the form of two parallel fringes hanging into the cavity (diaplexus
or choroid plexuses of the third ventricle). The dorsal leaf of the pial fold is in contact with the ventral face of the body of the fornix. Frontad, the velum tapers toward the region of the two portae, where the paraplexuses of the two sides are continuous with each other. The ventricular surface of the choroid plexuses is everywhere covered by endyma which is reflected from it to the fimbriated edge of the fornix on the one hand and to the line of the tenia semicircularis (over the thalamus by the lamina affixa) on the other. Its vascular components, in addition to undefined lymphatic channels, are: the prechoroid (anterior choroid) artery, a branch of the internal carotid, entering the paraplexus of the medicornu; the postchoroid (posterior choroid) artery from the postcerebral artery reaching the paraplexus in the neighborhood of the splenium. The venules of the plexus join to form a tortuous medicornual vein which terminates frontad by joining one of the velar veins.

The velar veins (veins of Galen), one on each side close to the median line, running in the fold of the velum, are formed by the union of the tænial, striatal, and medicornual veins. The two velar veins unite to form a common trunk which empties into the straight sinus.

The Hippocampus and Fornix.—The hippocampus and the fornix merit special description. The hippocampus, as seen in the medicornu, is a white eminence about 5 cm. in length, of a curved elongated form, enlarging cephalad and tapering caudad as the hippocampal fissure decreases in depth. The enlarged extremity is marked by alternate elevations and depressions, usually three in number, the hippocampal digitations; because of its resemblance to a lion's paw it is sometimes called the pes leonis or pes hippocampi. The white appearance of the ventricular aspect of the hippocampus is due to a stratum of white substance, the alveus, made up of myelinic axones from hippocampal cells and continued into the fimbria. The fimbria is folded so that its sharp margin is directed toward the cavity of the medicornu; eventually its fibres will be seen to enter into the formation of the fornix. The formation of the hippocampus is best observed in a coronal section (Fig. 608). In this view it is seen to be a peculiarly folded margin of the cerebral cortex, corrugated by the intrusion of the hippocampal and fimbriodentate
fissures. Morphologically it is a vestigial submerged portion of the rhinencephalon, as a part of which it has already been described.

Fig. 619.—The fornix, velum, and medicornu of the lateral ventricle.

Fig. 620.—Transverse section of the middle horn of the lateral ventricle.
The fornix (Figs. 615, 621, 622) is really a paired structure consisting of bilaterally symmetrical halves composed of longitudinally directed fibres which arch on each side from the region of the uncus to the albicans. The two lateral parts join each other in the mesal plane along the summit of the arch to form the body of the fornix (corpus fornicis). Frontad they diverge slightly as they proceed toward the albicantia; caudad they diverge more widely. The paired diverging portions are called
respectively the anterior and posterior pillars of the fornix. The fibres of each half-
fornix arise from the pyramidal cells in the hippocampus and their course will
be traced from this source to the ending in the albicans. Beginning at first as a
stratum of white substance (alveus) constituting the ectlal surface of the ventricular
bulge of the hippocampus, the fibres become collected along its medial border
in a narrow but distinct folded band, the fimbria. This increases in calibre
as increments are added to it along its course, until, at the apical region of the trigonum ventriculi, it leaves the dwindling hippocampus to ascend in a curved course (dorsi-mesad) toward the subsplenial callosal surface as a thick, flattened band. Once free from the hippocampus on each side, the two converging bands of opposite sides are called the posterior pillars or crura fornixis. The majority of the fibres continue frontad in each half-fornix, but a number course transversely to enter the crus fornixis of the opposite side to end in the hippocampal formation. These fibres, of transverse course, form a thin lamina filling in the small triangular space in the subsplenial region between the converging erum fornixis and constituting the fornicomissure (lyra; psalterium; hippocampal commissure). Occasionally a small recess called Verga’s ventricle is formed between callosum and fornicomissure.

The two half-fornices now become joined in the mesal plane and, leaving the subsplenic surface of the callosum, dip fronto-ventrad in an arch—the body of the fornix. Its caudal part is broad and each half is of triangular outline (on section) with a sharp edge directed laterad. Where it is not in contact with the callosum it affords attachment, on each side of the mesal plane, to the hemiseptum. Laterad of these lines of attachment the dorsal surface of each fornix enters into the formation of the floor of the lateral ventricle and is covered by endyma (Fig. 615). The ventral surface rests upon the velum, which separates it from the third ventricle and the dorsal surface of the thalamus.

Near the region of the precommissure the fornix again divides into its constituent lateral halves, separating as rounded strands called the fornicolumns or anterior pillars. These curve ventrad to form the frontal boundary of the porta and thence plunge into the hypothalamic gray, inclined slightly caudad, to end in the albicans. The terminals of the fornix fibres come into relation with the cells of the nucleus of the albicans, which in turn give off the bifurcating Y-shaped axone-bundles already described (p. 920).

In rare instances each fornicolumn has been seen to divide on approaching the precommissure, a part passing frontad thereof as an anomalous precommissural

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**Fig. 625.—A frontal section of the brain in the plane of the precommissure.**
fornicolumn. The fornix, in its course from hippocampus to albidans, gives off, in addition to those described as hippocampal commissural fibres, axones (a) to the opposite half-fornix, decussating in the fused portion (body), (b) to the hemiseptum, and (c) to the gray tissues of the preperforatum (Fig. 607). It constitutes an inner olfactory arc as distinguished from the epicallosal or outer arc, represented by the atrophied indusium and its longitudinal strie.

The Septum Lucidum (septum pellucidum).—The so-called septum lucidum really consists of two vertically placed lamina or hemisepa. Between them lies a narrow, enclosed space, the pseudocele or fifth ventricle (cavum septi pellucida), roofed in by the callosum, while the floor consists of the fused fornices and the rostrom. Each hemiseptum bounds a part of the precornu and body of the paracele in its mesal wall and in a lateral view is of triangular outline. The hemisepa represent the thin, undeveloped parts of the mesal walls of the cerebral vesicles, which were enclosed within the rapidly developing arch of the callosum. The pseudocele is therefore a closed-off part of the original intercerebral cleft and not a part of the neural cavity as its older name “fifth ventricle” seems to imply.

The Precommissure.—The precommissure is a bundle of white fibres, of oval outline in a sagittal section, which crosses the mid-line as a localized reinforcement of the terma, slightly bulging into the frontal part (aula) of the third ventricle and clothed by its endyma. It is a comparatively insignificant intercerebral commissure in the human brain, having become diminished as the callosum increased in mammalian development. It courses from side to side frontal of the fornicolumns, ventrad of the head of the caudatum, and passes, in part, through the frontal end of the lenticula. Its fibres radiate chiefly to the cortex of the temporal lobe and to certain parts of the rhinencephalon.

The bundle is slightly twisted in each lateral, buried part. Two divisions are distinguishable: 1. The pars anterior or frontal part (in the median plane) contains two groups of fibres belonging to the olfactory apparatus: (a) fibres arising from the mitral cells in the olfactory bulb of one side to the same layer in the opposite bulb; (b) fibres which associate the uncus of one side with that of the other. 2. The pars posterior contains the fibres passing between the cortices of the two temporal lobes.

Gray Masses in the Hemicerebrum.—Aside from the cortex, the hemicerebrum contains certain gray ganglionic masses in its interior, more or less embedded in the white centrum and called, because of their proximity to the base of the cerebrum, the basal ganglia. These comprise the caudatum, the lenticula, and the amygdala. It is usual to include the claustrum among the basal ganglia, but morphologically this structure belongs rather to the insular cortex.

Conventionally the caudatum and lenticula together are described as the striatum (corpus striatum)—a ganglionic mass which in earlier vertebrate brains bore intimate relations with the olfactory apparatus, but later, with the rise in functional dignity and growth of the neopallium, underwent specialization and differentiation concomitant with the reduction of the rhinencephalon. The intrusion of great projection fibre-masses, thrusting the cortical gray outward, has not been everywhere uniform, and we still find, in the human brain, a common ground in which the neopallial cortical gray, the striatum, rhinencephalon, and amygdala meet—the site of fusion being in the gray substance of the preperforatum. To the cortical mantle they are regarded as bearing the relation of subordinate (subcortical) centres. In the human brain the striatum—so-called because of its striated appearance in sections—is composed of two masses, the caudatum and lenticula, directly continuous with each other at their frontal ends (Fig. 627). The connecting gray bridge becomes broken up into numerous small bands of gray substance as the fibre-masses of the internal capsule insinuate themselves between the two nuclei (Fig. 624).
The Caudatum (nucleus caudatus) (Figs. 623, 626, 627) presents a ventricular and a capsular surface; the ventricular surface, covered by endyma, forms part of the floor of the body and precornu, while in the medicornu it is a constituent of its roof, owing to its arched contour in correspondence with the sweeping curve of the ventricle itself. It is of a pyriform shape with a very much attenuated tail. The large, thick head projects into the precornu whilst its thinner tail is prolonged caudo-laterad, separated from the thalamus by the narrow tenia semicircularis. Following the curved contour of the ventricle it is prolonged as a narrow gray band in the roof of the medicornu, where it joins the amygdala. The non-ventricular or capsular surface is embedded in the white substance of the hemi-cerebrum, and is chiefly related to the internal capsule.

The ventricular surface shows, in microscopic sections, a dense endymal lining. The capsular face is not sharply outlined, numerous strands of fibres, to and from the internal capsule, entering it obliquely so as to appear as streaks.

Fig. 626.—The basal ganglia and thalamus schematically represented in a supposedly transparent brain (right side); on the left is shown the outline of the paracele (lateral ventricle).
which extend to about the middle of the ganglion, there separating into finer and finer strands which become lost to the naked eye.

The Lenticula (Figs. 624, 626, 628) is wholly embedded in the white substance and must be studied in sections. In its shape it resembles an irregular triangular pyramid with its convex base directed laterad and parallel with and near to the cortical expanse of the insula and of about the same extent. Its ental, apical portion is directed toward the interval between caudatum (head) and thalamus. The contour and slope of the surfaces of the ental pyramidal face may be judged from the model pictured in Fig. 627. Its outline, as revealed in sections passing in different planes, is shown in Figs. 625 and 628.

Sections of the lenticula show it to be composed of three\(^1\) concentric segments separated by two white medullary laminae. The segments are known as articuli; the ental one is designated the putamen; the two ental zones constitute the pallidum (globus pallidus). The putamen is the larger and of a deeper reddish-gray tint; the two mesal divisions are lighter in color owing to a greater proportion of radiating streaks of white fibres passing to and from the internal capsule. The ental outline of the putamen is sharply defined against a white lamina, the external capsule.

The Amygdala is usually regarded as an hypertrophied aggregation of the temporal cortex which has become nearly isolated from its cortical connection by intruding white substance. It is a rounded, gray, striated mass situated in the forepart of the temporal lobe in the roof of the medicornu at its apex, where it produces the bulging called the amygdaloïd tubercle. Caudad it is joined by the tail of the caudatum; frontad it is continuous with the putamen. Except for the marked streaking shown in sections, its structure is like that of the cortex. Its cells apparently give rise to the narrow band of fibres—the tænia semicircularis— which courses along the mesal margin of the ventricular surface of the caudatum throughout its arched course and ends in the preperforatal gray so that it nearly completes a circle.

The Clastrum is a thin plate of gray substance embedded in the white substance which intervenes between the putamen and the insular cortex, and corresponding in extent to these. Its dorsal edge is very much attenuated; traced ventrad it thickens considerably and becomes continuous with the surface gray at the preperforatum. Its ental surface presents alternate ridges and depressions which correspond to the corrugations of the insular cortex. The “external capsule” intervenes between its ental face and the putamen of the lenticula. From the insular cortex proper it is separated by a white lamina which may be termed the periclastral lamina or capsula extrema. Apparently the claustrum is the thickened and isolated spindle-cell stratum of the insular cortex, a feature which

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\(^1\) Four and even five have been observed.
may be of significance in relation to the preponderatingly associative function of the insular region.

**Internal Capsule** (Fig. 628).—Between the lenticula on the one hand and the caudatum and thalamus on the other lies the internal capsule, a broad band of white fibres which, as seen on horizontal section, appears bent, very much as a leg is bent on the thigh, with the knee (genu) directed mesad. The frontal or caudato-lenticular division or limb is confined between the opposed faces of the caudatum and lenticula. The genu receives the mesal apex of the lenticula in its hollow, while

![Fig. 628.—Horizontal section through the cerebrum. The various structures are shown in their natural appearance on the right side and are named on the left side.](image)

the caudal or thalamo-lenticular limb lies between the opposed faces of lenticula and thalamus. The frontal limb constitutes about one-third, the caudal limb two-thirds of the internal capsule mass.

The term "internal capsule" is often loosely employed and is variously stated to include fibre-tracts which do not course between the cerebral cortex and the "lower" brain centres. In a strict sense it is a mass of fibres which converge, like the sticks of a fan, toward the cerebral base and into the crusta. Dorsad of the basal ganglia the fibres radiate in various directions, streaming among the radiating callosal fibres and forming the so-called corona radiata. Yet other
fibre-tracts leave and enter the great ganglia at various altitudes along the internal capsule, and we must therefore distinguish the following cerebral fibre-systems.

**Projecting systems**, ascending and descending (in the functional sense), of longer and shorter course, connecting the cerebral cortex with (a) spinal gray centres; (b) mid-brain and pontile nuclei; (c) basal ganglia and thalamus. The last-mentioned system traverses the internal capsule to a greater or lesser extent, but does not continue into the crista. These various systems are summarized on page 963. It may here be mentioned that the internal capsule, topograpically, exhibits a functional dissociation in that its frontal or lenticulo-caudal limb is composed of preponderantly corticipetal fibres, while corticifugal fibres form the major portion of the thalamolenticular limb (Fig. 629). In the frontal limb are the thalamo-frontal and thalamo-striate fibres; the former ending in the cortex of the frontal lobe, the latter in the caudatum and lenticula. The chief corticifugal components are the fronto-pontile tract, and fewer fronto-thalamic and striato-thalamic fibres. The fronto-pontile tract arises in the cortex of the prefrontal region, traverses the frontal limb of the internal capsule, forms the ental sector (one-fifth) of the crista, and ends in the nuclei pontis.

In the genu and the thalamolenticular limb of the internal capsule course several important fibre-tracts which are chiefly corticifugal.

The **Pyramidal (Motor) Tract**, in its course from the precentral cortex to the lower motor centres occupies the frontal half of this limb. The portion in the genu, often designated the **geniculate tract**, comprises the pyramidal fibres which are destined to go to the facial and hypoglossal nerve nuclei; further caudad lie, in succession, the fibres going to the motor centres for the upper and the lower extremity. The most caudal segment (also called the **retrolenticular part**) of the internal capsule contains (a) the **optic radiation**, composed of fibres coursing in both directions between the occipital cortex and the pulvinar, pregeniculum and pregenminum; (b) the **auditory radiation**, composed of fibres passing in both directions between the cortex of the temporal lobe (auditory centre) and the postgenminum and postgeniculum; (c) the **occipito-
pontile and temporo-pontile tracts from the occipital and part of the temporal cortex, coursing through the caudal segment of the internal capsule, constituting the ectal (one-fifth) sector of the crista and ending in the nuclei pontis. In addition there are scattered fibre-bundles which arise from the ventral portion of

the thalamus, enter the internal capsule to pass toward the cortex, in part through the lenticula, in part in the sublenticular zone, to form the \textit{ansa lenticularis}. The reinforcement of this sublenticular white-fibre tract by cortico-thalamic fibres from the temporal lobe to thalamus forms the \textit{ansa peduncularis}. The topographic relations of the various tract-masses as seen in a flat-wise section is schematically

![Diagram of motor path from right brain.](image)
shown in Fig. 630; on the whole they correspond to the cortical areas with which they are connected.

The External Capsule (Fig. 628).—The external capsule is a thin lamina of white substance interposed between the ectal face of the lenticula and the claustrum. Dorsally, frontad and caudad, at the corresponding borders of the lenticula, it joins the internal capsule mass, while ventrally it is continuous with the white centrum of the temporal lobe. Its comparatively few projection fibres course to and from the ventral parts of the thalamus; its chief constituents are association axones for the circuminsular cortical areas.

Intimate Structure of the Cerebral Cortex and its Special Types in Different Regions (Fig. 631).—A section of the cerebral cortex reveals a tendency on the part of its constituent cells to arrange themselves in layers which alternate with zones less rich in cellular elements. Among the cells course the axones arising from them or terminating in their neighborhood. The axones are chiefly amylene, though some are myelinic for a part of their intracortical course. The cells, of various sizes and shapes, together with their dendrites and axones are embedded in a matrix of neuroglia.

The nerve-cells in a typical section of the cortex are arranged in five tangential layers, as follows: (1) the molecular layer; (2) the ectal polymorphous cell layer; (3) the layer of small pyramidal cells; (4) the layer of large pyramidal cells; (5) the ental polymorphous cell layer.

The molecular layer (neuroglia layer) lies immediately subjacent to the pia and is chiefly made up of glia cells and fibres amongst which the dendrites of the subjacent layer of cells intrude.

The ectal polymorphous layer cells are polygonal, triangular and fusiform in shape and tend to gather in groups in certain cortical regions. The fusiform cells are placed with their long axes parallel (i.e., tangential) to the gyrall surface and are presumably associative in function.

The Layer of Small and the Layer of Large Pyramidal Cells.—The cells in the second and third layers may be studied together, since, with the exception of the difference in size and the more superficial position of the smaller cells, they resemble each other. The body of each cell is pyramidal in shape, its base being directed to the deeper parts and its apex toward the surface. It contains granular pigment, and stains deeply with ordinary reagents. The nucleus is nucleolated, of large size, and round or oval in shape. The base of the cell gives off the axone, and this passes into the central white substance,
giving off collaterals in its course to be distributed as a projection, commissural, or association fibres. Both the apical and basal parts of the cell give off dendrites. The apical dendrite is directed toward the surface, and ends in the molecular layer by dividing into numerous branches, all of which may be seen to be studded with projecting bristle-like processes when prepared by the silver or methylene-blue method. The larger pyramidal cells, especially in the precentral gyr, may exceed 50 µ in length and 40 µ in breadth, and are termed giant cells. The chief function of the small pyramidal cells is commissural and associative. The chief function of the large pyramids is motor, but they have also commissural and associative functions.

Layer of Ental Polymorphous Cells.—The cells in this layer, as their name implies, vary greatly in contour, the commonest varieties being of a spindle, star, oval, or triangular shape. Their dendrites are directed outward, toward, but do not reach, the molecular layer; their axones pass into the subjacent white substance. From this layer come commissural fibres, long association fibres, and some projection fibres.

There are two other kinds of cells in the cerebral cortex, but their axones pass in a direction opposite to that of the pyramidal and polymorphous cells, among which they lie. They are: (a) the cells of Golgi, the axones of which do not become myelinated, but divide immediately after their origin into a large number of branches, which are directed toward the surface of the cortex; (b) the cells of Martinotti, which are chiefly found in the polymorphous layer. Their dendrites are short, and may have an ascending or descending course, while their axones pass out into the molecular layer and form an extensive horizontal arborization.

Nerve-fibres in the Cortex.—These fill up a large part of the intervals between the cells. Some of these fibres form fasciculi; some are isolated, and others are arranged in plexuses. They may be myelinic or amyelinic, the latter comprising the axones of the smallest pyramidal cells and the cells of Golgi. In their direction the fibres may be either transverse, the transverse tangential or horizontal fibres, or vertical, the vertical or radial fibres. The transverse fibres run parallel to the surface of the hemisphere, intersecting the vertical fibres at a right angle. They consist of several strata, of which the following are the most important: (1) a stratum of white fibres covering the superficial aspect of the molecular layer; (2) the band of Bechterew, found in certain parts of the superficial portion of the layer of the smaller pyramidal cells; (3) the external or outer band of Baillarger or the band of Gennari, which runs through the layer of large pyramidal cells; (4) the internal band of Baillarger, which intervenes between the layer of large pyramidal cells and the polymorphous layer. According to Cajal, the transverse fibres consist of (a) the collaterals of the pyramidal and polymorphous cells and of the cells of Martinotti; (b) the arborizations of the axones of Golgi's cells; (c) the collaterals and terminal arborizations of the projection, commissural, or association fibres. The vertical fibres: Some of these, viz., the axones of the pyramidal and polymorphous cells, are directed toward the central white substance, while others, the terminations of the commissural, projection, or association fibres, pass outward to end in the cortex. The axones of the cells of Martinotti are also ascending fibres.

In certain parts of the cortex this typical structure is departed from. The chief of these regions are: (1) the occipital lobe, (2) the transtemporal gyres, (3) the hippocampus, (4) the dentate, and (5) the olfactory bulb.

Special Types of Gray Substance. 1. The Occipital Lobe.—In the cuneus and the calcarine fissure of the occipital lobe, Cajal has recently described as many as nine layers. Here the inner band of Baillarger is absent; the outer band of Baillarger or band of Gennari is, on the other hand, of considerable thickness. If a section be examined microscopically, an additional layer is seen to be interpolated.
between the molecular layer and the layer of small pyramidal cells. This extra layer consists of two or three strata of fusiform cells, the long axes of which are at right angles to the surface. Each cell gives off two dendrites, external and internal, from the latter of which the axone arises and passes into the white central substance. In the layer of small pyramidal cells, fusiform cells, identical with the above, are seen, as well as ovoid or star-like elements with ascending axones, the cells of Martinotti. This area of the cortex forms the visual centre, and it has been shown by Dr. J. S. Bolton⁷ that in old-standing cases of optic atrophy the thickness of Gennari's band is reduced by nearly 50 per cent.

2. The Transtemporal Gyres.—The transtemporal gyres are distinguished by a reduction of thickness of the pyramidal cell layer with closer approximation of the giant-cells to each other, while the fusiform cell layer is more deeply situated than elsewhere. This cortical formation is the end-station for cochlear nerve projections.

3. The Hippocampus.—In the hippocampus the molecular layer is very thick and contains a large number of Golgi cells. It has been divided into three strata: (a) S. convolutum or S. granulosum, containing many tangential fibres; (b) S. lacunosum, presenting numerous lymphatic or vascular spaces; (c) S. radiatum, exhibiting a rich plexus of fibrils. The two layers of pyramidal cells are condensed into one, and these are mostly of large size. The axones of the cells in the polymorphous layer may run in an ascending, descending, or horizontal direction. Between the polymorphous layer and the ventricular ependyma is the white substance of the alveus (Fig. 608).

4. The Dentate Gyre.—In the rudimentary dentate convolution the molecular layer contains some pyramidal cells, while the pyramidal layer is almost entirely represented by small ovoid elements.

5. The Olfactory Bulb.—In many of the lower animals this contains a cavity which communicates through the hollow olfactory stalk with the cavity of the lateral ventricle. In man the original cavity is filled by neuroglia and its wall becomes thickened, but much more so on its ventral than on its dorsal aspect. Its dorsal part contains a small amount of gray and white substance, but this is scanty and ill defined. A section through the ventral part shows it to consist of the following layers from without inward. (1) A layer of olfactory-nerve fibres, which are the myelinated axones prolonged from the olfactory cells of the nose, and which reach the bulb by passing through the cribriform plate of the ethmoid bone. At first they cover the bulb, and then penetrate it to end by forming synapses with the dendrites of the mitral cells, presently to be described. (2) Glomerular layer (stratum glomerulosum): This contains numerous spheroidal reticulated enlargements, termed glomeruli, which are produced by the branching and arborization of the processes of the olfactory nerve-fibres with the descending dendrites of the mitral cells. (3) Molecular layer: This layer is formed of a matrix of neuroglia, embedded in which are the mitral cells. These cells are pyramidal in shape, and the basal part of each gives off a thick dendrite which descends into the glomerular layer, where it arborizes as above, or, on the other hand, interfaces with similar dendrites of neighboring mitral cells. The axones pass through the next layer into the white substance of the bulb, from which, after becoming bent on themselves at a right angle, they are continued into the olfactory tract. (4) Nerve-fibre layer: This lies next the central core of neuroglia, and its fibres consist of the axones or afferent processes of the mitral cells which are passing on their way to the brain; some efferent fibres are, however, also present, and terminate in the molecular layer and presumably come via the precommisssure from the mitral cells of the opposite bulb.

The **claustrum**, although usually enumerated among the basal ganglia, is probably the thickened and isolated deepest layer of fusiform cells belonging to the cortex of the insula. The white lamina\(^1\) intervening between it and the cortex proper consists of association axones of longer and shorter course.

**Summary of the Cerebral Fibre Systems.**—The white substance of the cerebrum consists of myelinic fibres intricately interwoven but permitting of classification into three systems arranged according to the course they take. These systems comprise: (1) **association fibres**, which connect neighboring or distant parts within the same hemicerebrum; (2) **commissural fibres**, which unite allied parts in the two cerebral halves and come transversely across the mid-line to form the commissures; (3) **projection fibres**, which connect the cerebral cortex with lower centres in the brain and spinal cord, and, conversely, those fibres which connect lower centres with the cerebral cortex.

1. The **Association Fibres** (Fig. 632) connect different structures in the same hemispheres, and are in or near to the cortex. They take origin from the small pyramidal and polymorphous cells of the deep layer of the cortex. Their direction is parallel to the surface of the hemisphere, and in their course they cross the projection and commissural fibres. They are of two kinds: (1) those which unite adjacent convolutions, **short association fibres**; (2) those which pass between more distant parts in the same hemisphere, **long association fibres**.

The **short association fibres** are situated immediately beneath the gray cortex of the hemispheres, and connect together adjacent convolutions. They constitute subcortical tracts and are divided into **arcuate fibres** and **tangential fibres**. Some of these fibres connect the "visual sensor area with the visual memory area, and the auditory sensor with the auditory memory area."

The **long association fibres** associate cerebral centres which are far apart. They are gathered into bundles and dip down deep into the centrum ovale. They include the following: (a) the **uncinate fasciculus**; (b) the **superior longitudinal fasciculus**; (c) the **inferior longitudinal fasciculus** (doubtful); (d) the **cingulum**; and (e) the **fasciculus rectus**.

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1. Previously described as the *pericalveal lamina or capsula extrema.*
(a) The **Uncinate Fasciculus** (*f. uncinatus*) passes between the uncinate gyre and the orbital portion of the frontal lobe; in its course it curves beneath the depths of the basisylvian fissure (Fig. 632).

(b) The **Superior Longitudinal Fasciculus** (*fasciculus longitudinalis superior*) (Fig. 632).—The superior longitudinal fasciculus is beneath the convex surface of the hemisphere. It joins the frontal cortex with the parietal and temporal cortex and brings into relation the motor speech centres and the centres of auditory and visual memories.

(c) The **Inferior Longitudinal Fasciculus** is usually described as a tract associating the centres of auditory and visual memory. Such association fibres undoubtedly exist, but it is doubtful whether they are collected into a distinct fasciculus. The bundle which is usually designated by this term has been proved to be in part the projection system between the occipital cortex and the thalamus and pregeniculm (E. Redlich) and in part also the fibres from the temporal cortex (medietemporal and subtentorial gyre) to the crusta.

(d) The **Cingulum**, also called the *fornix periphericus*, is a band of white fibres that course in the white substance of the callosal gyr and runs excentrically to the calosum. Its fibres may be traced frontad into the mesal olfactory stria and the preperforatum, while caudal they radiate into the hippocampus. It may be regarded as an association tract of the rhinencephalon akin to the fornix.

(e) The **Fasciculus Rectus** or **Perpendicular Fasciculus** runs dorsoventrad in the occipito-parietal transition and associates the subparietal gyres...
with the medi- and subtemporal gyres; a part of the fasciculus associates the dorsal occipital region with its ventral part and with the subcollateral gyre (Fig. 632).

The FORNIX, previously described, may be enumerated among the long association tracts; it belongs exclusively to the olfactory apparatus.

2. The **Commissural Fibres** are grouped under the following heads: (a) the callosum, described on p. 939; (b) the precommis sure, described on p. 952; and (c) the fornico commis sure, described on p. 951.

3. The **Projection Fibres** connect the cerebral cortex with lower brain centres (caudatum and lenticula, thalamus, hypothalamic region, quadrigemina, pons, oblongata), and with the spinal cord centres. They either project impulses from the cortex to the periphery or bring in impressions from without. Their radiations to and from the cortex, together with the radiations of the callosal fibres, give rise to the characteristic appearance of the corona radiata. We may distinguish the projection tracts of long course from those of short course and, in the functional sense, those that are centrifugal, descending or motor, from those that are centripetal, ascending, or sensor. The latter mode of classification is more desirable.

1. **Descending (corticifugal) Tracts** are composed of axones arising from the cortical pyramidal cells.

   (a) The **pyramidal or motor tract** from the "motor area," comprising the precentral gyre and paracentral gyre, courses through the genu and frontal two-thirds of the thalamo-lenticular limb of the internal capsule, forms the middle (three-fifths) sector of the crus ta, passes through the pons into the postoblongata and spinal cord. The tract may be subdivided into a cortico-bulbar and a cortico-sinal division.

   The cortico-bulbar division is the pyramidal tract to the efferent cranial-nerve nuclei. Only those fibres which are destined to go to the facial and hypoglossal can be traced throughout. They originate in the ventral part of the precentral gyre (face and tongue centre), course through the genu of the internal capsule and end, contralaterally, in relation with the facial and hypoglossal-nerve nuclei (also called the emissary speech tract).

   The cortico-sinal division arises from the remainder of the motor area, courses through the frontal two-thirds of the internal capsule, through crus ta, pons, and postoblongata, to form the pyramids, and undergoing partial decussation, forms the direct and the crossed pyramidal tracts described in the spinal cord.

   (b) The fronto-pontile tract (Arnold’s bundle) arises in the midfrontal cortex, courses through the internal capsule (caudal part of frontal limb), forms the mesial sector (one-fifth) of the crus ta, and ends in the nuclei pontis.

   (c) The temporo-pontile tract (Türek’s bundle) arises in the cortex of the temporo-lab, descends through the internal capsule (caudal segment), forms the ectal (one-fifth) sector of the crus ta, and ends in the nuclei pontis. The existence of occipito-pontile fibres is denied by Archambault in a recent contribution (1906).

   (d) The occipito-mesencephalic tract arises in the visual area (cuneus and calcaine formation), courses through the retrolenticular part of the internal capsule, to end in the pregem inum and in relation with the nuclei for movements of the eyeball.

   (e) Part of the fibres composing the optic radiation are corticipetal, arising in the occipital cortex and ending in the pulvinar of the thalamus and the pregeniculum.

2. **Ascending (corticopetal) Tracts** arise mostly from the nuclei of the thalamus and hypothalamus, mid-brain, and cerebellum.

   (a) The terminal or cerebral part of the general sensor pathway of the body comprises the axones arising in the cells of the lateral nucleus of the thalamus and the hypothalamic nucleus—interposed way-stations which transfer the impressions carried along the medial lemniscus from the nuclei of the gracile and
cuneate fasciculi in the myeloblongata transition. They convey sensor impressions from the body periphery to the somesthetic area of the cortex—chiefly the postcentral and parietal gyres.

(b) The terminal or cerebral part of the general sensor pathway of the head and neck comprises the axones which arise from the afferent cranial-nerve nuclei (excepting the auditory) and course along the medial lemniscus to the thalamus and hypothalamic nucleus, to be thence projected to the somesthetic cerebral cortex.

(c) The terminal or cerebral part of the auditory pathway from the postgeminum, postgeniculum, and the interposed nucleus of the lateral lemniscus, ending in the auditory sphere of the cerebral cortex.

(d) The terminal part of the visual pathway, described on pages 919.

(e) The terminal (ascending) cerebello-cortical pathway, arising as the fibres of the cerebellar prepeduncles, decussating and ending in the rubrum (red nucleus) and lateral nucleus of thalamus, is thence directly projected by new axones to the somesthetic cortical area, or indirectly projected via thalamus (lateral nucleus).

Connections of the Striatum.—The connections of the caudatum and lenticula with each other and with the cortex may be summarized as follows:

(a) Fibres from the cortex to caudatum and lenticula, entering into the formation of the corona radiata.

(b) Fibres from the caudatum and putamen of lenticula coursing to the thalamus and hypothalamic region. Those from the caudatum pass through the internal capsule to traverse the pallidum, are joined by the fibres from the putamen to again traverse the internal capsule and end in the thalamus, forming the striato-thalamic radiation.

(c) Fibres coursing ventrad in the medullary laminae of the lenticula, and reinforced by additional fibres from the pallidum, course mesad to the hypothalamic region to form the subthalamic radiation or ansa lenticularis (described on p. 957). This radiation is further reinforced by the ventral stalk of the thalamo-cortical radiation to form the ansa peduncularis (described on p. 957).

The Olfactory Pathways. 1. Peripheral Pathway.—Impressions from the upper portion of the Schneiderian mucous membrane pass along the olfactory fila (central processes of the intra-epithelial bipolar olfactory cells) to the glomeruli olfactorii in the olfactory bulb (Fig. 634).

2. Central Pathway.—In the glomeruli the impression is transmitted to the brush-like, dendritic endings of the mitral cells and brush-cells; the axones of these cells carry the impression centrad to the gray masses of the olfactory tract, trigonum olfactorium, preperforatum, and adjacent parts (Fig. 630). These constitute the primary centres.

Fig. 634.—Schema of the olfactory bulb and tract neurones.
The primary centres are connected with secondary or cortical centres (hippocampus, gyrus dentatus, uncus) by the following tracts:

1. Lateral olfactory striae, from the olfactory trigone to the uncus, ending in the gyrus ambiens and gyrus semilunaris (p. 935).

2. Axones from cells in the olfactory trigonal gray through the fornix to hippocampus.

3. Striae medialis (Lancisii) from the trigone into gyrus subcallosus around the callosum to gyrus dentatus and hippocampus.

The amygdala is by some regarded a cortical centre to which impressions are carried by the tendia semicircularis.

The fornix fibres arise from the pyramidal cells in the hippocampus and the polymorphous cells of the dentate gyre. Some fibres traverse the median plane as the fornix commissure to the opposite hippocampus; the remainder end in the albicans gray nucleus or, in small part, are retroflexed as the stria medullaris thalami to the habenal ganglion.

In the albicans impressions are transmitted to the cells of two nuclear masses; from the medial nucleus arise axones constituting the fasciculus albicaninus principecs, each axone bifurcating and the diverging bundles forming, respectively, the albicantholamal and the albicanthotegmental fasciculi (p. 916).

The stria medullaris thalami consists of the following bundles ending in the habenal ganglion:

(a) Axones from hippocampus via fornix—the cortico-habenal tract; (b) axones from the hemiseptum and olfactory gray—the olfacto-habenal tract; (c) axones from the thalamus to the habenal ganglion—the thalamo-habenal tract.

In the habenal ganglion axones arise which pass as a distinct bundle ventrad through the tegmentum to the gray of the postperforatum (ganglion interpedunculare [intercerebrale] of Gudden)—the fasciculus retroflexus of Meynert.

The primary olfactory centres of the two sides are connected by the pars olfactoria of the precommissure, a bundle of fibres passing from side to side to end in the tract, granular stratum, and glomerular layer of the bulb.

Further connections are established with the tuber, mid-brain, and even spinal centres; one division has been named the olfacto-mesencephalic tract (Wallenberg).

The cingulum or fornix periphericus is an arcuate association bundle, or rather an arcuate series of short bundles which establishes the connections of the rhinencephalon with the adjacent cortical areas. (See p. 962.)

**Weight of the Brain.**—The average weight of the brain in the adult male is 1400 grams; that of the female 1250 grams. Among 1500 brains of males the brain-weights ranged from 960 grams to over 1900 grams; the great majority of this series ranged from 1250 grams to 1500 grams. The average weight in the newborn is 400 grams in the male and 350 grams in the female. The weight is doubled at the end of the first and trebled at the end of the fourth or fifth year, the female brain growing less rapidly than the male brain. Brain-growth generally ceases in the eighteenth or twentieth year, earlier in the female than the male. After the sixtieth year the brain loses weight, at first slowly, but more rapidly in advanced senescence. Other factors, besides age and sex, which influence brain-weight are stature, body-weight, cranial form, and race. Persons of large stature average heavier brains than those of short stature in absolute figures, but not relatively. Brachycephalic persons average heavier brains than the dolichocephalic. A most profound influence upon brain-weight appears to be exerted by racial differences. Representatives of the white race have heavier brains than those of the other races; although data are not sufficient to make a positive statement. Thus the few Eskimo brains that have been secured so far are notable for their size and weight. The following table gives approximately accurate averages based upon greater or lesser numbers of brain-weights:
The intellectual status is in some way reflected in the mass and weight of the brain. The average brain-weight of 100 men eminent in the professions, arts, and sciences, with an average age of 62 years, was 1470 grams, exceeding the average weight of the ordinary population of about the same age by more than 100 grams. A further analysis shows that the brains of men devoted to the higher intellectual occupations, such as the mathematical sciences, involving the most complex mechanisms of the mind, those of men who have devised original lines of research and those of forceful character are among the heaviest of all.

The brains of microcephalic idiots are far under the minimal size necessary for mental integrity, which is about 1000 grams in the male and 900 grams in the female. Certain idiotic individuals possess brains of normal size or even abnormally large brains, but structural defects underlie these forms of idiocy.

The whale, porpoise, dolphin, and elephant possess larger brains than man, but relative to the size and weight of the body the human brain is proportionately larger.

### Cortical Localization of Function

Patient researches conducted along clinico-pathologic, experimental, physiologic, and developmental lines have furnished us with a topographic map of the somesthetic and sense areas and, inferentially, of the association areas of the cerebral cortex. The somesthetic and sense areas constitute less than one-third of the cortical area, while the remainder is presumed to be devoted to the elaboration of the higher mental activities manifested by abstract thought, ideation, reasoning, and language. The acquisition of these specifically human mental attributes has been the chief factor in bringing about the superior structure of the human brain, and those cortical regions which were subjected to increased associations rose in functional dignity and increased in size. With over nine billion functional nerve-cells in the human cerebral cortex devoted to the mental processes and less than one-third of these concerned with emissary and receptive functions, the intricacy and capacity of the human brain for the manifold registration of sensations and the numerous transformations that characterize man's mental process far exceed that of any other animal.

The delineation of areas called motor, visual, auditory, etc., is not to be deemed as mathematically accurate or sharply defined as the boundaries of a State, county, or township. The areas rather shade off in a diffuse manner and the arbitrary demarcations employed in the appended figures merely show the maximum concentration of those cortical parts which most distinctly pertain to the function alleged for them.

The principal areas that are known to be functionally differentiated are the following:

1. **Motor Area.**—The motor area comprises the precentral gyr and parts of the frontal gyres adjacent thereto, together with the paracentral gyr and the adjacent portion of the superfrontal gyr on its medial face. Stimulation of various parts of this area causes movement, while their destruction impairs or abolishes voluntary movements. Within this motor area may be defined districts which are cortical projections of the muscular systems of the body. Thus, movements of the lower limb seem to be controlled by the dorsal part of the precentral and the paracentral
gyre: the trunk musculature by the area lying frontad both on the mesal aspect and in the dorsal superfrontal; the upper limb seems to be controlled by the mid-portion of the precentral; while the facial musculature is projected in the ventral part. The motor regions for the tongue, larynx, muscles of mastication, and pharynx lie in the frontal opercular part; and the movement of the head and eye are dominated by the medifrontal gyre, adjacent to the precentral. Recalling the fact that the pyramidal (motor) tract decussates in its course to the primary motor centres, it follows that the motor centres in one hemicerebrum control the movements of the opposite side of the body. As elsewhere in the cortex, these motor areas gradually pass one into the other and the boundaries are indeterminate. The localization of motor function is rather
for coördinated groups of muscles than for individual muscles; as a rule the most powerful articulation, as the thigh and the shoulder, is localizable frontal in the respective limb centres, while the smaller articulations and those more differentiated as regards motility (digits, etc.) are localizable more posteriorly.

2. Sensor Areas.—(a) The area for tactile and temperature impressions is more intensely localized in the postcentral gyre and in corresponding order with its neighboring precentral motor areas; that is to say, there is the most intimate intercommunication between the sensor and the motor regions which preside over corresponding parts of the body. So closely coupled are the related sensor and motor cells in the highest category of the reflex arc system represented in the cerebral cortex that both sensor and motor areas are included under the term somesthetic or senso-motor area, devoted to the registration of cutaneous impressions, impressions from the muscles, tendons, and joints; in short, the sense of movement. The cortical area embraced by the parietal gyre, together with its extension in the precuneous on the mesial aspect, appears to be devoted to the concrete perception of the form and solidity of objects and is therefore termed the stereognostic sense area.

(b) The auditory area is localized in the middle third of the supertemporal gyre and in the adjacent transtemporal gyres in the sylvian cleft.

(c) The visual area is most intensely localizable in the region of the calcarine fissure as well as in the cuneus as a whole. There seems to be an interrelation between the visual function and the special type of cortex already described, and chiefly characterized by the stripe of Gennari.

(d) The olfactory area comprises the uncus, frontal part of hippocampus, indusium, callosal gyre, parolfactory area, and preperforatum.

(e) The gustatory area has not yet been accurately localized; presumably it lies in the neighborhood of the olfactory area in the temporal lobe (uncinate and hippocampal gyre?).

3. The Language Areas.—The cortical zone of language comprises certain specialized areas which take part in the intimate relations of speech to thought-expression, to memory, in its reading form to sight, in writing to manual muscular innervation, and in "word-understanding" to hearing.

(a) The emissive (articular) centre for speech is localized in the region of the junction of the subfrontal gyre with the precentral gyre—a region known to be intimately related to the control of the muscles used in speech (larynx, tongue, jaw muscles). Destruction of this region at least causes a loss or disturbance of articulation of words.

(b) The auditory receptive centre, clinically known as the centre of "word-deafness," is localized in the marginal gyre and adjacent part of supertemoral gyre. A patient suffering with a lesion of this area may clearly hear but not understand the spoken word. The centre might also be called the lalognostic (word-understanding) centre.

(c) The visual receptive centre, clinically known as the centre of "word-blindness," is
localized in the angular gyre. Lesions of this area renders the patient incapable of understanding the significance of the words and objects which he sees.

(d) An emissive "writing" centre, not positively proven to exist, has been localized in the medifrontal gyre, frontad of the motor area for the upper limb.

(e) Of not a little importance with reference to the intellectual control of the faculty of language is the insula, purely an association centre, serving to connect the various receptive sense-areas relating to the understanding of the written and spoken word with the somesthetic emissary centres related to articulate speech and writing.

The union of the various centres enumerated above forms the cortical zone of language and is most intensely, if not exclusively, localized in the left hemicerebrum in right-handed persons, and vice versa in left-handed persons.

4. The Association Areas.—The remaining area of the cerebral cortex is presumably the organic substratum for the higher psychic activities. At the present time not much is known about them, but broadly stated the frontal association area is concerned rather with the powers of thought in the abstract; creative, constructive, and philosophic. The parieto-occipito-temporal association area, on the other hand, seems to be concerned more with the powers of conception of the concrete, for the comprehension of analogies, comparing, generalizing, and systematizing things heard, observed, and felt.

The great extent of the association areas in the human brain is a somatic expression of man's possession of an associative memory or ability to register and compare sensations far greater than that of the highest ape. The pattern of the fissures and gyres in the brains of the higher anthropoids and man present the same general features in all these types. In the course of evolution, however, the regions known as association areas assumed a greater energy of growth and expanded in proportion to the rise in functional dignity of these areas. They are regions of "unstable equilibrium" which afford greater and more complex associations as mental development
goes on in the species, and concomitant with this great cortical expansion the associating or coordinating fibre systems became more elaborate, complex, and far-reaching.

With the aid of the microscope the maturing of the brain-elements can be followed from the earliest stages of embryonic life to the adult period. The Flechsig method has shown how the function of nerve-fibres within the brain is only established when the myelin-sheath has developed. But this development of mature nerve-fibres does not occur simultaneously throughout the brain, but step by step in a definite order of succession: equally important bundles are myelinated simultaneously, but those of dissimilar importance develop one after another in accordance with Flechsig's law. The successive myelinization of fibre-bundles to and from the cerebral cortex corresponds to the successive awakenings of mental activities and faculties in the growing child. Flechsig's method of investigation has been of great service in the elucidation of the problems of cerebral localization.

Craniocerebral Topography.—The position of the principal fissures and convolution of the cerebrum and their relation to the outer surface of the scalp (Fig. 638) have been the subject of much investigation, and many systems have been devised by which one may localize these parts from an explanation of the external surface of the head.

These plans can only be regarded as approximately correct for several reasons: in the first place, because the relations of the convolutions and fissures to the surface are found to be quite variable in different individuals; secondly, because the surface area of the scalp is greater than the surface area of the brain, so that lines drawn on the one cannot correspond exactly to fissures or convolutions on the other; thirdly, because the fissures and convolutions in two individuals are never precisely alike. Nevertheless, the principal fissures and convolutions can be mapped out with sufficient accuracy for all practical purposes, so that any particular convolution can be generally exposed by removing with the trephine a certain portion of the skull's area. An excellent method is given by Chipault in his Chirurgie opératoire du système nerveux, 1894, vol. 1. The following systems have been the longest in vogue.

The various landmarks on the outside of the skull, which can be easily felt, and which serve as indications of the position of the parts beneath, have been already referred to, and the relation of the fissures and convolutions to these landmarks is as follows:

**Intercerebral or Longitudinal Fissure (Fig. 639).—** This corresponds to a line drawn from the glabella at the root of the nose to the external occipital protuberance.

**The Sylvian Fissure (Fig. 639).—** The position of the sylvian fissure is marked by a line starting from a point 3 cm. horizontally behind the external angular process of the frontal bone to a point 2 cm. below the most prominent point of the parietal eminence. The first 2 cm. will represent the basisylvian fissure, the remainder the sylvian fissure proper. The sylvian point is therefore
5 cm. behind and about 1 cm. above the level of the external angular process. The presylvian ramus of the fissure passes upward from this point parallel to, and immediately behind, the coronal suture.

The Tentorial Hiatus or Transverse Fissure.—This is between the cerebrum and cerebellum and corresponds to a line drawn from the inion to the external auditory meatus (the line $BC$ in Fig. 639).

Central Fissure.—To find the dorsal end of the central fissure, a measurement should be taken from the glabella to the external occipital protuberance. The position of the top of the fissure will be, measuring from in front, 53.6 per cent of the whole distance from the glabella to the external occipital protuberance. Professor Thane adopts a somewhat simpler method. He divides the distance from the glabella to the external occipital protuberance over the top of the head into two equal parts, and, having thus defined the middle point of the vertex, he takes a point half an inch behind it as the top of the sulus. This is not quite so accurate as the former method; but it is sufficiently so for all practical purposes, and on account of its simplicity is very generally adopted. From this point the fissure runs downward and forward for 9 to 10 cm., its axis making an angle of 67 degrees with the middle line. Cunningham states that this angle more nearly averages 71.5 degrees. In order to mark this groove, two strips of metal may be employed—one, the shorter, being fixed to the middle of the other at the angle mentioned. If the longer strip is now placed along the sagittal suture so that the junction of the two strips is over the point corresponding to the top of the furrow, the shorter, oblique strip will indicate the direction and 9 to 10 cm. will mark the length of the furrow. Dr. Wilson has devised an instrument, called a cyrrometer, which combines the scale of measurements for localizing the fissure with data for representing
its length and direction. Professor Thane gives the lower end of the furrow as close to the sylvian fissure, and about 1.5 cm. behind the sylvian point. So that, according to this anatomist, a line drawn from a point 1.5 cm. behind the mid-point between the glabella and external occipital protuberance to this spot would mark out the central fissure. Dr. Reid adopts a different method (Fig. 639). He first indicates on the surface the longitudinal fissure and the sylvian fissure (as above). He then draws two perpendicular lines from his "base-line" (that is, a line from the lowest part of the infraorbital margin through the middle of the external auditory meatus to the back of the head) to the top of the cranium, one (D E, Fig. 639) from the depression in front of the external auditory meatus, and the other (F G, Fig. 639) from the posterior border of the mastoid process at its root. He has thus described on the surface of the head a four-sided figure (F D G E, Fig. 639), and a diagonal line from the posterior superior angle to the anterior perpendicular line where it is crossed by the sylvian fissure will represent the furrow.

The Occipital Fissure on the dorsal surface of the cerebrum runs outward at right angles to the great longitudinal fissure for about 2 to 3 cm., from a point 0.5 cm. in front of the lambda (posterior fontanelle). Reid states that if the sylvian fissure be continued onward to the sagittal suture, the last 2 to 3 cm. of this line will indicate the position of the fissure (Fig. 639).

The Precentral Sulcus begins 2 cm. in front of the middle of the central fissure and extends nearly, but not quite, to the sylvian fissure.

The Supraorbital Fissure runs backward from the supraorbital notch, parallel with the line of the longitudinal fissure to 1 cm. in front of the line indicating the position of the central fissure. The Subfrontal Fissure follows the course of the supertemporal ridge on the frontal bone.

The Intraparietal Fissure, comprising the parietal, subcentral and paroccipital fissures, begins on a level with the junction of the middle and lower third of the central fissure, on a line carried across the head from the back of the root of one occipital to that of the other. After passing upward it curves backward, lying parallel to the longitudinal fissure, midway between it and the parietal eminence; then curves downward to end midway between the posterior fontanelle and the parietal eminence.

Kronlein's method for determining the portions of certain fissures of the brain is very useful and easy of application (Fig. 640). It is as follows: (1) The base line, Z M, is a horizontal line running at the level of the lower border of the orbit and the upper border of the external auditory meatus. (2) Another horizontal line, K K', is drawn parallel to Z M. The second horizontal line is on a level with the supraorbital ridge. (3) A vertical line, Z K, is erected from Z M at the middle of the zygotha and is carried to the line, K K'. (4) Another vertical line, A R, is erected from the base-line at the level of the articulation of the mandible and is carried to R. (5) A third vertical line, M P, is erected from the base-line at the posterior border of the mastoid process and is carried to the middle line of the skull, which is marked P. (6) A line is drawn from K to P. The portion of this line between R and P corresponds to the central fissure. (7) The angle P K K' is bisected by the line K S. K S corresponds to the sylvian fissure, and K is directly over the sylvian point. To reach the anterior branch of the middle meningeal, apply the trephine at K; to reach the posterior branch, apply it at K'. In absence of the temporal lobe the trephine should be applied, according to von Bergmann, in the region Aa K M.

THE MENINGES OR MENINGEAL MEMBRANES OF THE BRAIN (MENINGES ENCEPHALI).

Dissection.—To examine the brain with its membranes, the skull-cap must be removed. In order to effect this, saw through the external table, the section commencing, in front, about 2 cm. (1 in.) above the margin of the orbit, and extending, behind, to a little above the level with the occipital protuberance. Then break the internal table with the chisel and hammer, to avoid injuring the investing membranes or brain; loosen and forcibly detach the skull-cap, and dura will be exposed. The adhesion between the bone and the dura is very intimate, and much more so in the young subject than in the adult.

The membranes of the brain are from without inward: the dura, arachnoid, and the pia.

The Dura of the Brain (Dura Mater Encephali) (Figs. 641, 642, 643, 644).

The dura of the brain is a thick and dense, inelastic, fibrous membrane which lines the interior of the skull. It is a covering for the brain and is also the internal

1 Lancet, 1888, vol. i, p 408.
periosteum. Its outer surface is rough and fibrillated, and adheres closely to the inner surface of the bones by fibrous processes and blood-vessels. The adhesion is most marked on bony projections, opposite the sutures, and at the base of the skull. Except at the sutures the adhesions are not dense, and between the fibrous processes which pass to the bone are spaces which are thought to be lymph-spaces, and are called epidural spaces. At these points the outer surface of the dura is covered with endothelium. Fibrous tissue passes through the open sutures and joins the outer layer of the dura to the external periosteum. It is known as the sutural membrane. The inner surface of the dura limits the subdural space. It is smooth and lined by a layer of endothelium. The dura sends four processes inward, into the cavity of the skull, for the support and protection of the different parts of the brain, and is prolonged to the outer surface of the skull through the various foramina which exist at the base, and thus becomes continuous with the perioranum; its fibrous layer forms sheaths for the nerves which pass through these apertures. At the base of the skull it sends a fibrous prolongation into the foramen caecum; it sends a series of tubular prolongations around the filaments of the olfactory nerves as they pass through the cribiform plate, and also around the nasal nerve as it passes through the nasal slit; a prolongation is also continued through the sphenoidal fissure into the orbit, and another is continued into the same cavity through the optic foramen, forming a sheath for the optic nerve, where it is continued as far as the eyeball. In the posterior fossa it sends a process into the internal auditory

Fig. 641.—The structure of the dura. Section through the cranial vault of a child, slightly enlarged. (Poirier and Charpy.)

meatus, ensheathing the facial and auditory nerves; another through the jugular foramen, forming a sheath for the structures which pass through this opening; and a third through the anterior condyloid foramen. Around the margin of the foramen magnum it is closely adherent to the bone, and is continuous with the dura lining the spinal canal. The cavity or cave of Meckel (caveum Meckeli) (Fig. 641) is an osteo-fibrous recess near the apex of the petrous portion of the temporal bone, formed by folding of the dura in a bony depression. It contains the Gasserian ganglion. In certain situations, as already mentioned (p. 736), the fibrous layers of this membrane separate to form sinuses for the passage of venous blood. Upon the outer surface of the dura, in the situation of the longitudinal sinus, may be seen numerous small, whitish bodies, the arachnoid villi (p. 979).

Structure (Fig. 641).—The dura consists of white fibrous tissue with connective-tissue cells and elastic fibers arranged in flattened laminae, which are imperfectly separated by lacunae spaces and blood-vessels into two layers, endosteal and meningeal. The endosteal layer is the internal periosteum for the cranial bones and contains the blood vessels for their supply. At the margin of the foramen magnum it becomes continuous with the periosteum lining the spinal canal. The meningeal or supporting layer is lined on its inner surface by a layer of nucleated endothelium, similar to that found on serous membranes. By its reduplication the meningeal layer forms the falc, the tentorium and fascula, and the diaphragma sellae. The two layers are connected by fibers which intersect each other obliquely.
The Arteries of the Dura (see section on Arteries).—The arteries of the dura are very numerous, but are chiefly distributed to the bones. Those found in the anterior fossa are the predural branches of the anterior and posterior ethmoidal and internal carotid, and a branch from the medidural or middle meningeal. In the middle fossa are the medi- and parvidural branches of the internal maxillary, a branch from the ascending pharyngeal, which enters the skull through the foramen lacerum medium basis cranii, branches from the internal carotid, and a recurrent branch from the lacrimal. In the posterior fossa are dural branches from the occipital, one of which enters the skull through the jugular foramen, and the other through the mastoid foramen; the postdural or posterior meningeal, from the vertebral; occasionally dural branches from the ascending pharyngeal, which enter the skull, one at the jugular foramen, the other at the anterior condyloid foramen, and a branch from the medidural.

The Veins of the Dura.—The veins which return the blood from the dura (see p. 734), and partly from the bones, anastomose with the diploic veins (see p. 733). These vessels terminate in the various sinuses, with the exception of two which accompany the medidural artery, and pass out of the skull at the foramen spinosum to join the internal maxillary vein; above, the dural veins communicate with the superior longitudinal sinus. The sinuses are considered on pages 736 to 743 inclusive. On either side of the superior longitudinal sinus, especially near its middle, and also near the lateral and straight sinuses, are numerous spaces in the dura which communicate with the sinus, either by a small opening or a distinct venous channel. These spaces are the parasinoidal sinuses (lacunae laterales) (Fig. 642). Many of the dural veins do not open directly into the sinuses, but indirectly through the parasinoidal sinuses. These venous lacunae are often invaginated by arachnoid villi, and they communicate with the underlying cerebral veins, and also with the diploic and emissary veins.

The Lymphatics of the Dura.—The existence of lymphatic vessels is not proved. Some anatomists claim to have injected such vessels along the middle meningeal arteries (Mascagni, Arnold). Perivascular lymph-spaces do exist.

The Nerves of the Dura.—The nerves of the dura are filaments from the trochlear, the ophthalmic division of the trigeminal, the semilunar or Gasserian ganglion, the vagus, the hypoglossal, and the sympathetic.
Processes of the Dura (processus durae matris).—The processes of the dura sent inward into the cavity of the skull, are four in number: the falx, the tentorium, the falcula, and the diaphragma sellae.

The Falx (Figs. 642 and 644).—The falx or falx cerebri, so named from its sickle-like form, is a strong arched process of the dura, which descends vertically in the intercerebral fissure between the two hemispheres of the brain. It is narrow in front, where it is attached to the crista galli of the ethmoid bone, and broad behind, where it is connected with the upper surface of the tentorium. Its upper margin is convex, and attached to the inner surface of the skull, in the middle line, as far back as the internal occipital protuberance; it contains the superior or great longitudinal sinus (sinus sagittalis superior). Its lower margin is free, concave, and presents a sharp, curved edge, which contains the falcial or inferior longitudinal sinus (sinus sagittalis inferior). The tentorial or straight sinus (sinus rectus) is formed by the attachment of the falx to the tentorium.

The Tentorium (Figs. 642, 643, and 644).—The tentorium is an arched lamina of dura, elevated in the middle and slightly inclined toward the circumference. It intervenes between the upper surface of the cerebellum and the occipital lobes of the cerebrum. It is attached, behind, by its convex border to the transverse ridges upon the inner surface of the occipital bone, and there encloses on each side the transverse or lateral sinus (sinus transversus); frontad, to the superior margin of the petrous portion of the temporal bone on either side, there enclosing the superpetrosal sinus (sinus petrosus superior); and at the apex of this bone the free or internal border and the attached or external border meet, and, crossing one another, are continued forward, to be attached to the anterior and posterior clinoid processes respectively. Along the middle line of its upper surface the posterior border of the
falx is attached, the tentorial or straight sinus being placed at their point of junction. Its frontal border is free and concave, and with the dorsum sellae forms a large oval opening. This opening is called the incisura tentorii and transmits the mesencephalon.

The Falcula (Fig. 642).—The falcula is a small triangular process of dura received into the indentation between the two lateral lobes of the cerebellum behind. Its base is attached, above, to the under and back part of the tentorium; its posterior margin, to the lower division of the vertical crest on the inner surface of the occipital bone. As it descends it sometimes divides into two smaller folds, which are lost on the sides of the foramen magnum.

The Diaphragma Sellæ (Fig. 643).—The diaphragma sellae is a horizontal process formed by a reduplication of the meningeal layer of the dura. It forms a small circular fold, which constitutes a roof for the sella turcica. This almost completely covers the hypophysis, presenting merely a small central opening (foramen diaphragmatis sellae) for the passage of the infundibulum.

The Arachnoid (Arachnoidea Encephali) (Fig. 645).

The term arachnoid is from the Greek ἄραχνη εἰδος, like a spider’s web, so named for its extreme thinness. The cranial arachnoid is a delicate membrane which envelops the brain, lying between the pia internally and the dura externally; from this latter membrane it is separated by a very fine slit or space, the subdural space (cavum subdurale). The subdural space contains a very minute quantity of fluid of the nature of lymph. This fluid obtains exit by way of the

**Fig. 644.—Falx and tentorium, left lateral view. (Testut.)**

**Fig. 645.**
parasinoidal sinuses. The subdural space is prolonged upon emerging nerves and joins the lymph spaces of the nerves. The subdural space does not communicate with the subarachnoid space.

The arachnoid invests the brain loosely, being separated from direct contact with the cerebral substance by the pia, and a quantity of loose areolar tissue, the subarachnoidean areolar tissue. On the upper surface of the cerebrum the arachnoid is thin and transparent, and may be easily demonstrated by injecting a stream of air beneath it by means of a blowpipe; it passes over the convolutions without dipping down into the fissures between them, but does pass into the sylvian and intercerebral fissures and is prolonged upon the nerves as a sheath. At the base of the brain the arachnoid is thicker, and slightly opaque toward the central part; it covers the orbital surface of the anterior lobes, and extends across between the two temporal lobes so as to leave a considerable interval between it and the brain, the cisterna basalis.

The Subarachnoid Space (cavum subarachnoideale) (Fig. 646).—The subarachnoid space is the interval between the arachnoid and pia. It is not only on the surface, but dips between the convolutions. It is not, properly speaking, a space, for it is occupied everywhere by a spongy tissue consisting of trabecula of delicate connective tissue covered with endothelium, which pass from the pia to the arachnoid, and in the meshes of which the subarachnoid fluid is contained.
This so-called space is small on the surface of the cerebrum; but at the base of the brain the subarachnoid tissue is less abundant and its meshes larger.

In certain regions the arachnoid and pia are farther apart than was previously indicated, and these spaces are called subarachnoid cisternæ (cisternæ subarachnoïdalis). The largest space is the continuation of the posterior part of the subarachnoid space of the spinal cord. It is called the postcisterna (cisterna cerebellomedullaris). It is a space formed by the arachnoid passing across the back and under portions of the oblongata and cerebellum. It communicates with the fourth ventricle by three foramina. The largest opening is the metapore or foramen of Majendie (apertura medialis ventriculi quarti). It is in the middle line of the metatela. At the end of each recessus lateralis of the fourth ventricle there is also an opening, and each opening is called the foramen of Luschka or of Key and Retzius (apertura lateralis ventriculi quarti). The cisterna pontis is the continuation upward of the anterior part of the subarachnoid space of the cord. About the oblongata it is continuous with the postcisterna, so this important nerve-centre is surrounded by a large subarachnoid space. The crural cisterna or cisterna basalis (cisterna interpeduncularis) is formed by the arachnoid extending between the two temporal lobes, and contains the arteries forming the circulus.

![Diagram](image)

**Fig. 646.—The subarachnoid space. (Schematic.) (Poirier and Charpy.)**

The anterior subarachnoid space (cisterna pontis, interpeduncularis et chiasmatis) includes the cisterna pontis, the cisterna basalis, and the cisterna of the chiasm. There is a cisterna between the inferior edge of the falx and the superior surface of the callosum which contains the precerebral arteries, a cisterna in the sylvian fissure (cisterna sylviana) which contains the precerebral artery, and a cisterna between the quadrigemina which contains the vena magna Galeni.

The cerebro-spinal fluid (coeliolymph; liquor cerebrospinalis) fills the subarachnoid space. It is a clear, limpid fluid, having a saltish taste and a slightly alkaline reaction. According to Lassaigne, it consists of 98.5 parts of water, the remaining 1.5 per cent. being solid matters, animal and saline. It varies in quantity, being most abundant in old persons, and is quickly reproduced. Its chief use is probably to afford mechanical protection to the nervous centres, and to prevent the effects of concussions communicated from without.

**Structure.**—The arachnoid consists of bundles of connective tissue, the fine fibres of which form one layer and cross each other in every direction. At the level of the large fissures, and especially around the circulus, it is reinforced by thick fibrous tissue. Both surfaces are covered with endothelium. There are no blood-vessels in the arachnoid; the vessels which appear to be in it are really in the pia. There is no positive proof that nerves are present in the
arachnoid. It is true that Bochdalek and Luschka long ago described arachnoid nerves, but these observations have never been corroborated.

The Arachnoid Villi or Pacchionian Bodies (Granulationes Arachnoideales).

The arachnoid villi, erroneously called glandulae Pacchioni, are numerous small whitish or purplish projections, usually collected into clusters of variable size, which are found in the following situations: (1) Upon the outer surface of the dura, in the vicinity of the superior longitudinal sinus, being received into little depressions on the inner surface of the calvarium. (2) On the inner surface of the dura. (3) In the superior longitudinal sinus and the other sinuses.

A hasty examination would lead us to suppose that these bodies spring from the dura, but, as a matter of fact, they originate from the arachnoid. They are not glandular in structure, but are simply enlarged normal villi of the arachnoid. In their growth they appear to perforate the dura, and when a group of villi is of large size it causes absorption of the bone, and comes to be lodged in a pit or depression (foveola granularis [Pacchioni]) on the inner table of the skull. Their manner of growth is as follows: At an early period they project through minute holes in the inner layer of the dura, which open into large venous spaces situated in the tissues of the membrane, on either side of the longitudinal sinus and communicating with it. In their onward growth the villi push the outer layer of the dura before them, and this forms over them a delicate membranous sheath. In structure they consist of spongy trabecular tissue, covered over by a membrane, which is continuous with the arachnoid. The space between these two coverings, derived from the dura and arachnoid respectively, corresponds to and is continuous with the subdural space. The spongy tissue of which they are composed is continuous with the trabecular tissue of the subarachnoid space; so that fluid injected into the subarachnoid space finds its way into the Pacchionian bodies, and through their coverings filters into the superior longitudinal sinus. They are supposed to be a means of getting rid of an excess of cerebro-spinal fluid, when its quantity is increased above normal or

![Fig. 647.-Velum. (Poirier and Charpy.)](image-url)
for replenishing the cerebro-spinal fluid from the blood plasma when needed. Another means of getting rid of cerebro-spinal fluid is absorption by the lymph-spaces of the cranial nerves, which possess sheaths of arachnoid up to the points at which they emerge from the skull.

These bodies are not found in infancy, and very rarely until the third year. They are usually found after the tenth year; and from this period they increase in number as age advances. Occasionally they are wanting.

The Pia of the Brain (Pia Mater Encephali) (Figs. 646 and 647).

The pia of the brain is a vascular membrane, and derives its blood from the internal carotid and vertebral arteries. It consists of a minute plexus of blood-vessels, held together by an extremely fine areolar tissue. It invests the entire surface of the brain, dipping down between the convolutions and laminae, and is prolonged into the interior, forming the velum and the choroid plexuses of the lateral and fourth ventricles.
The Velum or the Tela Chorioidea Superior (tela chorioidea ventriculi tertii) (Fig. 647).—The velum is the prolongation of the pia into the interior of the brain through the medium of the transverse fissure. It is a double triangular vascular fold, that lies between the body of the fornix above and the optic thalami and the epithelial roof of the third ventricle below, and passes forward to the porta. At each edge of the velum is the paraplexus or choroid plexus (plexus chorioideus ventriculi lateralis) of the corresponding lateral ventricle. In front the two plexuses join behind the porta, and at the point of junction two lesser choroid plexuses pass back along the under surface of the velum to the third ventricle, the diaplexus or median plexus (plexus chorioideus ventriculi tertii). The velar veins or veins of Galen (p. 947) are two veins which lie on either side of the middle of the velum and pass back. Each velar vein is formed by the union of the vein from the striatum and the choroid vein from the choroid plexuses. The two velar veins unite and form the vena magna (Galen), which empties into the straight sinus.

The pia of the surfaces of the hemispheres, where it covers the gray matter of the convolutions, is very vascular, and gives off from its inner surface a multitude of minute vessels, which extend perpendicularly for some distance into the cerebral substance. At the base of the brain, in the situation of the pre- and post-perforatum, a number of long, straight vessels are given off, which pass through the white substance to reach the gray substance in the interior. On the cerebellum the membrane is more delicate, and the vessels from its inner surface are shorter. The pia of the spinal cord is thicker, firmer, and less vascular than that of the brain, and as it is traced upward over the oblongata it is seen to preserve these characters. At the upper border of the oblongata it is prolonged over the lower half of the fourth ventricle, forming, before it is reflected on to the under surface of the cerebellum, a covering for the fourth ventricle called the metatela or tela chorioidea inferior (tela chorioidea ventriculi quarti); this carries the choroid plexus of the fourth ventricle (plexus chorioideus ventriculi quarti).
The arteries of the pia (see pp. 628, 629, and 630) (Figs. 648 and 649) are the precerebrels, medicerebrels, postcerebrels, prechoroids, postchoroids, the precerebellars, medicerebellars, and posterebellars. (The vessels of the cerebral ganglionic system and of the cortical arterial system are considered on p. 632.)

The veins of the pia (see pp. 734, 735, and 736) are the basilar vein, the velar veins (Fig. 647), the veins constituting the choroid plexuses of the third ventricle, the lateral ventricles, and the fourth ventricle; the cerebral veins (Fig. 645) and the cerebellar veins (Fig. 645).

The nerves of the pia accompany the branches of the arteries and are derived chiefly from the sympathetic. A few fibres are derived from certain cranial nerves, all of which are probably of the afferent variety.

THE SPINAL NERVES (NERVI SPINALES).

The spinal nerves are so called because they apparently originate from the spinal cord, and are transmitted through the intervertebral foramina on either side of the spinal column. There are thirty-one pairs of spinal nerves, which are arranged into the following groups, corresponding to the region of the spine through which they pass:

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>8 pairs</td>
</tr>
<tr>
<td>Thoracic</td>
<td>12 &quot;</td>
</tr>
<tr>
<td>Lumbar</td>
<td>5 &quot;</td>
</tr>
<tr>
<td>Sacral</td>
<td>5 &quot;</td>
</tr>
<tr>
<td>Coccygeal</td>
<td>1 pair</td>
</tr>
</tbody>
</table>

It will be observed that each group of nerves corresponds in number with the vertebrae in that region, except the cervical and coccygeal. Sometimes there is no thirty-first pair. Occasionally below the thirty-first pair there may be one or even two filamentous pairs which do not pass out of the vertebral canal.

Each spinal nerve arises by two roots, a ventral or motor root and a dorsal or sensor root, the latter being distinguished by a ganglion termed the spinal ganglion.

The Roots of the Spinal Nerves (Figs. 540, 541, 650, 651, 652).

The Ventral Root (radix anterior).—The superficial origin is from the ventro-lateral columns of the cord, corresponding to the situation of the ventral cornu of gray matter. Each root is composed of from four to eight filaments.

The deep origin can be traced from cells in the gray substance of the ventral cornu of the same as well as of the opposite side. The majority of the axones arise from the various groups of cells in the ventral cornu of the same side, while others arise from the large cells of the ventral cornu of the opposite side, the axones passing across the median plane in the ventral white commissure. The axone bundles, after leaving the gray substance, penetrate horizontally through the longitudinal bundles of the ventro-lateral column to emerge as described above.

The Dorsal Root (radix posterior).—The superficial origin is by filaments (filar radiculairia), from the dorso-lateral fissure of the cord. The real origin of these fibres is from the nerve-cells in the dorsal-root ganglion, from which they can be traced into the cord in two main bundles, the course of which has already been studied (p. 849).

The ventral roots are smaller than the dorsal, devoid of ganglionic enlargement,
and their component fibrils are collected into two bundles near the intervertebral foramina.

The dorsal roots of the nerves are larger, but the individual filaments are finer and more delicate than those of the ventral. The cells of the ganglion upon each dorsal root give rise to central and peripheral processes; the central processes constitute the dorsal roots, the peripheral processes are modified dendrites (p. 827) which join the ventral efferent axones and form the spinal nerve trunk ensheathed by a tubular process of the dura and pia.

The dorsal root of the first cervical nerve forms an exception to these characters. It is smaller than the ventral, has occasionally no ganglion developed upon it, and when the ganglion exists it is often situated within the dura. The first cervical may have a rudimentary dorsal root or no dorsal root.

Within the vertebral canal the nerve-roots are separated from each other by the ligamentum denticulatum (Fig. 651). In the cervical region the spinal portion of the accessory nerve separates the roots. Each root obtains a covering of pia, which becomes continuous with the neurilemma; "the arachnoid invests each root as far as the point where it meets with the dura; the two roots, after piercing the dura separately, are enclosed by it in a single tubular sheath, in which is included the spinal ganglion of the dorsal root." (Cunningham.)

The Ganglia of the Spinal Nerves (Ganglia Spinales) (Figs. 650, 651, 652).

A ganglion is developed upon the dorsal root of each of the spinal nerves. The ganglion upon the dorsal root of the first cervical nerve may be rudimentary or absent. These ganglia are of an oval form and of a reddish color; they bear a proportion in size to the nerves upon which they are formed, and are placed in the intervertebral foramina, ectad of the point where the nerves perforate the dura. Each ganglion is bifid internally, where it is joined by the two bundles of the dorsal root, the two portions being united into a single mass externally. The ganglia upon the first and second cervical nerves form an exception to these characters, being placed on the arches of the vertebra over which the nerves pass. The ganglia of the sacral nerves are placed within the vertebral canal; and that on the coccygeal nerve, also in the canal, is situated at some distance from the origin of the dorsal root.

The ganglion in an embryo is composed of bipolar nerve-cells. In an adult the bipolar nerve-cells by fusion of their two poles form unipolar elements. The process of each unipolar cell divides into two a short distance from the cell. One of the processes from each cell passes to the spinal cord, and the other passes into the spinal nerve. On the dorsal roots of the lumbar and sacral nerves, between the spinal ganglia and the cord, small cellular masses occasionally exist. They are called accessory or aberrant ganglia (ganglia aberrantia).
Distribution of the Spinal Nerves.

Immediately beyond the ganglion the two roots coalesce, their fibres intermingle, and the trunk thus formed constitutes the spinal nerve; it passes out of the intervertebral foramen, and divides into a dorsal primary division for the supply of the dorsal part of the body, and a ventral primary division for the supply of the ventral part of the body (Fig. 651). Each division contains fibres from both roots.

![Diagram of spinal nerve constitution](image)

Before dividing, each spinal nerve gives off a small recurrent or meningeal branch (ramus meningeus) (Fig. 651), which is joined by a filament from the communicating branch of the sympathetic (ramus communicans) (Fig. 651), which connects the ganglion with the ventral division. The meningeal branches unite and form one nerve, which passes inward through the intervertebral foramen and supplies the dura, sending branches to the vertebrae and vertebral ligaments.

The Dorsal Primary Divisions (rami posteriores) (Fig. 631).—The dorsal primary divisions of the spinal nerves are generally smaller than the ventral; they arise from the trunk resulting from the union of the roots, in the intervertebral foramina; and, passing dorsad, divide into internal and external branches, which are distributed to the muscles and integument behind the spine. The dorsal primary divisions of the spinal nerves form two smallplexuses, the dorsal cervical plexus and the dorsal sacral plexus. The first cervical, the fourth and fifth sacral, and the coccygeal nerves do not divide into external and internal branches.
The Ventral Primary Divisions (rami anteriores) (Fig. 651).—The ventral primary divisions of the spinal nerves supply the parts of the body ventrad of the spine, including the limbs. They are for the most part larger than the dorsal primary divisions. Each division, soon after its origin, receives a slender filament from the sympathetic, which is called the gray ramus communicans. In the thoracic region the ventral primary divisions of the spinal nerves are quite separate from each other, and are uniform in their distribution; but in the cervical, lumbar, and sacral regions they form intricate plexuses previous to their distribution. The ventral primary divisions of certain thoracic, lumbar, and sacral nerves give off a delicate collection of nerve-filaments to the sympathetic cord. These are called the white rami communicantes or the visceral branches of the spinal nerves.

Points of Emergence of the Spinal Nerves.

The roots of the spinal nerves from their origin in the cord run obliquely caudad to their point of exit from the intervertebral foramina, the amount of obliquity varying in different regions of the spine, and being greater in the lower than the
upper part. The level of their emergence from the cord is within certain limits variable, and of course does not correspond to the point of emergence of the nerve from the intervertebral foramina (Fig. 653).

THE CERVICAL NERVES (NN. CERVICALES).

The Roots of the Cervical Nerves.

The roots of the cervical nerves increase in size from the first to the fifth, and then remain the same size to the eighth. The dorsal roots bear a proportion to the ventral as 3 to 1, which is much greater than in any other region, the individual filaments being also much larger than those of the ventral roots. The dorsal root of the first cervical is an exception to this rule; it is smaller than the ventral root. In direction the roots of the cervical are less oblique than those of the other spinal nerves. The first cervical nerve is directed a little cephalad and ectad; the second is horizontal; the others are directed obliquely caudad and ectad, the lowest being the most oblique, and consequently longer than the upper, the distance between their place of origin and their point of exit from the vertebral canal never exceeding the depth of one vertebra.

The First Cervical or Suboccipital Nerve (n. suboccipitalis) (Fig. 654).—The dorsal root may be rudimentary or absent. The trunk of the first cervical nerve leaves the vertebral canal between the occipital bone and the dorsal arch of the atlas (Figs. 16 and 202).

The Trunk of the Second Cervical Nerve leaves the vertebral canal between the dorsal arch of the atlas and the lamina of the axis; and the eighth (the last) between the last cervical and first thoracic vertebrae.

Each nerve, at its exit from the intervertebral foramen, divides into a dorsal and a ventral division. The ventral divisions of the four upper cervical nerves form the cervical plexus. The ventral divisions of the four lower cervical nerves, together with the first thoracic, form the brachial plexus.

The Dorsal Divisions of the Cervical Nerves (Rami Postiores).

The Dorsal Division of the First Cervical Nerve (Fig. 654) differs from the dorsal divisions of the other cervical nerves in not dividing into an internal and external branch. It is larger than the ventral division, and escapes from the vertebral canal between the occipital bone and the dorsal arch of the atlas, lying beneath the vertebral artery. It enters the suboccipital triangle formed by the Rectus capitis posticus major, the Obliquus superior and Obliquus inferior, and, by muscular branches, supplies the Recti and Obliqui muscles, and the Complexus. From the branch which supplies the Inferior oblique a communicating filament is given off which joins the second cervical nerve. This nerve also occasionally gives off a cutaneous filament, which accompanies the occipital artery and communicates with the occipitalis major and minor nerves.

The Dorsal Division of the Second Cervical Nerve is three or four times greater in diameter than the ventral division, and the largest of all the dorsal cervical divisions. It emerges from the vertebral canal between the dorsal arch of the atlas and lamina of the axis, below the Inferior oblique. It supplies a twig to this muscle, and receives a communicating filament from the first cervical. It then divides into an internal and an external branch.

The internal branch called, from its size and distribution, the great occipital nerve (occipitalis major) (Fig. 654), ascends obliquely inward between the Obliquus
inferior and Complexus, and pierces the latter muscle and the Trapezius near their attachments to the cranium. It is now joined by a filament from the dorsal division of the third cervical nerve, the anastomotic, and, ascending on the back part of the head with the occipital artery, divides into two branches, which supply the integument of the scalp as far forward as the vertex, communicating with the occipitalis minor. It gives off an auricular branch to the back part of the ear and muscular branches to the Complexus.

The external branch is often joined by the external branch of the dorsal division of the third cervical nerve, and supplies the Splenius, Trachelo-mastoid, and Complexus.

The Dorsal Division of the Third Cervical Nerve (Fig. 654) is smaller than the preceding, but larger than the fourth; it differs from the dorsal divisions of the remaining cervical nerves in its supplying an additional filament, the third occipital nerve, to the integument of the occiput. The dorsal division of the third nerve, like the others, divides into an internal and external branch.

The internal or cutaneous branch passes between the Complexus and Semispinalis, and, piercing the Splenius and Trapezius, supplies the skin over the latter muscle.

The external branch joins with that of the dorsal division of the second to supply the Splenius, Trachelo-mastoid, and Complexus.

The third or least occipital nerve (n. occipitalis minimus or n. occipitalis tertius) (Fig. 654) arises from the internal or cutaneous branch of the dorsal division of the third cervical nerve, beneath the Trapezius; it then pierces that muscle, and supplies the skin on the lower and back part of the head. It lies to the inner side of the occipitalis major, with which it is connected.

The dorsal division of the suboccipital nerve and the internal branches of the dorsal divisions of the second and third cervical nerves are occasionally joined beneath the Complexus by communicating branches. This communication is described by Cruveilhier as the dorsal cervical plexus.

The Dorsal Divisions of the Fourth, Fifth, Sixth, Seventh, and Eighth Cervical Nerves pass dorsad, and divide, behind the Intertransversales muscles, into internal and external branches.

The internal branches, the larger, are distributed differently in the upper and lower part of the neck. Those derived from the fourth and fifth nerves pass between the Complexus and Semispinalis muscles, and, having reached the spinous
processes, perforate the aponeurosis of the Splenius and Trapezius, and are continued outward to the integument over the Trapezius, whilst those derived from the three lowest cervical nerves are the smallest, and are placed beneath the Semispinalis colli, which they supply, and then pass into the Interspinalis, Multifidus spinae, and Complexus, and send twigs through this latter muscle to supply the integument near the spinous processes (Hirschfeld).

The external branches supply the muscles at the side of the neck—viz., the Cervicalis ascendens, Transversalis colli, and Trachelo-mastoid.

The Ventral Divisions of the Cervical Nerves (Rami Anteriores).

The Ventral Division of the First Cervical Nerve (Fig. 656) is of small size. It escapes from the vertebral canal through a groove upon the dorsal arch of the atlas. In this groove it lies beneath the vertebral artery, to the inner side of the Rectus capitis lateralis. As it crosses the foramen in the transverse process of the atlas it receives a filament from the sympathetic. It then descends ventrad of the transverse process, to communicate with an ascending branch from the second cervical nerve.

Communicating filaments from the loop between this nerve and the second cervical nerve join the vagus, the hypoglossal, and sympathetic, and some branches are distributed to the Rectus lateralis and the two Anterior recti. The fibres which communicate with the hypoglossal simply pass through the latter nerve to become for the most part the descendens hypoglossi. According to Valentin, the ventral division of the suboccipital nerve distributes filaments to the occipito-atlantal articulation and to the mastoid process of the temporal bone.

The Ventral Division of the Second Cervical Nerve (Fig. 656) escapes from the vertebral canal, between the dorsal arch of the atlas and the lamina of the axis, and, passing forward on the outer side of the vertebral artery, divides ventrad of the Intertransverse muscle into an ascending branch, which joins the first cervical; and one or two descending branches, which join the third cervical. It gives off the small occipital; a branch to assist in forming the great auricular; another to assist in forming the superficial cervical; one of the communicantes hypoglossi, and a filament to the Sterno-mastoid, which communicates in the substance of the muscle with the spinal accessory.

The Ventral Division of the Third Cervical Nerve (Fig. 656) is double the size of the preceding. At its exit from the intervertebral foramen it passes caudad and outward beneath the Sterno-mastoid muscle, and divides into two branches. The ascending branch joins the ventral division of the second cervical; the descending branch passes down ventrad of the Scalenus anticus muscle and communicates with the fourth cervical. It gives off the larger part of the great auricular and superficial cervical nerves; one of the communicantes hypoglossi; a branch to the supraclavicular nerves; a filament to assist in forming the phrenic; and muscular branches to the Levator anguli scapulae and Trapezius; this latter nerve communicates beneath the muscle with the accessory nerve. Sometimes the nerve to the Scalenus medius is derived from this source.

The Ventral Division of the Fourth Cervical Nerve (Fig. 656) is of the same size as the preceding. It receives a branch from the third, sends a communicating branch to the fifth cervical, and, passing caudad and outward, divides into numerous filaments, which cross the dorsal triangle of the neck, forming the supraclavicular nerves. It gives a branch to the phrenic nerve, while it is contained in the intertransverse space, and sometimes a branch to the Scalenus medius muscle. It also gives a branch to the Levator anguli scapulae and to the Trapezius, which unites with the branch given off from the third nerve, and communicates beneath the muscle with the accessory nerve.
The Ventral Divisions of the Fifth, Sixth, Seventh, and Eighth Cervical Nerves are remarkable for their size. They are much larger than the preceding nerves, and are all of equal dimensions. They assist in the formation of the brachial plexus.

The Cervical Plexus (Plexus Cervicalis) (Figs. 655 and 656).

The cervical plexus is formed by the ventral divisions of the four upper cervical nerves. It is situated opposite the four upper cervical vertebrae, resting upon the Levator anguli scapulae and Scalenus medius muscles, and covered in by the Sterno-mastoid.

Its branches may be divided into two groups, superficial and deep, which may be thus arranged:

Superficial

- Ascending
  - Occipitalis minor.
  - Auricularis magnus.
  - Superficialis colli.

- Descending
  - Supracleavicular
  - Supracleavicular.
  - Communicating.
  - Muscular.
  - Communicantes hypoglossi.
  - Phrenic.

Deep

- Internal
  - Communicating.

- External
  - Communicating.
  - Muscular.

The Superficial Branches of the Cervical Plexus. The Small Occipital Nerve (n. occipitalis minor) (Fig. 655).—The small occipital nerve arises from the second cervical nerve, sometimes also from the third; it curves round the dorsal border of the Sterno-mastoid, and ascends, running parallel to the dorsal border of the muscle, to the back part of the side of the head. Near the cranium it perforates the deep fascia, and is continued cephalad along the side of the head behind the ear, supplying the integument, and communicating with the occipitalis major, auricularis magnus, and with the dorsal auricular branch of the facial.

This nerve gives off an auricular branch, which supplies the integument of the upper and back part of the auricle, communicating with the mastoid branch of the auricularis magnus. The auricular branch is occasionally derived from the great occipital nerve. The occipitalis minor varies in size; it is occasionally double.

The Great Auricular Nerve (n. auricularis magnus) (Fig. 655).—The great auricular nerve is the largest of the ascending branches. It arises from the second and third cervical nerves, winds around the dorsal border of the Sterno-mastoid, and, after perforating the deep fascia, ascends upon that muscle beneath the Platysma to the parotid gland, where it divides into facial, auricular, and mastoid branches.

The Facial Branches pass across the parotid, and are distributed to the integument of the face over the parotid gland; others penetrate the substance of the gland and communicate with the facial nerve.

The Auricular Branches ascend to supply the integument of the back of the pinna, except at its upper part, communicating with the auricular branches of the facial and vagus nerves. A filament pierces the pinna to reach its outer surface, where it is distributed to the lobule and lower part of the concha.
The Mastoid Branch communicates with the occipitalis minor and the dorsal auricular branch of the facial, and is distributed to the integument behind the ear.

The Superficial Cervical Nerve or the Superficialis Colli (n. cutaneus colli) (Fig. 655).—The superficial cervical nerve or the superficialis colli arises from the second and third cervical nerves, turns around the dorsal border of the Sterno-mastoid about its middle, and, passing obliquely forward beneath the external jugular vein to the ventral border of the muscle, perforates the deep cervical fascia, and divides beneath the Platysma into two branches, which are distributed to the ventro-lateral parts of the neck.

The Ascending Branch or Branches (rami superiores) gives a filament which accompanies the external jugular vein; it then passes cephalad to the submaxillary region, and divides into branches, some of which form a plexus with the cervical branches of the facial nerve beneath the Platysma; others pierce that muscle and are distributed to the integument of the upper half of the neck, at its forepart, as high as the chin.
The Descending Branches (*rami inferiores*), usually represented by two or more filaments, pierce the Platysma, and are distributed to the integument of the side and front of the neck, as low as the sternum.

**The Descending or Supracleavicularch Branches (nn. *supraclavicales*)** (Fig. 655).— The descending or supraclavicular branches arise from the third and fourth cervical nerves; emerging beneath the dorsal border of the Sterno-mastoid, they descend in the dorsal triangle of the neck beneath the Platysma and deep cervical fascia. Near the clavicle they perforate the fascia and Platysma to become cutaneous, and are arranged, according to their position, into three groups.

The **Internal or Suprasternal Branches (nn. *supraclavicales anteriores*)** cross obliquely over the external jugular vein and the clavicular and sternal attachments of the Sterno-mastoid muscle, and supply the integument as far as the median line. They furnish one or two filaments to the sterno-clavicular joint.

The **Middle or Supracleaviocular Branches (nn. *supraclavicales medii*)** cross the clavicle, and supply the integument over the Pectoral and Deltoid muscles, communicating with the cutaneous branches of the upper intercostal nerves.
THE NERVE SYSTEM

The External or Supra-acromial Branches (nn. supraclaviculares posteriores) pass obliquely across the outer surface of the Trapezius and the acromion, and supply the integument of the upper and back part of the shoulder.

The Deep Branches of the Cervical Plexus (Fig. 656). Internal Series.
The Communicating Branches.—The communicating branches consist of several filaments which pass from the loop between the first and second cervical nerves ventrad of the atlas to the vagus, hypoglossal, and sympathetic; of branches from all four cervical nerves to the superior cervical ganglion of the sympathetic, together with a branch from the fourth to the fifth cervical.

Muscular Branches.—Muscular branches supply the Anterior recti and Rectus lateralis muscles; they proceed from the first cervical nerve, and from the loop formed between it and the second.

The Communicantes Hypoglossi (Fig. 656).—The communicantes hypoglossi consist usually of two filaments, one being derived from the second and the other from the third cervical. These filaments pass caudad on the outer side of the internal jugular vein, cross ventrad of the vein a little below the middle of the neck, and form a loop with the descendens hypoglossi ventrad of the sheath of the carotid vessels. Occasionally, the junction of these nerves takes place within the sheath.

The Phrenic or the Internal Respiratory Nerve of Bell (n. phrenicus) (Figs. 656 and 657).—The phrenic nerve arises chiefly from the fourth cervical nerve, with a few filaments from the third and a communicating branch from the fifth. It descends to the root of the neck, running obliquely across the front of the Scalenus anticus muscle, and beneath the Sterno-mastoid muscle, the posterior belly of the Omohyoid muscle, and the Transversalis colli and suprascapular vessels. It next passes over the first part of the subclavian artery, between it and the subclavian vein, and, as it enters the chest, crosses the internal mammary artery near its origin. Within the chest it descends nearly vertically ventrad of the root of the lung and by the side of the pericardium, between it and the mediastinal portion of the pleura, to the Diaphragm, where it divides into branches, some few of which are distributed to its thoracic surface, but most of which separately pierce that muscle and are distributed to its under surface (rami phrenicoabdominales). A ramus pericardicus is distributed to the pericardium. The two phrenic nerves differ in their length, and also in their relations at the upper part of the thorax.

The right phrenic nerve is situated more deeply, and is shorter and more vertical in direction than the left; it lies on the outer side of the right vena innominata and postcava.

The left phrenic nerve is farther longer than the right, from the inclination of the heart to the left side, and from the Diaphragm being lower on this than on the opposite side. It enters the thorax behind the left innominate vein, and crosses ventrad of the vagus and the arch of the aorta and the root of the lung. In the thorax each phrenic nerve is accompanied by a branch of the internal mammary artery, the comes nervi phrenici.

Each nerve supplies filaments to the Diaphragm, pericardium, and pleura, and near the chest is joined by a filament from the sympathetic, and, occasionally, by one from the union of the descendens hypoglossi with the spinal nerves; this filament is found, according to Swan, only on the left side. The phrenic frequently receives a filament from the nerve to the Subclavius muscle. Branches have been described as passing to the peritoneum.

From the right nerve one or two filaments pass to join in a small ganglion with phrenic branches of the solar plexus; and branches from this ganglion are distributed to the hepatic plexus, the adrenal gland, and postcava.

From the left nerve filaments pass to join the phrenic plexus of the sympathetic, but without any ganglionic enlargement.
Surgical Anatomy.—Irritation of the phrenic nerve causes hiccup and persistent cough. Bilateral paralysis of the phrenic causes death from paralysis of the Diaphragm. This form of death is seen by the surgeon in fracture-dislocation of the third cervical vertebra. Division of the phrenic on one side is not fatal, and is occasionally practised by the surgeon in removing a tumor of the neck. In Hearn's and Franklin's cases of removal of the vagus, the phrenic was also divided. Unilateral division of the phrenic nerve causes paralysis of the corresponding half of the Diaphragm, which is difficult of recognition, because, as Gowers points out, the patient can still take deep inspirations, the thoracic muscles not being paralyzed.

The Deep Branches of the Cervical Plexus. External Series. Communicating Branches.—The deep branches of the external series of the cervical plexus communicate with the accessory nerve, in the substance of the Sterno-mastoid muscle, in the dorsal triangle, and beneath the Trapezius.

Muscular Branches.—Muscular branches are distributed to the Sterno-mastoid, Trapezius, Levator anguli scapulae, and Scalenus medius. The branch for the Sterno-mastoid is derived from the second cervical; the Trapezius and Levator anguli scapulae receive branches from the third and fourth.
The Scalenus medius is derived sometimes from the third, sometimes the fourth, and occasionally from both nerves.

**Surgical Anatomy.**—The cervical plexus may be damaged by wounds or contusions, which may or may not be associated with fracture of the clavicle. Paralysis ensues, the extent depending on the degree of damage. After a contusion the paralysis is apt to be temporary and to be followed by pain and muscular spasm in the arm. Paralysis of the arm due to plexus injury may be partial or complete. In some cases there is complete motor palsy and partial sensor palsy, the sensor impulses passing along undamaged collaterals. In certain spasmatic difficulties the surgeon occasionally stretches the cervical plexus. It is reached by an incision at the dorsal margin of the Sternocleidomastoid muscle. This incision begins two inches below the level of the tip of the mastoid and is carried downward for three inches.

![Diagram of the Nerve System](image)

**The Brachial Plexus (Plexus Brachialis) (Figs. 658, 659, 660).**

The brachial plexus is formed by the union of the ventral divisions of the four lower cervical and the greater part of the first thoracic nerves, receiving usually a fasciculus from the fourth cervical nerve, and frequently one from the second thoracic nerve. It extends from the lower part of the side of the neck to the axilla. It is very broad, and presents little of a plexiform arrangement at its commencement. It is narrow opposite the clavicle, becomes broad and forms a more dense interlacement in the axilla, and divides opposite the coracoid process into numerous branches for the supply of the upper limb. The nerves which form the plexus are all similar in size, and their mode of communication is subject to considerable variation, so that no one plan can be given as applying to every case.¹ The follow-

¹ Kerr, Bardeen, and Elting, from a study of 175 brachial plexuses, recognized seven types. In 58 percent, the outer cord was formed from the fourth to the seventh, the inner cord from the eighth to the ninth spinal nerves, and the dorsal or posterior cord from the fourth to the ninth. In 30 percent, the outer cord was formed from the fifth to the seventh, the inner cord from the eighth to the ninth, and the dorsal cord from the fifth to the ninth.
ing appears, however, to be the most constant arrangement: above the clavicle (pars supraclavicularis) the fifth and sixth cervical unite soon after their exit

**Fig. 659.**—The right brachial plexus (infraclavicular portion) in the axillary fossa, viewed from below and in front. The pectoralis major and minor muscles have been in large part removed; their attachments have been reflected. (Spalteholz.)

**Fig. 660.**—Plan of the brachial plexus. (Gerrish.)
from the intervertebral foramina to form a common trunk. The eighth cervical and first thoracic also unite to form one trunk. So that the nerves forming the plexus, as they lie on the Scalenus medius ectad to the outer border of the Scalenus anticus muscle, are blended into three trunks—an upper one, formed by the junction of the fifth and sixth cervical nerves; a middle one, consisting of the seventh cervical nerve; and a lower one, formed by the junction of the eighth cervical and first thoracic nerves. As they pass beneath the clavicle, to compose the infraclavicular part of the plexus (pars infraclavicularis), each of
these three trunks divides into two branches, a ventral and a dorsal.¹ The ventral divisions of the upper and middle trunks then unite to form a common cord, which is situated on the outer side of the middle part of the axillary artery, and is called the outer cord of the brachial plexus (fasciculus lateralis). The ventral division of the lower trunk passes caudad on the inner side of the axillary artery in the middle of the axilla, and forms the inner cord of the brachial plexus (fasciculus medialis). The dorsal divisions of all three trunks unite to form the dorsal cord of the brachial plexus (fasciculus posterior), which is situated behind the second portion of the axillary artery. From this dorsal cord are given off the two lower subscapular nerves, the upper subscapular nerve being given off from the dorsal division of the upper trunk prior to its junction with the dorsal division of the lower and middle trunks. The dorsal cord divides into the circumflex and musculospiral nerves.

The brachial plexus communicates with the cervical plexus by a branch from the fourth to the fifth cervical nerve, and with the phrenic nerve by a branch from the fifth cervical, which joins that nerve on the Anterior scalenus muscle; the fifth and sixth cervical nerves are joined by filaments to the middle cervical ganglion of the sympathetic, the seventh and eighth cervical to its inferior ganglion, and the first thoracic nerve to its first thoracic ganglion. Close to their exit from the intervertebral foramina the nerves give off the filaments to the ganglia.

¹ The dorsal division of the lower trunk is very much smaller than the others, and is frequently derived entirely from the eighth cervical nerve.—Ed. of 15th English edition.
**Relations.**—In the neck, the brachial plexus lies in the posterior triangle, being covered by the skin, Platysma, and deep fascia; it is crossed by the posterior belly of the Omo-hyoid muscle and by the transversalis colli artery. When the dorsal scapular artery arises from the third part of the subclavian it usually passes between the roots of the plexus. The plexus lies at first between the Anterior and Middle scaleni muscles, and then above and to the outer side of the subclavian artery; it next passes behind the clavicle and Subclavius muscle, lying upon the first serration of the Serratus magnus, and the Subscapularis muscles. It is in close relation with the apex of the lung (Luschka). In the axilla it is placed on the outer side of the first portion of the axillary artery; it surrounds the artery in the second part of its course, one cord lying upon the outer side of that vessel, one on the inner side, and one behind it, and at the lower part of the axillary space gives off its terminal branches to the upper extremity.

**Branches.**—The branches of the brachial plexus are arranged in two groups—viz., those given off above the clavicle, and those below the clavicle.

**Branches above the Clavicle** (Figs. 658 and 660).—The branches above the clavicle, from the pars supracleavicularis, are—

- Communicating.
- Muscular.
- Long thoracice.
- Suprascapular.

**The Communicating Branch** (Figs. 657 and 660).—The communicating branch with the phrenic is derived from the fifth cervical nerve or from the loop between the fifth and sixth; it joins the phrenic on the Anterior scalenus muscle. The communications with the sympathetic have already been referred to.

**The Muscular Branches** (*rami musculares*).—The muscular branches supply the Longus colli, Scaleni, Rhomboidei, and Subclavius muscles. Those for the
Longus colli and Scaleni arise from the four lower cervical nerves at their exit from the intervertebral foramina. The Rhomboid branch, called the dorsal
scapular nerve (n. dorsalis scapulae) (Figs. 658 and 660), arises from the fifth cervical, pierces the Scaenus medius, and passes beneath the Levator anguli scapulae, which it occasionally supplies, to the Rhomboid muscles. The nerve to the Subclavius (n. subclavius) is a small filament which arises from the fifth cervical at its point of junction with the sixth nerve; it descends in front of the third part of the subclavian artery to the Subclavius muscle, and is usually connected by a filament with the phrenic nerve.

The Long Thoracic or the External Respiratory Nerve of Bell or Posterior Thoracic Nerve (n. thoracis longus) (Figs. 658, 659, 660, and 665).—The long thoracic supplies the Serratus magnus muscle, and is remarkable for the length of its course. It sometimes arises by two roots from the fifth and sixth cervical nerves immediately after their exit from the intervertebral foramina, but generally by three roots from the fifth, sixth, and seventh nerves. These unite in the substance of the Middle scalenus muscle, and, after emerging from it, the nerve passes caudad behind the brachial plexus and the axillary vessels, resting on the outer surface of the Serratus magnus. It extends along the side of the chest to the lower border of that muscle, supplying filaments to each of the muscular digitations.

The Suprascapular Nerve (n. suprascapularis) (Figs. 658, 660, and 665).—The suprascapular nerve arises from the cord formed by the fifth and sixth cervical nerves; passing obliquely outward beneath the Trapezius and the Omo-hyoid, it enters the suprascapular fossa below the transverse or suprascapular ligament, and, passing beneath the Supraspinatus muscle, curves around the external border of the spine of the scapula to the infraspinous fossa. In the suprasciposus fossa it gives off two branches to the Supraspinatus muscle, and an articular filament to the shoulder-joint; and in the infraspinous fossa it gives off two branches to the Infraspinatus muscle, besides some filaments to the shoulder-joint and scapula.

Branches below the Clavicle (Figs. 659 and 660).—The branches below the clavicle, that is, the branches from the pars subclavicularis of the brachial plexus, are derived from the three cords of the brachial plexus, in the following manner:

From the Outer Cord.—From the outer cord arise the external anterior thoracic nerve, the musculo-cutaneous, and the outer head of the median.

From the Inner Cord.—From the inner cord arise the internal anterior thoracic nerve, the medial nerve of the forearm or internal cutaneous, the medial nerve of the upper arm or lesser internal cutaneous (nerve of Wrisberg), the ulnar, and inner head of the median.

From the Dorsal Cord.—From the dorsal cord arise two of the three subscapular nerves, the third taking origin from the dorsal division of the trunk formed by the fifth and sixth cervical nerves; the cord then divides into the musculo-spiral and circumflex nerves.

These branches from below the clavicle may be arranged according to the parts they supply:

To the chest . . . . . . . . . . Anterior thoracic.

To the shoulder . . . . . . . . . .

To the arm, forearm, and hand . . . .

Anterior thoracic.

Subscapular.

Circumflex.

Musculo-cutaneous.

Internal cutaneous or medial nerve of the upper arm.

Lesser internal cutaneous or medial nerve of the forearm.

Median.

Ulnar.

Musculo-spiral.
The fasciculi of which these nerves are composed may be traced through the plexus to the spinal nerves from which they originate. They are as follows:

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Origin</th>
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<tbody>
<tr>
<td>External anterior thoracic from</td>
<td>5th, 6th, and 7th cervical.</td>
</tr>
<tr>
<td>Internal anterior thoracic</td>
<td>8th cervical and 1st thoracic.</td>
</tr>
<tr>
<td>Subscapular</td>
<td>5th, 6th, 7th, and 8th cervical.</td>
</tr>
<tr>
<td>Circumflex</td>
<td>5th and 6th cervical.</td>
</tr>
<tr>
<td>Musculo-cutaneous</td>
<td>5th and 6th cervical.</td>
</tr>
<tr>
<td>Internal cutaneous</td>
<td>8th cervical and 1st thoracic.</td>
</tr>
<tr>
<td>Lesser internal cutaneous</td>
<td>1st thoracic.</td>
</tr>
<tr>
<td>Median</td>
<td>6th, 7th, and 8th cervical, and 1st thoracic.</td>
</tr>
<tr>
<td>Ulnar</td>
<td>8th cervical and 1st thoracic.</td>
</tr>
<tr>
<td>Musculo-spiral</td>
<td>6th, 7th, and 8th cervical, sometimes also from the 5th.</td>
</tr>
</tbody>
</table>

**NOTE.**—In this the reconstructive period of anatomic nomenclature the terms "anterior" and "posterior" are yet retained in the description of the relations of structures in the extremities, for "ventral" and "dorsal" are not uniformly applicable in the same strict sense as in the trunk and neck regions. Further, the designations "in front of" and "behind" are applied only to the position of structures when the body is standing erect and with the volar surface of the hand turned "forward." The employment of the word "dorsum" for the back of the hand is already quite general.

**The Anterior Thoracic Nerves** *(nn. thoracales anteriores)* *(Figs. 658, 659, and 660).*—The anterior thoracic nerves, two in number, supply the Pectoral muscles.

The **External** or **Superficial Anterior Thoracic Nerve** *(Figs. 658 and 665)*, the larger of the two, *arises* from the outer cord of the brachial plexus, through which its fibres may be traced to the fifth, sixth, and seventh cervical nerves. It passes inward, across the axillary artery and vein, pierces the costo-coracoid membrane, and is distributed to the under surface of the Pectoralis major muscle. It sends caudal a communicating filament to join the internal anterior thoracic nerve, and this communicating filament forms a loop around the inner side of the axillary artery.

The **Internal** or **Deep Anterior Thoracic Nerve** *arises* from the inner cord and through it from the eighth cervical and first thoracic nerves. It passes behind the first part of the axillary artery, then curves forward between the axillary artery and vein, and joins with the filament from the anterior nerve. It then passes to the under surface of the Pectoralis minor muscle, where it divides into a number of branches, which supply the muscle on its under surface. Some two or three branches pass through the muscle and reach the Pectoralis major.

The **Subscapular Nerves** *(nn. subscapulares)* *(Figs. 659 and 660).*—The subscapular nerves *arise* from the dorsal cord of the plexus. There are three subscapular nerves, and they supply the Subscapularis, Teres major, and Latissimus dorsi muscles, and give filaments to the shoulder-joint. The fasciculi of which they are composed may be traced to the fifth, sixth, seventh, and eighth cervical nerves.

The **First, Short, or Upper Subscapular Nerve**, the smallest, *arises* from the dorsal division of the upper trunk of origin of the brachial plexus, and enters the upper part of the Subscapularis muscle; this nerve is frequently represented by two branches.

The **Second or Lower Subscapular Nerve** *arises* from the dorsal cord of the brachial plexus, enters the axillary border of the Subscapularis and terminates in the Teres major. The latter muscle is sometimes supplied by a separate branch.
The Third, Middle or Long Subscapular Nerve (n. thoracodorsalis) (Fig. 659), the largest of the three, arises from the dorsal cord of the brachial plexus and follows the course of the subscapular artery, along the dorsal wall of the axilla to the Latissimus dorsi muscle, through which it may be traced as far as its lower border.

The Circumflex Nerve (n. axillaris) (Figs. 660 and 666).—The circumflex nerve supplies some of the muscles, the shoulder-joint, and the integument of the shoulder (Figs. 661 and 662). It arises from the dorsal cord of the brachial plexus, in common with the musculo-spiral nerve, and its fibres may be traced through the dorsal cord to the fifth and sixth cervical nerves. It is at first placed behind the axillary artery, between it and the Subscapularis muscle, and passes caudad and outward to the lower border of that muscle. It then winds dorsal in company with the posterior circumflex artery, through a quadrilateral space bounded above by the Teres minor muscle, below by the Teres major muscle, internally by the long head of the Triceps muscle, and externally by the neck of the humerus. The nerve then divides into two branches.

The Upper Branch (Fig. 666) winds dorsad around the surgical neck of the humerus, beneath the Deltoid, with the posterior circumflex vessels, as far as the anterior border of that muscle, supplying it, and giving off cutaneous branches, which pierce the muscle and ramify in the integument covering its lower part (Fig. 663).

The Lower Branch (Fig. 666), at its origin, distributes filaments to the Teres minor and back part of the Deltoid muscles. Upon the filaments to the former muscle an oval enlargement usually exists. The nerve then pierces the deep fascia, and supplies the integument over the lower two-thirds of the posterior surface of the Deltoid (n. cutaneus brachii lateralis), as well as that covering the long head of the Triceps (caput longum n. tricipitis brachii) (Fig. 664).

The circumflex nerve, before its division, gives off an articular filament, which enters the shoulder-joint below the Subscapularis muscle.

The Musculo-cutaneous or the External Cutaneous Nerve or the Perforating Nerve of Casserius¹ (n. musculocutaneus) (Figs. 659, 660, and 665).—The musculo-cutaneous or the external cutaneous nerve supplies some of the muscles of the arm and the integument of the forearm. It arises from the outer cord of the brachial plexus, opposite the lower border of the Pectoralis minor muscle, receiving filaments from the fifth, sixth, and seventh cervical nerves. It perforates the coraco-brachialis muscle (Fig. 665), passes obliquely between the Biceps and Brachialis anticus muscles to the outer side of the arm, and, a little above the elbow, winds around the outer border of the tendon of the Biceps, and, perforating the deep fascia, becomes cutaneous (Fig. 661). This nerve, in its course through the arm, supplies the Coraco-brachialis, Biceps, and the greater part of the Brachialis anticus muscles. The branch to the Coraco-brachialis is given off from the nerve close to its origin, and in some instances, as a separate filament from the outer cord of the plexus. The branches to the Biceps and Brachialis anticus are given off after the nerve has pierced the Coraco-brachialis. The nerve also sends a small branch to the humerus, which enters the nutrient foramen with the accompanying artery, and a filament from the branch supplying the Brachialis anticus, goes to the elbow-joint. The musculo-cutaneous furnishes the chief nerve supply to this joint.

The Cutaneous Portion of the Musculo-cutaneous Nerve (n. cutaneus antibrachii lateralis) passes behind the median cephalic vein, and divides, opposite the elbow-joint, into an anterior and a posterior branch.

The anterior branch descends along the radial border of the forearm to the wrist, and supplies the integument over the outer half of the anterior surface. At

¹ See foot-note, page 1042.
THE BRACHIAL PLEXUS

the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the dorsum of the wrist, supplying the carpus. The nerve then passes distal to the ball of the thumb, where it terminates in cutaneous filaments. It communicates with a branch from the radial nerve and with the palmar cutaneous branch of the median.

The posterior branch passes distal along the back part of the radial side of the forearm to the wrist. It supplies the integument of the lower third of the forearm, communicating with the radial nerve and the external cutaneous branch of the musculo-spiral. The cutaneous areas supplied by the musculo-cutaneous nerve are indicated in Figs. 663 and 664.

The musculo-cutaneous nerve presents frequent irregularities. It may adhere for some distance to the median and then pass outward, beneath the Biceps, instead of through the Coraco-brachialis. Frequently some of the fibres of the median run for some distance in the musculo-cutaneous and then leave it to join their proper trunk. Less frequently the reverse is the case, and the median sends a branch to joint the musculo-cutaneous. Instead of piercing the Coraco-brachialis muscle the nerve may pass under it or through the Biceps. Occasionally it gives a filament to the Pronator radii teres muscle, and it has been seen to supply the back of the thumb when the radial nerve was absent.

The Internal Cutaneous Nerve (n. cutaneus antibrachii medialis) (Figs. 659, 660, and 663).—The internal cutaneous nerve or medial cutaneous nerve of the forearm is one of the smallest branches of the brachial plexus. It arises from the inner cord in common with the ulnar nerve and internal head of the median nerve, and, at its commencement, is placed on the inner side of the axillary artery, and afterward of the brachial artery. It derives its fibres from the eighth cervical and first thoracic nerves. It passes down the inner side of the arm, pierces the deep fascia with the basilic vein, about the middle of the limb, and, becoming cutaneous, divides into two branches, anterior and posterior.

This nerve gives off, near the axilla, a cutaneous filament, which pierces the fascia and supplies the integument covering the Biceps muscle nearly as far as the elbow. This filament lies a little external to the common trunk, from which it arises.

The anterior branch, the larger of the two, passes usually in front of, but occasionally behind, the median basilic vein. It then descends on the anterior surface of the ulnar side of the forearm, distributing filaments to the integument as far as the wrist, and communicating with a cutaneous branch of the ulnar nerve (Fig. 661).

The posterior branch passes obliquely distal on the inner side of the basilic vein, passes in front of, or over, the internal condyle of the humerus to the back of the forearm, and descends on the posterior surface of its ulnar side as far as the wrist, distributing filaments to the integument (Fig. 662). It communicates, above the elbow, with the lesser internal cutaneous nerve, and above the wrist with the dorsal cutaneous branch of the ulnar nerve (Swan). The cutaneous areas supplied by the internal cutaneous nerve are indicated in Figs. 663 and 664.

The Lesser Internal Cutaneous Nerve or the Nerve of Wrisberg (n. cutaneus brachii medialis) (Figs. 659, 660, and 665).—The lesser internal cutaneous nerve or medial cutaneous nerve of the upper arm is distributed to the integument on the inner side of the arm. It is the smallest of the branches of the brachial plexus, and, arising from the inner cord, receives its fibres from the first thoracic nerve. It passes through the axillary space, at first lying behind, and then on the inner side of the axillary vein, and communicates with the intercosto-brachial nerve. It descends along the inner side of the brachial artery to the middle of the arm, where it pierces the deep fascia, and is distributed to the integument of the back of the lower third of the arm, extending as far as the elbow (Figs. 661, 662, and
663), where some filaments are lost in the integument ventrad of the inner condyle, and others over the olecranon. It communicates with the posterior branch of the internal cutaneous nerve.

In some cases the nerve of Wrisberg and the intercosto-brachial or intercosto-humeral nerve are connected by two or three filaments which form a plexus at the back part of the axilla. In other cases the intercosto-brachial is of large size, and takes the place of the nerve of Wrisberg, receiving merely a filament of communication from the brachial plexus, which filament represents the latter nerve. In other cases this filament is wanting, the place of the nerve of Wrisberg being supplied entirely by the intercosto-brachial.

The Median Nerve (n. medianus) (Figs. 659, 660, and 665).—The median nerve has received its name from the course it takes along the middle of the arm and forearm to the hand, lying between the ulnar and musculo-spiral nerves, and the ulnar and the radial nerves. It arises by two roots, one from the outer and one from the inner cord of the brachial plexus; these embrace the lower part of the axillary artery, uniting either in front or on the outer side of that vessel. The median nerve receives filaments from the sixth, seventh, and eighth cervical and the first thoracic nerves and sometimes from the fifth cervical as well. As it descends through the arm, it lies at first on the outer side of the brachial artery, crosses that vessel in the middle of its course, usually in front, but occasionally behind it, and lies on its inner side to the bend of the elbow, where it is placed beneath the bicipital fascia, and is separated from the elbow-joint by the Brachialis anticus muscle. In the forearm it passes between the two heads of the Pronator radii teres muscle, and descends beneath the Flexor sublimis muscle, lying on the Flexor profundus muscle, to within two inches (3 cm.) above the annular ligament, where it becomes more superficial, lying between the tendons of the Flexor sublimis and Flexor carpi radialis muscles, beneath, and rather to the radial side or under the tendon of the Palmaris longus, covered by the integument and fascia. It then passes through the carpal canal (canalis carpi) beneath the annular ligament into the hand. In its course through the forearm it is accompanied by the arteria comnis nervi mediani, a branch of the anterior interosseous artery.

Branches.—With the exception of the nerve to the Pronator radii teres muscle, which sometimes arises above the elbow-joint, and filaments to the elbow-joint, the median nerve gives off no branches in the arm. In the forearm its branches are muscular, anterior interosseous, and palmar cutaneous, and two articular twigs to the elbow-joint.

The Muscular Branches (rami musculares) supply all the superficial muscles on the front of the forearm except the Flexor carpi ulnaris. These branches are derived from the nerve near the elbow.

The Volar Interosseous or Anterior Interosseous (n. interosseus [antibrachii] volaris) (Fig. 665) supplies the deep muscles on the front of the forearm, except the inner half of the Flexor profundus digitorum. It accompanies the volar interosseous artery along the interosseous membrane, in the interval between the Flexor longus pollicis and Flexor profundus digitorum muscles, both of which it supplies, and terminates below in the Pronator quadratus muscle, sending filaments to the inferior radio-ulnar articulation and the wrist-joint.

The Palmar Cutaneous Branch (ramus cutaneus palmaris n. mediani) arises from the median nerve at the lower part of the forearm. It pierces the fascia above the annular ligament, and, descending over that ligament, divides into two branches; of which the outer branch supplies the skin over the ball of the thumb, and communicates with the anterior cutaneous branch of the musculo-cutaneous nerve; and the inner branch supplies the integument of the palm of the hand, communicating with the cutaneous branch of the ulnar.

In the palm of the hand the median nerve is covered by the integument and palmar fascia and is crossed by the superficial palmar arch. It rests upon the
tendons of the flexor muscles. In this situation it becomes enlarged, somewhat flattened, of a reddish color, and divides into two branches. Of these, the **external branch** supplies a muscular branch to some of the muscles of the thumb and digital branches to the thumb and index finger; the **internal branch** supplies digital branches to the contiguous sides of the index and middle and of the middle and ring fingers. The digital branches, before they subdivide, are called **common palmar digital branches of the median nerve** (nn. digitales volares communes).

The branch to the muscles of the thumb (ramus muscularis) is a short nerve which divides to supply the Abductor, Opponens, and the superficial head of the Flexor brevis pollicis muscles, the remaining muscles of this group being supplied by the ulnar nerve.

The **Collateral Palmar Digital** or the **Digital Branches** (nn. digitales volares proprii) are five in number. The **first** and **second** pass along the borders of the thumb, the external branch communicating with branches of the radial nerve. The **third** passes along the radial side of the index finger, and supplies the First lumbricalis muscle. The **fourth** subdivides to supply the adjacent sides of the index and middle fingers, and sends a branch to the Second lumbricalis muscle. The **fifth** supplies the adjacent sides of the middle and ring fingers, and communicates with a branch from the ulnar nerve.

Each digital nerve, opposite the base of the first phalanx, gives off a dorsal branch, which joins the dorsal digital nerve from the radial nerve and runs along the side of the dorsum of the finger, to end in the integument over the last phalanx. At the end of the finger the digital nerve divides into a palmar and a dorsal branch, the former of which supplies the extremity of the finger, and the latter ramifies around and beneath the nail. The digital nerves, as they run along the fingers, are placed superficial to the digital arteries. The cutaneous areas supplied by the median nerve are shown in Figs. 663 and 664.

**The Ulnar Nerve** (n. ulnaris) (Figs. 659, 660, and 665).—The ulnar nerve is placed along the inner or ulnar side of the upper limb, and is distributed to the muscles and integument of the forearm and hand. It is smaller than the median, behind which it is placed, diverging from it in its course down the arm. It **arises** from the inner cord of the brachial plexus, in common with the inner head of the median and the internal cutaneous nerve, and derives its fibres from the eighth cervical and first thoracic nerves. At its commencement it lies to the inner side of the axillary artery, and holds the same relation with the brachial artery to the middle of the arm. From this point it runs obliquely across the internal head of the Triceps, pierces the internal intermuscular septum, and descends to the groove between the internal condyle and the olecranon, accompanied by the inferior profunda artery. **At the elbow** it rests upon the back of the inner condyle, and passes into the forearm between the two heads of the Flexor carpi ulnaris muscle. **In the forearm** it descends in a perfectly straight course along the ulnar side of the extremity, lying upon the Flexor profundus digitorum muscle, its upper half being covered by the Flexor carpi ulnaris muscle, its lower half lying on the outer side of the muscle, being covered by the integument and fascia. The ulnar artery, in the upper third of its course, is separated from the ulnar nerve by a considerable interval, but in the rest of its extent the nerve lies to its inner side. **At the wrist** the ulnar nerve crosses the annular ligament on the outer side of the pisiform bone, to the inner side of and a little behind the ulnar artery, and immediately beyond this bone divides into two branches, the superficial and the deep palmar.

**Branches.**—The branches of the ulnar nerve are—

In the forearm

- Articular.
- Muscular.
- Cutaneous.
- Dorsal cutaneous.

In the hand

- Superficial palmar.
- Deep palmar.
The **Articular Branches** distributed to the elbow-joint consist of several small filaments. They arise from the nerve as it lies in the groove between the inner condyle of the humerus and the olecranon process of the ulnar.

The **Muscular Branches** (*rami musculares*) are two in number—one supplying the Flexor carpi ulnaris; the other, the inner half of the Flexor profundus digitorum. They arise from the trunk of the nerve near the elbow.

The **Cutaneous Branch** arises from the ulnar nerve about the middle of the forearm, and divides into two branches.

One branch (frequently absent) pierces the deep fascia near the wrist, and is distributed to the integument, communicating with a branch of the internal cutaneous nerve.

The second branch, the **palmar cutaneous** (*ramus cutaneus palmaris*) lies on the ulnar artery, which it accompanies to the hand, some filaments entwining around the vessel; it ends in the integument of the palm, communicating with branches of the median nerve.

The **Dorsal Cutaneous Branch** (*ramus dorsalis manus*) arises about two inches above the wrist; it passes dorsal beneath the Flexor carpi ulnaris muscle, perforates the deep fascia, and, running along the ulnar side of the back of the wrist and hand, divides into branches (*nn. digitales dorsales*); one of these supplies the inner side of the little finger; a second supplies the adjacent sides of the little and ring fingers; a third joins the branch of the radial nerve which supplies the adjoining sides of the middle and ring fingers, and assists in supplying these parts; a fourth is distributed to the metacarpal region of the hand, communicating with a branch of the radial nerve.

On the little finger the dorsal digital branches extend only as far as the base of the terminal phalanx, and on the ring finger as far as the base of the second phalanx; the more distal parts of these digits are supplied by dorsal branches derived from the palmar digital branches of the ulnar.

The **Superficial Palmar Branch** (*ramus superficialis n. ulnaris*) supplies the Palmaris brevis and the integument on the inner side of the hand, and terminates in two digital branches, which are distributed, one to the ulnar side of the little finger, the other to the adjoining sides of the little and ring fingers, the latter communicating with a branch from the median. The digital branches are distributed to the fingers in the same manner as the digital branches of the median.

The **Deep Palmar Branch** (*ramus profundus n. ulnaris*), accompanied by the deep branch of the ulnar artery, passes between the Adductor and Flexor brevis minimi digitii muscles; it then perforates the Opponens minimi digitii and follows the course of the deep palmar arch beneath the flexor tendons. At its origin it supplies the muscles of the little finger. As it crosses the deep part of the hand it sends two branches to each intersosseous space, one for the Dorsal and one for the Palmar intersosseous muscle, the branches to the Second and Third palmar intersosseal supplying filaments to the two inner Lumbrical muscles. At its termination between the thumb and index finger, it supplies the Adductores transversus et obliquus pollicis and the inner head of the Flexor brevis pollicis. It also sends articular filaments to the wrist-joint, and to the bones and joints of the hand.

It will be remembered that the inner part of the Flexor profundus digitorum muscle is supplied by the ulnar nerve; the two inner Lumbricales, which are connected with the tendons of this part of the muscle, are therefore supplied by the same nerve. The outer part of the Flexor profundus is supplied by the median nerve; the two outer Lumbricales, which are connected with the tendons of this part of the muscles, are therefore supplied by the same nerve. Brooks states that in twelve instances out of twenty-one he found that the third lumbrical received a twig from the median nerve, in addition to its branch from the ulnar. The palmar branches of the ulnar which go to the fingers are called by
Toldt before division common palmar digital branches, and after division collateral palmar digital branches. The cutaneous areas supplied by the ulnar nerve are shown in Figs. 663 and 664.

The Musculo-spiral Nerve (n. radiolus) (Figs. 660, 665, and 666).—The musculospiral nerve, the largest branch of the brachial plexus, supplies the muscles of the back part of the arm and forearm, and the integument of the same parts, as well as that of the back of the hand (Figs. 663 and 664). It arises from the posterior cord of the brachial plexus, of which it may be regarded as the continuation. It receives filaments from the sixth, seventh, and eighth, and sometimes also from the fifth cervical and first thoracic nerves. At its commencement it is placed behind the axillary artery and the upper part of the brachial artery, passing down in front of the tendons of the Latissimus dorsi and Teres major muscles. It winds around the humerus in the musculo-spiral groove with the superior profunda artery, passing from the inner to the outer side of the bone, between the internal and external heads of the Triceps muscle (Fig. 666). It pierces the external intermuscular septum, and descends between the Brachialis anticus and Supinator longus muscles to the front of the external condyle of the humerus, where it sends filaments to the elbow-joint and divides into the radial and posterior interosseous nerves.

Branches.—The branches of the musculo-spiral nerve are—


Cutaneous.

The Muscular Branches (rami musculares n. radialis) are divided into internal, posterior, and external; they supply the Triceps, Aneoneus, Supinator longus, Extensor carpi radialis longior, and Brachialis anticus muscles. These branches are derived from the nerve at the inner side, back part, and outer side of the arm.
The **internal muscular branches** supply the inner and middle heads of the Triceps muscle. That to the inner head of the Triceps is a long, slender filament which lies close to the ulnar nerve, as far as the lower third of the arm, and is therefore frequently spoken of as the **ulnar collateral branch**.

The **posterior muscular branch**, of large size, arises from the nerve in the groove between the Triceps muscle and the humerus. It divides into branches which supply the outer and inner heads of the Triceps and the Anconeus muscles. The branch for the latter muscle is a long, slender filament which descends in the substance of the Triceps to the Anconeus.

The **external muscular branches** supply the Supinator longus, Extensor carpi radialis longior, and (usually) the outer part of the Brachialis anticus muscles.

The **Cutaneous Branches** are three in number, one **internal** and two **external**.

The **internal cutaneous branch** (n. cutaneus brachii posterior) arises in the axillary space with the inner muscular branch. It is of small size, and passes through the axilla to the inner side of the arm, supplying the integument on its posterior aspect nearly as far as the olecranon. In its course it crosses beneath the intercosto-brachial nerve, with which it communicates.

The **external cutaneous branch** (n. cutaneus antibrachii dorsalis) divides into two branches, and each one perforates the outer head of the Triceps muscle at its attachment to the humerus. The **upper** and smaller one passes to the front of the elbow, lying close to the cephalic vein, and supplies the integument of the lower half of the arm on its anterior aspect. The **lower branch** pierces the deep fascia below the insertion of the Deltoid muscle, and passes down along the outer side of the arm and elbow, and then along the back part of the radial side of the forearm to the wrist, supplying the integument in its course, and joining, near its termination, with the posterior cutaneous branch of the musculo-cutaneous nerve.

The **Radial Nerve** (ramus superficialis n. radialis) (Fig. 665), passes along the front of the radial side of the forearm to the commencement of its lower third. It lies at first a little to the outer side of the radial artery, concealed beneath the Supinator longus muscle. In the middle third of the forearm it lies beneath the same muscle, in close relation with the outer side of the artery. It leaves the artery about three inches above the wrist, passes beneath the tendon of the Supinator longus muscle, and, piercing the deep fascia at the outer border of the forearm, divides into two branches.

The **external branch**, the smaller of the two, supplies the integument of the radial side and ball of the thumb, joining with the anterior branch of the musculo-cutaneous nerve.

The **internal branch** communicates, above the wrist, with the posterior cutaneous branch from the musculo-cutaneous, and on the back of the hand forms an arch with the dorsal cutaneous branch of the ulnar nerve. It then divides into four **digital nerves** (nn. digitales dorsales), which are distributed as follows: The first supplies the ulnar side of the thumb; the second, the radial side of the index finger; the third, the adjoining sides of the index and middle fingers; and the fourth, the adjacent borders of the middle and ring fingers.¹ The latter nerve communicates with a filament from the dorsal branch of the ulnar nerve.

The **Dorsal or Posterior Interosseous Nerve** (n. interosseus [antibrachii]dorsalis) (Figs. 665 and 666).—The dorsal interosseous nerve winds to the back of the forearm around the outer side of the radius, passes between the two planes of fibres of the Supinator brevis muscle, and is prolonged distad between the superficial and deep layer of muscles, to the middle of the forearm. Considerably diminished in size, it descends on the interosseous membrane, beneath the Extensor longus pollicis muscle, to the back of the carpus, where it presents a gangliform

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¹ According to Hutchinson, the digital nerve to the thumb reaches only as high as the root of the nail; the one to the forefinger as high as the middle of the second phalanx, and the one to the middle and ring fingers not higher than the first phalangeal joint (London Hospital Gazette, vol. iii, p. 319).—En. 18th English edition.
enlargement from which filaments are distributed to the inferior radio-ulnar articulation, to the wrist-joint, and to the ligaments and articulations of the carpus. It supplies all the muscles of the radial and posterior brachial regions, excepting the Anconeus, Supinator longus, and Extensor carpi radialis longior.

**Surgical Anatomy.**—The brachial plexus may be ruptured by traction on the limb, leading to complete paralysis. Bristow has reported three cases of avulsion of the plexus and has described twenty-four cases. In these cases it is generally believed that the lesion is rather a tearing away of the nerves from the spinal cord than a solution of continuity of the nerve-fibres themselves. In a case operated upon by Bristow it was found that the plexus had given way where the four cervical nerves and the first thoracic nerve unite to form three trunks. In supraclavicular division of the brachial plexus, not only will there be motor and sensor paralysis in the limb, but the Serratus magnus muscle will probably be paralyzed, because of injury to the dorsal thoracic nerves. In the axilla any of the nerves forming the brachial plexus may be injured by a wound of this part, the median being the one which is most frequently damaged from its exposed position. The musculo-spiral, on account of its sheltered and deep position, is least often wounded. The brachial plexus in the axilla is often damaged from the pressure of a crutch, producing the condition known as *crutch paralysis*. In these cases the musculo-spiral is the nerve most frequently implicated; the ulnar nerve being the one that appears to suffer next in frequency.

The *circumflex nerve* is of particular surgical interest. On account of its course around the surgical neck of the humerus, it is liable to be torn in fractures of this part of the bone, and in dislocations of the shoulder-joint, leading to paralysis of the deltoid, and, according to Erb, inflammation of the shoulder-joint is liable to be followed by a neuritis of this nerve from extension of the inflammation to it.

Mr. Hilton takes the circumflex nerve as an illustration of a law which he lays down, that “the same trunks of nerves whose branches supply the groups of muscles moving a joint furnish also a distribution of nerves to the skin over the insertions of the same muscles, and the interior of the joint receives its nerves from the same source.” In this way he explains the fact that an inflamed joint becomes rigid, because the same nerves which supply the interior of the joint supply the muscles which move that joint.

The *median nerve* is liable to injury in wounds of the forearm. When paralyzed, there is loss of flexion of the second phalanges of all the fingers and of the terminal phalanges of the index and middle fingers. Flexion of the terminal phalanges of the ring and middle fingers can still be effected by that portion of the Flexor profundus digitorum which is supplied by the ulnar nerve. There is power to flex the proximal phalanges through the Interossei. The thumb cannot be flexed or opposed, and is maintained in a position of extension and adduction. All power of pronation is lost. The wrist can be flexed, if the hand is first adducted, by the action of the Flexor carpi ulnaris. There is loss or impairment of sensation on the palmar surface of the thumb, index, middle, and outer half of the ring fingers, and on the dorsal surface of the same fingers over the last two phalanges; except in the thumb, where the loss of sensation is limited to the back of the last phalanx. In order to expose the median nerve for the purpose of *stretching* it an incision should be made along the radial side of the tendon of the Palmaris longus muscle, which serves as a guide to the nerve.

The *ulnar nerve* is liable to be injured in wounds of the forearm. When paralyzed, there is loss of power of flexion in the ring and little fingers; there is impaired power of ulnar flexion and adduction of the hand; there is inability to spread out the fingers from paralysis of the Interossei; and there is inability to adduct the thumb. The fingers cannot be flexed at the first joints, and cannot be extended at the other joints. A *claw-hand* develops, the first phalanges being overextended and the others flexed. Sensation is lost or impaired in the skin of the ulnar side of the hand anteriorly and posteriorly, involving the little finger, the ring finger, and the ulnar half of the middle finger posteriorly, and anteriorly involving the little finger and the ulnar half of the ring finger. In order to expose the nerve in the lower part of the forearm, an incision should be made along the outer border of the tendon of the Flexor carpi ulnaris, and the nerve will be found lying on the ulnar side of the ulnar artery.

The *musculo-spiral nerve* is probably more frequently injured than any other nerve of the upper extremity. In consequence of its close relationship to the humerus as it lies in the musculo-spiral groove, it is frequently torn or injured in fractures of this bone, or subsequently involved in the callus that may be thrown out around a fracture, and thus pressed upon and its functions interfered with. It is also liable to be squeezed against the bone by kicks or blows and it may be divided by wounds of the arm. When paralyzed, the hand is flexed at the wrist and lies flaccid. This condition is known as *drop-wrist*. The fingers are also flexed, and on an attempt being made to extend them the last two phalanges only will be extended through the action of the Interossei, the first phalanges remaining flexed. There is no power of extending the wrist. Supination is completely lost when the forearm is extended on the arm, but is.

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1 Annals of Surgery, September, 1902.
possible to a certain extent if the forearm is flexed so as to allow of the action of the Biceps. The power of extension of the forearm is lost on account of paralysis of the Triceps. Loss of sensation may be considerable or slight. Its area is shown in Fig. 664. The best position in which to expose the nerve for the purpose of stretching is to make an incision along the inner border of the Supinator longus muscle, just above the level of the elbow-joint. The skin and superficial structures are to be divided and the deep fascia exposed. The white line in this structure indicating the border of the muscle is to be defined, and the deep fascia divided in this line. By now raising the Supinator longus the nerve will be found lying beneath it, on the Brachialis anticus muscle.

Post-anesthetic paralysis. When a person emerges from the influence of a general anesthetic palsy of the arm may be found to exist. The brachial plexus may have been compressed during the operation by drawing the arm strongly from the body or elevating it by the side of the head. In such a case the plexus was compressed by the head of the humerus (Braun).

The median nerve is stretched when the arm is rotated externally and drawn backward and outward. The ulnar nerve is stretched when the forearm is flexed and supinated (Braun). Garrigues believes that in most cases of post-anesthetic paralysis the brachial plexus was squeezed between the collar bone and the first rib by the head of the patient being drawn to the opposite side or being allowed to fall back.

THE THORACIC NERVES (NN. THORACALES).

The thoracic nerves are twelve in number on each side. The first appears between the first and second thoracic vertebrae, and the last between the last thoracic and first lumbar.

The Roots of the Thoracic Nerves.

The roots of the thoracic nerves are of small size, and vary but slightly from the second to the last. Both roots are very slender, the dorsal roots slightly exceeding the ventral in thickness. They gradually increase in length from above downward, and in the lower part of the thoracic region pass down in contact with the spinal cord for a distance equal to the height of at least two vertebrae, before they emerge from the vertebral canal. They then join in the intervertebral foramen, and at their exit divide into two primary divisions, a dorsal (posterior) and a ventral (intercostal).

The Dorsal Divisions of the Thoracic Nerves (Rami Posteriores).

The dorsal divisions of the thoracic nerves are smaller than the ventral, pass dorsal between the transverse processes, and divide into medial or internal and lateral or external branches.

The Medial Branches.—The medial branches of the six upper nerves pass inward between the Semispinalis dorsi and Multifidius spine muscles, which they supply, and then, piercing the origins of the Rhomboidei and Trapezius muscles, become cutaneous by the side of the spinous processes and ramify in the integument. The medial branches of the six lower nerves are distributed to the Multifidus spine, without giving off any cutaneous filaments.

The Lateral Branches.—The lateral branches increase in size from above caudal. They pass through the Longissimus dorsi muscle to the cellular interval between it and the Iliocostalis muscle, and supply those muscles, as well as their continuations cephalad to the head, and also the Levatores costarum muscles; the five or six lower nerves also give off cutaneous filaments, which pierce the Serratus posticus inferior and Latissimus dorsi muscles in a line with the angles of the ribs, and then ramify in the integument.

The Cutaneous Branches.—The cutaneous branches of the dorsal primary divisions of the thoracic nerves are twelve in number. From each ramus medialis of the upper six nerves comes a ramus cutaneus medialis, and from each ramus
lateralis of the lower six nerves comes a ramus cutaneus lateralis. The six upper cutaneous nerves are derived from the medial branches of the dorsal divisions of the thoracic nerves. They pierce the origins of the Rhomboidei and Trapezius muscles, and become cutaneous by the side of the spinous processes, and then ramify in the integument. They are frequently furnished with gangliform enlargements. The six lower cutaneous nerves are derived from the lateral branches of the dorsal divisions of the thoracic nerves. They pierce the Serratus posticus inferior and Latissimus dorsi muscles in a line with the angles of the ribs, and then ramify in the integument.

The Ventral Divisions of the Thoracic Nerves or the Intercostal Nerves (Rami Anteriores).

The ventral divisions of the thoracic nerves or the intercostal nerves (nn. intercostales) are twelve in number on each side. They are, for the most part, distributed to the parietes of the thorax and abdomen, separately from each other, without being joined in a plexus; in which respect they differ from the other spinal nerves. Each nerve is connected with the adjoining ganglion of the sympathetic by one or two filaments (ramus communicans). The intercostal nerves may be divided into two sets, from the difference they present in their distribution. The six upper, with the exception of the first and the intercosto-brachial branch of the second, are limited in their distribution to the parietes of the chest. The six lower supply the parietes of the chest and abdomen, the last one sending a cutaneous filament to the buttock.

The Ventral Division of the First Thoracic Nerve.—The ventral division of the first thoracic nerve divides into two branches: one, the larger, leaves the thorax ventrad of the neck of the first rib, and enters into the formation of the brachial plexus; the other and smaller branch runs along the first intercostal space, forming the first intercostal nerve (n. intercostalis I), giving off muscular branches, and terminates on ventral part of the chest by forming the first ventral cutaneous nerve (ramus cutaneus anterior n. intercostalis I) of the thorax. Occasionally this ventral cutaneous branch is wanting. The first intercostal nerve, as a rule, gives off no lateral cutaneous branch, but sometimes a small branch is given off which communicates with the intercosto-brachial. It frequently receives a connecting twig from the second thoracic nerve, which passes upward over the neck of the second rib.

The Ventral Divisions of the Upper Thoracic Nerves (nn. intercostales).

—The ventral divisions of the second, third, fourth, fifth, and sixth thoracic nerves and the small branch from the first thoracic are confined to the parietes of the thorax, and are named upper or pectoral intercostal nerves. They pass forward in the intercostal spaces with the intercostal vessels, being situated below them. At the back of the chest they lie between the pleura and the External intercostal muscle, but are soon placed between the two planes of Intercostal muscles as far as the middle of the rib. They then enter the substance of the Internal intercostal muscles, and, running amidst their fibres as far as the costal cartilages, they gain the inner surface of the muscles and lie between them and the pleura. Near the sternum, they cross ventrad of the internal mammary artery and Triangularis sterni muscle, pierce the Internal intercostal muscles, the anterior intercostal membrane, and Pectoralis major muscle, and supply the integument of ventral wall of the chest and over the mammary gland, forming the ventral cutaneous nerves of the thorax; the branch from the second nerve is joined with the suprACLAVICULAR nerves of the cervical plexus.

Branches.—Numerous slender muscular filaments (rami musculares) supply the Intercostals, the InfraCostales, the Levatores costarum, Serratus posticus superior,
and Triangularis sterni muscles. Some of these branches, in the ventral wall of the chest, cross the costal cartilages from one to another intercostal space.

**Lateral Cutaneous Nerves of the Thorax** (*rami cutanei laterales* [*pectorales]*) (Fig. 659).—These are derived from the intercostal nerves, midway between the vertebrae and sternum; they pierce the External intercostal and Serratus magnus muscles, and divide into two branches, **ventral** and **dorsal**.

The **Ventral Branches** (*rami anteriores*) are reflected forward to the side and the forepart of the chest, supplying the integument of the chest and mamma; those of the fifth and sixth nerves supply the upper digitations of the External oblique muscle.

The **Dorsal Branches** (*rami posteriores*) are reflected dorsad to supply the integument over the scapula and over the Latissimus dorsi muscle.

The **Lateral Cutaneous Branch of the Second Intercostal Nerve** (*n. intercosto-brachialis*) is of large size, and does not divide, like the other nerves, into a ventral and dorsal branch. It may unite with a branch of the third intercostal. The single nerve or the united nerve is named, from its origin and distribution, the
intercosto-brachial or intercosto-humeral nerve (Figs. 659 and 665). It pierces the External intercostal muscle, crosses the axilla to the inner side of the arm, and joins with a filament from the medial cutaneous nerve of the upper arm (nerve of Wrisberg). It then pierces the fascia, and supplies the skin of the upper half of the inner and back part of the arm (Figs. 663 and 664), communicating with the internal cutaneous branch (n. cutaneus antibrachii medialis) of the musculo-spiral nerve. The size of this nerve is in inverse proportion to the size of the other cutaneous nerves, especially the nerve of Wrisberg. A second intercosto-brachial nerve is frequently given off from the third intercostal. It supplies filaments to the armpit and inner side of the arm. It may or may not send a branch to the intercosto-brachial.

The Ventral Divisions of the Lower Thoracic Nerves.—The ventral divisions of the seventh, eighth, ninth, tenth, and eleventh thoracic nerves are continued ventrad from the intercostal spaces into the abdominal wall, and the twelfth thoracic is continued throughout its whole course in the abdominal wall, since it is placed below the last rib; hence these nerves are named lower or abdominal intercostal nerves. They have (with the exception of the last) the same arrangement as the upper ones as far as the anterior extremities of the intercostal spaces, where they pass behind the costal cartilages, and between the Internal oblique and Transversalis muscles, to the sheath of the Rectus, which they perforate. They supply the Rectus muscle, and terminate in branches which become subcutaneous near the linea alba. These branches are named the ventral or anterior cutaneous nerves of the abdomen. They are directed outward as far as the lateral cutaneous nerves, supplying the integument of the front of the belly. The lower intercostal nerves supply the Intercostals, Serratus posticus inferior, and Abdominal muscles, and, about the middle of their course, give off lateral cutaneous branches which
pierce the External intercostal and External oblique muscles, in the same line as the lateral cutaneous nerves of the thorax, and divide into ventral and dorsal branches, which are distributed to the integument of the abdomen and back; the ventral branches supply the digitations of the External oblique muscle and extend caudal and forward nearly as far as the margin of the Rectus muscle; the dorsal branches pass dorsad to supply the skin over the Latissimus dorsi muscle.

The Last Thoracic Nerve.—The last thoracic is larger than the other thoracic nerves. Its ventral division runs along the lower border of the last rib, and passes under the external arcuate ligament of the Diaphragm. It then runs ventrad of the Quadratus lumborum muscle, perforates the Transversalis muscle, and passes distad between it and the Internal oblique muscle, to be distributed in the same manner as the lower intercostal nerves. It communicates with the iliohypogastric branch of the lumbar plexus, and is frequently connected with the first lumbar nerve by a slender branch, the thoraco-lumbar nerve, which descends in the substance of the Quadratus lumborum muscle. It gives a branch to the Pyramidalis muscle.

The Cutaneous Branches.—There are two cutaneous branches, a ventral and a lateral.

The Ventral Cutaneous Branch is a terminal branch and is a direct prolongation of the intercostal. It supplies an area of skin of the abdominal wall between the umbilicus and pubis.

The Lateral Cutaneous Branch (ramus cutaneus lateralis [abdominalis] intercostalis XII) is remarkable for its large size; it perforates the Internal and External oblique muscles, passes over the crest of the ilium ventrad of the iliac branch of the iliohypogastric, and is distributed to the integument of the front part of the glutal region, some of its filaments extending as low down as the trochanter major. It does not divide into a ventral and a dorsal branch, like the other lateral cutaneous branches of the intercostal nerves.

Surgical Anatomy.—The lower seven intercostal nerves and the iliohypogastric from the first lumbar nerve supply the skin of the abdominal wall. They run caudal and inward fairly equidistant from each other. The sixth and seventh supply the skin over the “pit of the stomach,” the eighth corresponds to about the position of the middle line transversa; the tenth to the umbilicus; and the iliohypogastric supplies the skin over the pubes and external abdominal ring. There are several points of surgical significance about the distribution of these nerves, and it is important to remember their origin and course, for in many diseases affecting the nerve-trunks at or near their origin the pain is referred to their peripheral origins. Thus in Pott’s disease of the spine children will often be brought to the surgeon suffering from pain in the belly. This is due to the fact that the nerves are irritated at the seat of disease as they issue from the spinal canal. When the irritation is confined to a single pair of nerves, the sensation complained of is often a feeling of constriction, as if a cord were tied around the abdomen; and in these cases the situation of the sense of constriction may serve to localize the disease in the spinal column. In other cases, where the bone disease is more extensive and two or more nerves are involved, a more diffused pain in the abdomen is complained of. A similar condition is sometimes present in affections of the cord itself, as in tabes dorsalis.

Again, it must be borne in mind that the same nerves which supply the skin of the abdomen supply also the muscles which constitute the greater part of the abdominal wall. Hence, it follows that any irritation applied to the peripheral terminations of the cutaneous branches in the skin of the abdomen is immediately followed by reflex contraction of the abdominal muscles. A good practical illustration of this may sometimes be seen in watching two surgeons examine the abdomen of the same patient. One, whose hand is cold, causes the muscles of the abdominal wall to at once contract and the belly to become rigid, and thus not nearly so suitable for examination; the other, who has taken the precaution to warm his hand, examines the abdomen without exciting any reflex contraction. The supply of both muscles and skin from the same source is of importance in protecting the abdominal viscera from injury. A blow on the abdomen, even of a severe character, will do no injury to the viscera if the muscles are in a condition of firm contraction; whereas in cases where the muscles have been taken unawares, and the blow has been struck while they were in a state of rest, an injury insufficient to produce any lesion of the abdominal wall has been attended with rupture of some of the abdominal contents. The importance, therefore, of immediate reflex contraction upon the receipt of an injury.
THE VENTRAL DIVISIONS OF THE LUMBAR NERVES

cannot be overestimated, and the intimate association of the cutaneous and muscular fibres in the same nerve produces a much more immediate response on the part of the muscles to any peripheral stimulation of the cutaneous filaments than would be the case if the two sets of fibres were derived from independent sources.

Again, the nerves supplying the abdominal muscles and skin are derived from the lower intercostal nerves and are intimately connected with the sympathetic supplying the abdominal viscera through the lower thoracic ganglia from which the splanchnic nerves are derived. In consequence of this, in rupture of the abdominal viscera and in acute peritonitis the muscles of the belly-wall become firmly contracted, and thus as far as possible preserve the abdominal contents in a condition of rest.

THE LUMBAR NERVES (NN. LUMBALES).

The lumbar nerves are five in number on each side. The first lumbar nerve appears between the first and second lumbar vertebrae, and the last between the last lumbar vertebra and the base of the sacrum.

The Roots of the Lumbar Nerves.

The roots of the lumbar nerves are the largest, and their filaments the most numerous, of all the spinal nerves, and they are closely aggregated together upon the lower end of the cord. The ventral roots are the smaller, but there is not the same disproportion between them and the dorsal roots as in the cervical nerves. The roots of these nerves have a vertical direction, and are of considerable length, more especially the lower ones, since the spinal cord does not extend beyond the first lumbar vertebra. The roots become joined in the intervertebral foramina, and the nerves so formed divide at their exit into two divisions, dorsal and ventral.

The Dorsal Divisions of the Lumbar Nerves (Rami Posteriores).

The dorsal divisions of the lumbar nerves diminish in size from above downward; they pass dorso-laterad between the transverse processes, and divide into medial and lateral branches.

The Medial Branches (rami mediales).—The medial branches, the smaller, pass inward close to the articular processes of the vertebrae, and supply the Multifidus spine and Interspinales muscles.

The Lateral Branches (rami laterales).—The lateral branches supply the Erector spinae and Intertransverse muscles. From the three upper branches cutaneous nerves are derived which pierce the aponeurosis of the Latissimus dorsi muscle and descend over the dorsum of the crest of the ilium, to be distributed to the integument of the gluteal region, some of the filaments passing as far as the trochanter major (Fig. 672).

The dorsal division of the fifth lumbar nerve usually sends a branch which forms a loop with the dorsal division of the first sacral nerve.

The Ventral Divisions of the Lumbar Nerves (Rami Anteriores).

The ventral divisions of the lumbar nerves increase in size from above caudad. At their origin they communicate with the lumbar ganglia of the sympathetic by long, slender filaments, which accompany the lumbar arteries around the sides of the bodies of the vertebrae, beneath the Psoas muscle. The nerves pass obliquely outward behind the Psoas magnus or between its fasciculi, distributing filaments to it and the Quadratus lumborum. The ventral divisions of the five lumbar, five sacral, and first coccygeal nerve constitute the lumbo-sacral plexus (plexus lumbosacralis). This is subdivided into the lumbar plexus, the sacral plexus, and the pudendal plexus. The ventral divisions of the four upper nerves.
are connected together in this situation by anastomotic loops, and form the lumbar plexus. The ventral division of the fifth lumbar, joined with a branch from the fourth, descends across the base of the sacrum to join the ventral division of the first sacral nerve and assists in the formation of the sacral plexus. The cord resulting from the union of the fifth lumbar and the branch from the fourth is called the lumbo-sacral cord (truncus lumbosacralis) (Figs. 670 and 675).

**The Lumbar Plexus (Plexus Lumbalis) (Figs. 669, 670).**

The lumbar plexus is formed by the loops of communication between the ventral divisions of the four upper lumbar nerves. The plexus is narrow above, and often connected with the last thoracic nerve by a slender branch, the dorsi-lumbar nerve. The plexus is broad below, where it is joined to the sacral plexus by the lumbo-sacral cord. The lumbar plexus is situated in the substance of the Psoas muscle near its dorsal part, in front of the transverse processes of the lumbar vertebrae.

The mode in which the plexus is arranged varies in different subjects.\(^1\) It differs from the brachial plexus in not forming an intricate interlacement, but the several nerves of distribution arise from one or more of the spinal nerves in the following manner: The first lumbar nerve receives a branch from the last thoracic, gives off a larger branch, which subdivides into the ilio-hypogastric and ilio-inguinal nerves; the first lumbar also gives off a communicating branch which passes down to the second lumbar nerve, and a third branch which unites with a branch of the second lumbar, to form the genito-femoral nerve. The second, third, and fourth lumbar nerves divide into ventral and dorsal divisions. The ventral division of the second divides into two branches, one of which joins with the above-mentioned branch of the first nerve to form the genito-femoral; the other unites with the ventral division of the third nerve, and a part of the ventral division of the fourth nerve to form the obturator nerve. The remainder of the ventral division of the fourth nerve passes down to communicate with the fifth lumbar nerve. The dorsal divisions of the second and third nerves divide into two branches, a smaller branch from each uniting to form the lateral or external cutaneous nerve, and a larger branch from each, which join the whole of the dorsal division of the fourth lumbar nerve to form the femoral or anterior crural nerve. The accessory obturator, when it exists, is formed by the union of two small branches given off from the third and fourth nerves.

From this arrangement it follows that the ilio-hypogastric and ilio-inguinal are derived entirely from the first lumbar nerve; the genito-femoral from the first

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\(^1\) For statistical studies of the variations encountered in different individuals, see the article by Bardeen in the American Journal of Anatomy.
and second nerves; the lateral cutaneous from the second and third; the femoral and obturator by fibres derived from the second, third, and fourth; and the accessory obturator, when it exists, from the third and fourth.

**Branches** (Figs. 669 and 670).—The branches of the lumbar plexus are—the

- Ilio-hypogastric.
- Ilio-inguinal.
- Genito-femoral.
- Lateral cutaneous.
- Obturator.
- Accessory obturator.
- Femoral (Anterior crural).

**The Ilio-hypogastric Nerve** (*n. iliohypogastricus*) (Figs. 669 and 670).—The ilio-hypogastric nerve *arises* from the first lumbar nerve. It emerges from the outer border of the Psoas muscle at its upper part, and crosses obliquely ventrad of the Quadratus lumborum to the crest of the ilium. It then perforates the Transversalis muscle dorsally near the crest of the ilium. It gives off **muscular branches** (*rami musculares*) to the abdominal wall, and divides between the Transversalis and the Internal oblique into two cutaneous branches, **iliac** and **hypogastric**.

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**Fig. 670.**—The lumbar plexus and its branches.

The **Iliac Branch** (*ramus cutaneus lateralis*) pierces the Internal and External oblique muscles immediately above the crest of the ilium, and is distributed to the integument of the gluteal region, behind the lateral cutaneous branch of the last thoracic nerve (Fig. 676). The size of this nerve bears an inverse proportion to that of the cutaneous branch of the last thoracic nerve.
The Hypogastric Branch (ramus cutaneus anterior) (Fig. 671) continues onward between the Internal oblique and Transversalis muscles. It then pierces the Internal oblique, and becomes cutaneous by perforating the aponeurosis of the External oblique, about an inch (2 cm.) above and a little lateral of the external abdominal ring, and is distributed to the integument of the hypogastric region. The ilio-hypogastric nerve communicates with the last thoracic and ilio-inguinal nerves.

The Ilio-inguinal Nerve (n. ilioinguinalis) (Figs. 669, 670, and 671).—The ilio-inguinal nerve, smaller than the preceding, arises with it from the first lumbar nerve. It emerges from the outer border of the Psoas muscle just below the ilio-hypogastric nerve, and, passing obliquely across the Quadratus lumborum and Iliacus muscles, perforates the Transversalis near the forepart of the crest of the ilium, and communicates with the ilio-hypogastric nerve between that muscle and the Internal oblique. The nerve then pierces the Internal oblique, distributing muscular branches (rami musculares) to it, and, accompanying the spermatic cord through the external abdominal ring, is distributed to the integument of the upper and inner part of the thigh, and to the scrotum in the male (nn. scrotales anteriores) and to the labium majus in the female (nn. labiales anteriores). The size of this nerve is in inverse proportion to that of the ilio-hypogastric. Occasionally it is very small, and ends by joining the ilio-hypogastric; in such cases a branch from the ilio-hypogastric takes the place of the ilio-inguinal, or the ilio-inguinal nerve may be altogether absent.

The Genito-femoral or Genito-crural Nerve (n. genitofemoralis) (Figs. 669 and 670) arises from the first and second lumbar nerves. It passes obliquely through the substance of the Psoas muscle, and emerges from its inner border at a level corresponding to the intervertebral substance between the third and fourth lumbar vertebrae; it then descends on the surface of the Psoas muscle, under cover of the peritoneum, and divides into a genital and a femoral branch.

The Genital Branch or External Spermatic Nerve (n. spermaticus externus) passes outward on the Psoas magnus, and pierces the fascia transversalis, or passes through the internal abdominal ring; in the male it then descends along the back part of the spermatic cord to the scrotum, and supplies the Cremaster muscle. In the female it accompanies the round ligament, and is lost upon it.

The Femoral Branch or Lumbo-inguinal Nerve (n. lumboinguinalis) (Fig. 671) descends on the external iliac artery, sending a few filaments around it, and, passing beneath Poupart's ligament to the thigh, enters the sheath of the femoral vessels, lying superficial and a little external to the femoral artery. It pierces the anterior layer of the sheath of the vessels, and, becoming superficial by passing through the fascia lata, it supplies the skin of the anterior aspect of the thigh as far as midway between the pelvis and knee. On the front of the thigh it communicates with the outer branch of the middle cutaneous nerve, derived from the femoral nerve. A few filaments from this nerve may be traced on to the femoral artery; they are derived from the nerve as it passes beneath Poupart's ligament.

The Lateral Cutaneous Nerve (n. cutaneus femoris lateralis) (Figs. 669, 670, 671, and 672).—The lateral cutaneous nerve arises from the second and third lumbar nerves. It emerges from the outer border of the Psoas muscle about its middle, and crosses the Iliacus muscle obliquely, toward the anterior1 superior spine of the ilium. It then passes under Poupart's ligament and over the Sartorius muscle into the thigh, where it divides into two branches, anterior and posterior.

The Anterior Branch descends in an aponeurotic canal formed in the fascia lata, becomes superficial about four inches below Poupart's ligament, and divides into branches which are distributed to the integument along the anterior and outer part of the thigh, as far down as the knee. This nerve occasionally communicates with a branch of the long saphenous nerve in front of the knee-joint.

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1 Cf. note on p. 1005.
Rural or external saphenous.

Femoral or anterior crural.

Middle cutaneous.

Anterior division of obturator.

Internal cutaneous.

Saphenous.

Musculo-cutaneous.

Anterior tibial.

Sural or external saphenous.

Anterior tibial.

Fig. 671.—Cutaneous nerves of lower extremity. Front view.

Fig. 672.—Nerves of the lower extremity. Front view.
The **Posterior Branch** pierces the fascia lata, and subdivides into branches which pass dorsad across the outer and posterior surface of the thigh, supplying the integument from the crest of the ilium as far as the knee.

The **Obturator Nerve** (*n. obturatorius*) (Figs. 669, 670, and 672).—The obturator nerve supplies the Obturator externus and Adductor muscles of the thigh, the articulations of the hip and knee, and occasionally the integument of the thigh and leg. It arises by three branches—from the second, the third, and the fourth lumbar nerves. Of these, the branch from the third is the largest, while that from the second is often very small. It descends through the inner fibres of the Psoas muscle, and emerges from its inner border near the brim of the pelvis; it then runs along the lateral wall of the pelvis, above the obturator vessels, to the upper part of the obturator foramen, where it enters the thigh, and divides into an anterior and a posterior branch, separated by some of the fibres of the Obturator externus muscle, and lower down by the Adductor brevis muscle.

The **Anterior Branch** (*ramus anterior*) (Fig. 672) passes down in front of the Adductor brevis, being covered by the Pectineus and Adductor longus, and at the lower border of the latter muscle communicates with the internal cutaneous and saphenous nerves, forming a kind of plexus. It then descends upon the femoral artery, upon which it is finally distributed. The nerve, near the obturator foramen, gives off an articular branch to the hip-joint. Behind the Pectineus it distributes muscular branches to the Adductor longus and Gracilis, and usually to the Adductor brevis, and in rare cases to the Pectineus, and receives a communicating branch from the accessory obturator nerve.

Occasionally the communicating branch to the internal cutaneous and saphenous nerves is continued down, as a **cutaneous branch** (*ramus cutaneus*), to the thigh and leg. When this is so, this occasional cutaneous branch emerges from beneath the lower border of the Adductor longus, descends along the posterior margin of the Sartorius to the inner side of the knee, where it pierces the deep fascia, communicates with the long saphenous nerve, and is distributed to the integument of the inner side of the leg as low down as its middle. When this communicating branch is small its place is supplied by the internal cutaneous nerve.

The **Posterior Branch** (*ramus posterior*) pierces the Obturator externus, sending branches to supply it, and passes behind the Adductor brevis on the front of the Adductor magnus, where it divides into numerous muscular branches, which supply the Adductor magnus, and the Adductor brevis when the latter does not receive a branch from the anterior division of the nerve. One of the branches gives off a filament to the knee-joint.

The **Articular Branch for the Knee-joint** is sometimes absent; it perforates the lower part of the Adductor magnus, and enters the popliteal space; it then descends upon the popliteal artery, as far as the back part of the knee-joint, where it perforates the posterior ligament, and is distributed to the synovial membrane. It gives filaments to the popliteal artery in its course.

The **Accessory Obturator Nerve or the Accessory Anterior Femoral Nerve of Winslow** (*n. obturatorius accessorius*) (Fig. 675).—The accessory obturator nerve is not constantly present. It is of small size, and arises by separate filaments from the third and fourth lumbar nerves. It descends along the inner border of the Psoas muscle, crosses the ascending ramus of the os pubis, and passes under the outer border of the Pectineus muscle, where it divides into numerous branches. One of these supplies the Pectineus, penetrating its under surface; another is distributed to the hip-joint; while a third communicates with the anterior branch of the obturator nerve. When this nerve is absent the hip-joint receives two branches from the obturator nerve. Occasionally the articular branch is very small, and becomes lost in the capsule of the hip-joint.
The Femoral or Anterior Crucial Nerve (n. femoralis) (Figs. 669, 670, and 672).—The femoral nerve is the largest branch of the lumbar plexus. It supplies muscular branches to the Iliacus, Pectineus, and all the muscles on the front of the thigh, excepting the Tensor fasciae latae; cutaneous filaments to the front and inner side of the thigh, and to the leg and foot (Fig. 667); and articular branches to the hip and knee. It arises from the second, third, and fourth lumbar nerves, sometimes from the first or fifth as well. It descends through the fibres of the Psoas muscle, emerging from this muscle at the lower part of its outer border, and passes caudad between it and the Iliacus muscle, and beneath Poupart’s ligament, into the thigh, where it becomes somewhat flattened, and divides into an anterior and a posterior part. Under Poupart’s ligament it is separated from the femoral artery by a portion of the Psoas muscle, and lies beneath the iliac fascia.

Within the abdomen the femoral nerve gives off from its outer side some small muscular branches to the Iliacus, and a branch to the femoral artery which is distributed upon the upper part of that vessel. The origin of this branch varies; it occasionally arises higher than usual, or it may arise lower down in the thigh.

External to the pelvis the following branches are given off:

<table>
<thead>
<tr>
<th>From the Anterior Division.</th>
<th>From the Posterior Division.</th>
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<tbody>
<tr>
<td>Middle cutaneous.</td>
<td>Long saphenous.</td>
</tr>
<tr>
<td>Internal cutaneous.</td>
<td>Muscular.</td>
</tr>
<tr>
<td>Muscular.</td>
<td>Articular.</td>
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</tbody>
</table>

The middle and internal cutaneous branches of the femoral nerve are the rami cutanei anteriores n. femoralis of the new nomenclature.

The Middle Cutaneous Nerve (Figs. 671 and 672) pierces the fascia lata (generally the Sartorius muscle also) about three inches (8 cm.) below Poupart’s ligament, and divides into two branches (Fig. 671), which descends in immediate proximity along the forepart of the thigh, to supply the integument as low as the front of the knee, where it communicates with the internal cutaneous nerve and the patellar branch of the saphenous nerve, to form the patellar plexus. In the upper part of the thigh the outer division of the middle cutaneous nerve communicates with the femoral branch of the genito-femoral nerve.

The Internal Cutaneous Nerve (Fig. 671) passes obliquely across the upper part of the sheath of the femoral artery, and divides in front or at the inner side of that vessel into two branches, anterior and posterior or internal.

The anterior branch runs caudad on the Sartorius, perforates the fascia lata at the lower third of the thigh, and divides into two branches, one of which supplies the integument as low down as the inner side of the knee; the other crosses to the outer side of the patella, communicating in its course with the nervus cutaneus patellae, a branch of the saphenous nerve.

The posterior or internal branch descends along the inner border of the Sartorius muscle to the knee, where it pierces the fascia lata, communicates with the long saphenous nerve, and gives off several cutaneous branches. The nerve then passes down the inner side of the leg, to the integument of which it is distributed. This nerve, beneath the fascia lata, at the lower border of the Adductor longus, joins in a plexiform network by uniting with branches of the saphenous and obturator nerves (Fig. 672). When the communicating branch from the obturator nerve is large and continued to the integument of the leg, the inner branch of the internal cutaneous is small and terminates at the plexus, occasionally giving off a few cutaneous filaments.

The internal cutaneous nerve, before dividing, gives off a few filaments, which pierce the fascia lata, to supply the integument of the inner side of the thigh.
One of these filaments passes through the saphenous opening; a second becomes subcutaneous about the middle of the thigh (Fig. 671); and a third pierces the fascia at its lower third (Fig. 671).

The Muscular Branches of the Anterior Division (rami musculares).—The nerve to the Pectineus is often duplicated; it arises from the femoral nerve immediately below Poupart’s ligament, and passes inward behind the femoral sheath to enter the anterior surface of the muscle. The nerve to the Sartorius arises in common with the middle cutaneous.

The Saphenous, Long Saphenous or Internal Saphenous Nerve (n. saphenus) (Figs. 671 and 672) is the largest of the cutaneous branches of the femoral nerve. It approaches the femoral artery where this vessel passes beneath the Sartorius, and lies ventrad of it, beneath the aponeurotic covering of Hunter’s canal, as far as the opening in the lower part of the Adductor magnus. It then leaves the artery, and proceeds distally along the inner side of the knee, beneath the Sartorius muscle, pierces the fascia lata opposite the interval between the tendons of the Sartorius and Gracilis muscles, and becomes subcutaneous. The nerve then passes along the inner side of the leg (Fig. 671), accompanied by the internal saphenous vein, descends behind the internal border of the tibia, and, at the lower third of the leg, divides into two branches: one continues its course along the margin of the tibia, terminating at the inner ankle; the other passes in front of the ankle, and is distributed to the integument along the inner side of the foot, as far as the great toe, communicating with the internal branch of the musculo-cutaneous nerve.

The saphenous nerve about the middle of the thigh gives off a communicating branch which joins the plexus formed by the obturator and internal cutaneous nerves.

At the inner side of the knee it gives off a large patellar branch, the nervus cutaneus patellae (ramus infrapatellarius), which pierces the Sartorius and fascia lata, and is distributed to the integument in front of the patella. This nerve communicates above the knee with the anterior branch of the internal cutaneous and with the middle cutaneous; below the knee, with other branches of the saphenous; and on the outer side of the joint, with branches of the external cutaneous nerve, forming a plexiform network, the patella plexus (plexus patellae). The cutaneous nerve of the patella is occasionally small, and terminates by joining the internal cutaneous, which supplies its place in front of the knee.

Below the knee the branches of the saphenous nerves are distributed to the integument of the front and inner side of the leg, communicating with the cutaneous branches from the internal cutaneous or from the obturator nerve. The nerve also sends filaments to the ankle-joint.

The Muscular Branches of the Posterior Division.—The muscular branches of the posterior division supply the four parts of the Quadriceps extensor muscle.

The branch to the Rectus muscle enters its under surface high up, sending off a small filament to the hip-joint.

The branch to the Vastus externus muscle, of large size, follows the course of the descending branch of the external circumflex artery to the lower part of the muscle. It gives off an articular filament to the knee-joint.

The branch to the Vastus internus muscle is a long branch which runs down on the outer side of the femoral vessels in company with the saphenous nerve for its upper part. It enters the muscle about its middle, and gives off a filament which can usually be traced caudad on the surface of the muscle to the knee-joint.

The branch to the Crureus muscle enters the muscle on its anterior surface about the middle of the thigh, and sends a filament through the muscle to the Subcrureus and the knee-joint.
The articular branch to the hip-joint is derived from the nerve to the Rectus muscle.

The articular branches to the knee-joint are three in number. One, a long, slender filament, is derived from the nerve to the Vastus externus muscle; it penetrates the capsular ligament of the joint on its anterior aspect. Another is derived from the nerve to the Vastus internus muscle. It can usually be traced downward on the surface of this muscle to near the joint; it then penetrates the muscle and accompanies the deep branch of the anastomotica magna artery, pierces the capsular ligament of the joint on its inner side, and supplies the synovial membrane. The third branch is derived from the nerve to the Crureus.

THE SACRAL AND COCCYGEAL NERVES (NN. SACRALES ET COCCYGEUS).

The sacral nerves are five in number on each side. The four upper ones pass from the sacral canal through the sacral foramina; the fifth through the foramina between the sacrum and coccyx.

The Roots of the Upper Sacral Nerves.

The roots of the upper sacral nerves are the largest of all the spinal nerves; while those of the lower sacral and the coccygeal nerve are the smallest. They are longer than those of any of the other spinal nerves, on account of the spinal cord not extending beyond the first lumbar vertebra. From their great length, and the appearance they present in connection with their attachment to the spinal cord, the roots of origin of these nerves are called collectively the cauda equina.

Each sacral and coccygeal nerve separates into two divisions, dorsal and ventral.

The Dorsal Divisions of the Sacral Nerves (Rami Posteriorum) (Fig. 673).

The dorsal divisions of the sacral nerves are small, diminish in size from above caudad, and emerge, except the last, from the sacral canal by the dorsal sacral foramina.

The Upper Sacral Nerves.—Each of the three upper ones is covered, at its exit from the sacral canal, by the Multifidus spine muscle, and divides into a medial branch and a lateral branch.

The Medial Branches (ramus medialis).—The medial branches are small, and supply the Multifidus spine muscle.

The Lateral Branches (ramus lateralis).—The lateral branches join with one another, and with the last lumbar and fourth sacral nerves, in the form of loops on the dorsal surface of the sacrum, constituting the dorsal sacral plexus. From these loops branches pass to the outer surface of the great sacro-ischiatic ligament, where they form a second series of loops beneath the Gluteus maximus muscle. Cutaneous branches from this second series of loops, usually two or three in number, pierce the Gluteus maximus muscle along a line drawn from the posterior superior spine of the ilium to the tip of the coccyx. They supply the integument over the dorsal part of the gluteal region.

The Lower Sacral Nerves.—The dorsal divisions of the two lower sacral nerves are situated below the Multifidus spine muscle. They are of small size, and do not divide into medial and lateral branches, but join with each other, and with the dorsal division of the coccygeal nerve to form the dorsal sacro-coccygeal nerve, which passes through the sacro-sciatic ligament, and forms loops on the back of the sacrum, filaments from which supply the Extensor coccygeus and the integument over the coccyx.
THE NERVE SYSTEM

FIG. 673.—The posterior sacral nerves.

FIG. 674.—Side view of pelvis, showing sacral nerves.
The Ventral Divisions of the Sacral Nerves (Rami Anteriores) (Fig. 675).

The ventral divisions of the sacral nerves diminish in size from above downward. The four upper ones emerge from the anterior sacral foramina; the ventral division of the fifth, after emerging from the vertebral canal through its terminal opening, curves forward between the sacrum and the coccyx. All the ventral sacral nerves at their exit from the sacral foramina communicate with the sacral ganglia of the sympathetic. The first nerve (Fig. 674), of large size, unites with the lumbo-sacral cord (truneus lumbosacralis), formed by the fifth lumbar, and a branch from the fourth lumbar (n. furcalis). The second (Fig. 674), equal in size to the preceding, and the third (n. bigeminus) (Fig. 674), about one-fourth the size of the second, unite with this trunk, and form, with a small fasciculus from the fourth, the sacral plexus, a visceral branch being given off from the third nerve to the bladder (Fig. 675).

The Fourth Ventral Sacral Nerve sends a branch to join the sacral plexus. The remaining portion of the nerve divides into visceral and muscular branches, and a communicating filament descends to join the fifth sacral nerve.

The visceral branches are distributed to the viscera of the pelvis, communicating with the sympathetic nerve. These branches ascend upon the rectum and bladder, and in the female upon the vagina, communicating with branches of the sympathetic from the pelvic plexus. The visceral branches of the third and fourth sacral do not join the gangliated cord.

The muscular branches are distributed to the Levator ani, Coccygeus, and Sphincter ani. The branch to the Sphincter ani pierces the Levator ani, so as to reach the ischio-rectal fossa, where it is found lying in front of the coccyx. Cutaneous filaments arise from the latter branch, which supply the integument between the anus and coccyx. Another cutaneous branch is frequently given off from this nerve, though sometimes from the pudic (Schwalbe). It perforates the great sacro-sciatic ligament, and, winding around the lower border of the Gluteus maximus, supplies the skin over the lower and inner part of this muscle.

The Fifth Ventral Sacral Nerve, after passing from the lower end of the sacral canal, curves forward through the fifth sacral foramen, formed between the lower part of the sacrum and the transverse process of the first piece of the coccyx. It pierces the Coccygeus muscle, and descends upon its anterior surface to near the tip of the coccyx, where it again perforates the muscle, to be distributed to the integument over the back part and side of the coccyx. This nerve communicates above with the fourth sacral and below with the coccygeal nerve, and supplies the Coccygeus muscle.

The Dorsal Division of the Coccygeal Nerve.

The coccygeal nerve divides into its ventral and dorsal divisions in the vertebral canal. The dorsal division is the smaller. It does not divide, but receives, as already mentioned, a communicating branch from the last sacral, and is lost in the integument over the back of the coccyx.

The Ventral Division of the Coccygeal Nerve.

The ventral division of the coccygeal nerve is a delicate filament which escapes at the termination of the sacral canal; it passes caudad behind the rudimentary transverse process of the first piece of the coccyx, and curves ventrad through the notch between the first and second pieces, piercing the Coccygeus muscle and descending on its ventral surface to near the tip of the coccyx, where it again
pierces the muscle, to be distributed to the integument over the back part and side of the coccyx. It is joined by a branch from the fifth ventral sacral as it descends on the surface of the Coccygeus muscle.

The Pudendal Plexus (plexus pudendus).—The pudendal plexus is formed by fibres obtained from the ventral divisions of the first three sacral nerves and by the ventral divisions of the two lower sacral nerves and the coccygeal nerve. It is, so to speak, interpolated in the sacral plexus and is considered as a portion of it.

The Sacral or Sciatic Plexus (Plexus Sacralis) and the Pudic or Pudendal Plexus (Plexus Pudendalis) (Fig. 675).

The sacral plexus is formed by the lumbo-sacral cord, the ventral divisions of the three upper sacral nerves, and a branch from the fourth. The pudic or pudendal plexus is considered with the sacral plexus. It is usually composed of the ventral divisions of the second, third, fourth and fifth sacral nerves and the coccygeal nerve. It is irregular in composition. Prof. Cunningham says: "There is no distinct point of separation between the two plexuses. On the contrary, there is considerable overlapping, so that two and sometimes three of the principal nerves derived from the pudendal plexus have their origin in common with nerves of the sacral plexus." The nerves of these two plexuses proceed in different directions: the upper ones obliquely caudad and outward, the lower ones nearly horizontally outward, and they all unite into two cords; an upper and larger cord, which is formed by the lumbo-sacral cord with the first, second, and the greater part of the third sacral nerves; and a lower and smaller cord, formed by the remainder of the third, with a portion of the fourth sacral nerve. The upper cord is prolonged into the great sciatic nerve and the lower into the pudic. Frequently a small filament is given off from the second sacral nerve to join the lower cord.
THE SACRAL OR SCIATIC PLEXUS

Each of the nerves which form the plexus joins the sympathetic by gray rami communicantes. White rami communicantes join the third sacral and sometimes also the second and fourth sacrals to the sympathetic.

The sacro-pudendal plexus is triangular in form, its base corresponding with the exit of the nerves from the sacrum, its apex with the lower part of the great sacro-sciatic foramen. It rests upon the anterior or ventral surface of the Pyriformis, and is covered ventrad by the pelvic fascia, which separates it from the sciatic and pudic branches of the internal iliac artery and from the viscera of the pelvis. The sacral plexus proper sends branches to the lower extremity; the pudendal plexus proper is largely limited to supplying the perineum.

Branches.—The branches of the sacro-pudendal plexus are divided into collateral and terminal branches.

<table>
<thead>
<tr>
<th>Collateral branches</th>
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<tbody>
<tr>
<td>Muscular.</td>
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<tr>
<td>Superior gluteal.</td>
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<tr>
<td>Inferior gluteal.</td>
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<tr>
<td>Small sciatic.</td>
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<tr>
<td>Perforating cutaneous.</td>
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<tr>
<th>Terminal branches</th>
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<tbody>
<tr>
<td>Pudic.</td>
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<tr>
<td>Great sciatic.</td>
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</tbody>
</table>

The Muscular Branches (rami musculares).—The muscular branches supply the Pyriformis, Obturator internus, the two Gemelli and the Quadratus femoris. The branch to the Pyriformis muscle arises from the upper two sacral nerves before they enter the plexus; the branch to the Obturator internus muscle arises at the junction of the lumbo-sacral and first sacral nerves; it passes out of the pelvis through the great sacro-sciatic foramen below the Pyriformis, crosses the spine of the ischium, and re-enters the pelvis through the lesser sacro-sciatic foramen to enter the inner surface of the Obturator internus; the branch to the Gemellus superior muscle arises in common with the nerve to the Obturator internus muscle; it enters the muscle at the upper part of its dorsal surface; the small branch to the Gemellus inferior and Quadratus femoris muscles also arises from the upper part of the plexus; it passes through the great sacro-sciatic foramen below the Pyriformis, and courses down beneath the great sciatic nerve, the Gemelli and tendon of the Obturator internus, supplies the muscles on their deep or ventral surface, and gives off an articular branch to the hip-joint. A second articular branch is occasionally derived from the upper part of the sacral plexus.

The Superior Gluteal Nerve (n. gluteus superior) (Figs. 675 and 677).—The superior gluteal nerve arises from the back part of the lumbo-sacral cord, with some filaments from the first sacral nerve; it passes from the pelvis through the great sacro-sciatic foramen above the Pyriformis muscle, accompanied by the gluteal vessels, and divides into a superior and an inferior branch.

The Superior Branch follows the line of origin of the Gluteus minimus, and supplies the Gluteus medius muscle.

The Inferior Branch crosses obliquely between the Gluteus minimus and medius, distributing filaments to both these muscles, and terminates in the Tensor fasciae femoris muscle, extending nearly to its lower end.

The Inferior Gluteal Nerve (n. gluteus inferior) (Fig. 675).—The inferior gluteal nerve arises from the lumbo-sacral cord and first and second sacral nerves, and is intimately connected with the small sacrotuberous at its origin. It passes out of the pelvis through the great sciatic notch, beneath the Pyriformis muscle, and, dividing into a number of branches, enters the Gluteus maximus muscle on its under surface.

The Small Sciatic Nerve (n. cutaneus femoris posterior) (Figs. 675, 676, and 677).—The small sciatic or postfemoral cutaneous nerve supplies the integument of the perineum and back part of the thigh and leg. It is usually formed by the union of
two branches, which arise from the second and third nerves of the sacral plexus. It issues from the pelvis through the great sacro-sciatic foramen below the Pyriformis muscle, descends beneath the Gluteus maximus with the sciatic artery, and at the lower border of that muscle passes along the back part of the thigh, beneath the fascia lata and over the long head of the Biceps, to the lower part of the popliteal region, where it pierces the fascia and becomes cutaneous. It then accompanies the external saphenous vein (v. saphena parva) to about the middle of the leg, its terminal filaments communicating with the sural or external saphenous nerve.

The Branches of the small sciatic nerve are all cutaneous, and are grouped as follows: gluteal, perineal, and femoral.

The Gluteal Cutaneous Branches (nn. clunium inferiores [laterales]) consist of two or three ascending filaments, which turn upward around the lower border of the Gluteus maximus to supply the integument covering the lower and outer part of that muscle.

The Perineal Cutaneous Branches (rami perineales) are distributed to the skin at the upper and inner side of the thigh, on its posterior aspect. One branch, longer than the rest, the inferior pudendal or long scrotal nerve (Fig. 677), curves forward below the tuber ischii, pierces the fascia lata, and passes forward beneath the superficial fascia of the perineum to be distributed to the integument of the scrotum in the male and the labium in the female, communicating with the superficial perineal and inferior hemorrhoidal nerves.

The Femoral Cutaneous Branches are numerous descending filaments, derived from both sides of the nerves, which are distributed to the back, inner, and outer sides of the thigh, to the skin covering the popliteal space, and to the upper part of the leg.

The Perforating Cutaneous Nerve (n. clunium inferior medialis) (Fig. 675).—The perforating cutaneous nerve usually arises from the second and third sacral nerves, and is of small size. It is continued dorsad through the great sacro-sciatic ligament, and, winding around the lower border of the Gluteus maximus, supplies the integument covering the inner and lower part of that muscle.

The Pudic Nerve (n. pudendus) (Figs. 675 and 677).—The pudic nerve is the direct continuation of the lower cord of the sacral plexus, and derives its fibres from the third and fourth sacral nerves, and frequently from the second also. It leaves the pelvis through the great sacro-sciatic foramen, below the Pyriformis. It then crosses the spine of the ischium, and re-enters the pelvis through the lesser sacro-sciatic foramen. It accompanies the pudic vessels upward and forward along the outer wall of the ischio-rectal fossa, being contained in a sheath of the obturator fascia, termed Alcock’s canal, and divides into two terminal branches, the perineal nerve and the dorsal nerve of the penis or clitoris. Before its division it gives off the inferior hemorrhoidal nerve.

The Inferior Hemorrhoidal Nerve (n. haemorrhoidalis inferior) is occasionally derived separately from the sacral plexus. It passes across the ischio-rectal fossa, with its accompanying vessels, toward the lower end of the rectum, and is distributed to the Sphincter ani externus and to the integument around the anus. Branches of this nerve communicate with the inferior pudendal and superficial perineal nerves at the forepart of the perineum.

The Perineal Nerve (n. perinei), the inferior and larger of the two terminal branches of the pudic, is situated below the pudic artery. It accompanies the superficial perineal artery in the perineum, dividing into cutaneous and muscular branches.

The cutaneous branches (superficial perineal) are two in number, posterior and anterior. The posterior or external branch pierces the base of the triangular liga-

ment of the urethra, and passes forward along the outer side of the urethral triangle in company with the superficial perineal artery; it is distributed to the
THE SACRAL OR SCIATIC PLEXUS

Superior gluteal.

Pudic.
Nerve to obturator internus.

Small sciatic.

Inferior pudendal.

Descending cutaneous.

Internal popliteal.

External popliteal, or common peroneal.

Sural or external saphenous.
Posterior tibial.

Communicans peronei.

Plantar cutaneous.

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FIG. 676.—Cutaneous nerves of lower extremity. Posterior view.

FIG. 677.—Nerves of the lower extremity. Posterior view.

N. B.—In this diagram the external saphenous (or sural nerve) and communicans peronei are not in their normal position. They have been displaced by the removal of the superficial muscles.
skin of the scrotum (*nn. scrotales posteriores*). It communicates with the inferior hemorrhoidal, the inferior pudendal, and the other superficial perineal nerve. The anterior or internal branch also pierces the base of the triangular ligament, and passes forward nearer to the middle line, to be distributed to the inner and back part of the scrotum. Both these nerves supply the labia majora in the female.

The muscular branches are distributed to the Transversus perinaei, Accelerator urinae, Erector penis, and Compressor urethrae. A distant branch is given off from the nerve to the Accelerator urinae, which pierces this muscle, and supplies the corpus spongiosum, ending in the mucous membrane of the urethra. This is the nerve to the bulb.

The Dorsal Nerve of the Penis (*n. dorsalis penis*) is the deepest division of the pudic nerve; it accompanies the pudic artery along the ramus of the ischiium; it then runs forward along the inner margin of the ramus of the os pubis, between the superficial and deep layers of the triangular ligament. Piercing the superficial layer it gives a branch to the corpus cavernosum, and passes forward, in company with the dorsal artery of the penis, between the layers of the suspensory ligament, on to the dorsum of the penis, along which it is carried as far as the glans, to which it is distributed.

In the female the dorsal nerve is very small, and supplies the clitoris (*n. dorsalis clitoridis*).

The Great Sciatic Nerve (*n. ischiadicus*) (Figs. 675 and 677).—The great sciatic nerve supplies nearly the whole of the integument of the leg, the muscles of the back of the thigh, and those of the leg and foot. It is the largest nerve cord in the body, measuring three-quarters of an inch in breadth, and is the direct continuation of the upper division of the sacral plexus. It passes out of the pelvis through the great sacro-sciatic foramen, below the Pyriformis muscle. It descends between the trochanter major and tuberosity of the ischiium, along the back part of the thigh, to about its lower third, where it divides into two large branches, the internal or tibial and external popliteal or peroneal nerves (Fig. 677).

This division may take place at any point between the sacral plexus and the lower third of the thigh. When the division occurs at the plexus (in 10 per cent. of cases) the two nerves descend together side by side; or they may be separated, at their commencement, by the interposition of part or the whole of the Pyriformis muscle. As the nerve descends along the back of the thigh, it rests upon the dorsal surface of the ischiium, the nerve of the Quadratus femoris, and the External rotator muscles, in company with the small sciatic nerve and artery, being covered by the Gluteus maximus; lower down, it lies upon the Adductor magnus, and is covered by the long head of the Biceps. The great sciatic, even when apparently a single nerve, is really two nerves appearing as one.

**Branches.**—The branches of the nerve, before its division, are articular and muscular.

The Articular Branches (*rami articulares*) arise from the upper part of the nerve; they supply the hip-joint, perforating the posterior part of its fibrous capsule. These branches are sometimes derived from the sacral plexus.

The Muscular Branches (*rami musculares*) are distributed to the flexors of the leg—viz., the Biceps, Semitendinosus, and Semimembranosus, and a branch goes to the Adductor magnus. These branches are given off beneath the Biceps muscle.

The Internal Popliteal or Tibial Nerve (*n. tibialis*) (Figs. 675 and 677), in reality, arises from the fourth and fifth lumbar nerves and the first three sacral nerves, and becomes a part of the trunk of the great sciatic in the buttock, to emerge from it again at the bifurcation of the sciatic. It is the larger of the two terminal branches of the great sciatic, descends along the back part of the thigh, through the middle of the popliteal space, to the lower part of the Popliteus muscle, where it passes with the artery beneath the arch of the Soleus and becomes the posttibial. It is over-
lapped by the hamstring muscles above, and then becomes more superficial, and lies to the outer side of, and some distance from, the popliteal vessels; opposite the knee-joint it is in close relation with the vessels, and crosses to the inner side of the artery. Below, it is overlapped by the Gastrocnemius muscle.

The branches of this nerve are—articular, muscular, and a cutaneous branch, the communicating tibial nerve.

The articular branches (rami articulares), usually three in number, supply the knee-joint; two of these branches accompany the superior and inferior internal articular arteries, and a third, the azygos articular artery.

The muscular branches (rami musculares), four or five in number, arise from the nerve as it lies between the two heads of the Gastrocnemius muscle; they supply that muscle, and the Plantaris, Soleus, and Popliteus. The filaments which supply the Popliteus turn around its lower border and are distributed to its deep surface.

The tibial communicating nerve (n. cutaneus surae medialis) is the cutaneous branch. It descends between the two heads of the Gastrocnemius muscle, and about the middle of the back of the leg pierces the deep fascia, and joins the peroneal or fibular communicating nerve (ramus anastomoticus peronaeus) from the external popliteal nerve to form the sural nerve (external or short saphenous) (Fig. 677). The sural nerve, formed by the communicating branches of the internal and external popliteal nerves, passes downward and outward near the outer margin of the tendo Achillis, lying close to the small saphenous vein, to the interval between the external malleolus and the os calcis. It divides in two branches, the posterior of which breaks up into lateral calcaneal branches (rami calcanei laterales). The anterior branch (n. cutaneus dorsalis lateralis) winds around the outer malleolus, and is distributed to the integument along the outer side of the foot and little toe, communicating on the dorsum of the foot with the musculo-cutaneous nerve. In the leg its branches communicate with those of the small sciatic. The cutaneous area supplied by the sural nerve is indicated in Fig. 679.

The Posttibial Nerve (Fig. 677) is the terminal portion of the internal popliteal nerve. It commences at the lower border of the Popliteus muscle, and passes along the back part of the leg with the posterior tibial vessels to the interval between the inner malleolus and the heel, where it divides into the external and internal plantar nerves. It lies upon the deep muscles of the leg, and is covered in the upper part by the muscles of the calf, lower down by the skin and fascia. In the upper part of its course it lies to the inner side of the posterior tibial artery, but it soon crosses that vessel, and lies to its outer side as far as the ankle. In the lower third of the leg it is placed parallel with the inner margin of the tendo Achillis.

The branches of the posttibial nerve are muscular, medial or internal calcaneal or calcaneo-plantar, and articular.

The muscular branches (rami musculares) arise either separately or by a common trunk from the upper part of the nerve. They supply the Soleus, Tibialis posticus, Flexor longus digitorum, and Flexor longus hallucis muscles; the branch to the latter muscle accompanying the peroneal artery. The branch to the Soleus enters its deep surface, while the branch which this muscle receives from the internal popliteal enters its superficial aspect.

The medial or internal calcaneal or calcaneo-plantar branches (rami calcanei mediales) perforate the internal annular ligament, and supply the integument of the heel and inner side of the foot (Fig. 679).

The articular branch (ramus articularis ad articulationem talocruralen) is given off just above the bifurcation of the nerve and supplies the ankle-joint.

The Medial or Internal Plantar Nerve (n. plantaris medialis) (Fig. 678), the larger of the two terminal branches of the posttibial, accompanies the medial plantar artery along the inner side of the foot. From its origin at the inner ankle it passes
beneath the Abductor hallucis, and divides into the common plantar digital nerves (nn. digitales plantares communes), which pass distal between the Abductor hallucis and the Flexor brevis digitorum, dividing opposite the bases of the metatarsal bones into four collateral plantar digital branches, and communicating with the lateral plantar nerve.

In its course the medial plantar nerve gives off cutaneous branches, which pierce the plantar fascia and supply the integument of the sole of the foot (Fig. 679); muscular branches, which supply the Abductor hallucis and Flexor brevis digitorum; articular branches, to the articulations of the tarsus and metatarsus; and four collateral plantar digital branches (nn. digitales plantares proprii). The three outer branches pass between the divisions of the plantar fascia in the clefts between the toes; the first (innermost) branch becomes cutaneous more proximally between the Abductor hallucis and Flexor brevis digitorum. They are distributed in the following manner: The first supplies the inner border of the great toe, and sends a filament to the Flexor brevis hallucis muscle; the second bifurcates, to supply the adjacent sides of the great and second toes, sending a filament to the First lumbrical muscle; the third supplies the adjacent sides of the second and third toes; the fourth supplies the corresponding sides of the third and fourth toes, and receives a communicating branch from the external plantar nerve (Fig. 679). Each digital nerve gives off cutaneous and articular filaments; and opposite the last phalanx sends a dorsal branch, which supplies the structures around the nail, the continuation of the nerve being distributed to the ball of the toe. It will be observed that the distribution of these branches is precisely similar to that of the median nerve in the hand.

The Lateral or External Plantar Nerve (n. plantaris lateralis) (Fig. 678), the smaller of the two, completes the nerve supply to the structures of the sole of the foot (Fig. 679), being distributed to the little toe, and one-half of the fourth, as well as to most of the deep muscles, its distribution being similar to that of the ulnar in the hand. It passes obliquely distal with the lateral plantar artery to the outer side of the foot, lying between the Flexor brevis digitorum and Flexor accessorius, and in the interval between the former muscle and Abductor minimi digiti divides into a
superficial and a deep branch. Before its division it supplies the Flexor accessorius and Adductor minimi digiti.

The superficial branch (ramus superficialis) separates into two digital nerves. Before division they are called common plantar digital nerves (nn. digitales plantares communes), after division the collateral plantar digital nerves (nn. digitales plantares proprii): one, the external branch, the smaller of the two, supplies the outer side of the little toe, the Flexor brevis minimi digiti, and the two Interosseous muscles of the fourth metatarsal space; the other and larger digital branch supplies the adjoining sides of the fourth and fifth toes, and communicates with the medial plantar nerve.

The deep or muscular branch (ramus profundus) accompanies the lateral plantar artery into the deep part of the sole of the foot, beneath the tendons of the Flexor muscles and Adductor obliquus hallucis, and supplies all the Interossei (except those in the fourth metatarsal space), the three outer Lumbricales, the Adductor obliquus hallucis, and the Adductor transversus hallucis.

The External Popliteal or Common Peroneal Nerve (n. peroneaeus communis) (Figs. 675 and 677) in reality arises from the fourth and fifth lumbar and the first and second sacral nerves. It is about one-half the size of the internal popliteal, descends obliquely along the outer sides of the popliteal space to the head of the fibula, close to the inner margin of the Biceps muscle. It is easily felt beneath the skin behind the head of the fibula at the inner side of the tendon of the Biceps. It passes between the tendon of the Biceps and outer head of the Gastrocnemius muscle, winds around the neck of the fibula, between the Peroneus longus and the bone, and divides beneath the muscle into the deep peroneal (anterior tibial) and muscular cutaneous nerves.

The branches of the peroneal nerve, previous to its division, are articular and cutaneous.

The articular branches (rami articales) are three in number: two of these accompany the superior and inferior lateral articular arteries to the outer side of the knee. The upper one occasionally arises from the great sciatic nerve before its bifurcation. The third (recurrent) articular nerve is given off at the point of division of the peroneal nerve; it ascends with the anterior recurrent tibial artery through the Tibialis anticus muscle to the front of the knee, which it supplies.

The Sural or Lateral Cutaneous Branch (n. cutaneus surae lateralis).—There may be two or three of these branches. They supply the integument along the back part and outer side of the leg. The largest cutaneous branch of the peroneal is the peroneal communicating (ramus anastomoticus peroneaeus or communicans fibularis), arises near the head of the fibula, crosses the external head of the Gastrocnemius to the middle of the leg, and joins with the communicans tibialis to form the external saphenous. This nerve occasionally exists as a separate branch, which is continued as far down as the heel.

The Deep Peroneal or Anterior Tibial Nerve (n. peroneaeus profundus) (Fig. 672) commences at the bifurcation of the peroneal nerve, between the fibula and upper part of the Peroneus longus muscle, passes obliquely distad beneath the Extensor longus digitorum muscle to the forepart of the interosseous membrane, and gets into relation with the anterior tibial artery above the middle of the leg; it then descends with the artery to the front of the ankle-joint, where it divides into an external and an internal branch. This nerve lies at first on the outer side of the anterior tibial artery, then in front of it, and again at its outer side at the ankle-joint.

The branches of the anterior tibial nerve in its course through the leg are the muscular branches (rami musculares) to the Tibialis anticus, Extensor longus digitorum, Peroneus tertius, and Extensor proprius hallucis muscles, and an articular branch to the ankle-joint.
The external or tarsal branch of the anterior tibial passes outward across the tarsus, beneath the Extensor brevis digitorum, and, having become enlarged, like the posterior interosseous nerve at the wrist, supplies the Extensor brevis digitorum muscle. From the enlargement three minute interosseous branches are given off which supply the tarsal joints and the metatarso-phalangeal joints of the second, third, and fourth toes. The first of these sends a filament to the second dorsal interosseous muscle.

The internal branch, the continuation of the nerve, accompanies the dorsalis pedis artery along the inner side of the dorsum of the foot, and at the first interosseous space divides into two dorsal digital branches (mn. digitales dorsales hallucis lateralis et digitii secundi medialis), which supply the adjacent sides of the great and second toes, communicating with the internal branch of the musculo-cutaneous nerve. Before it divides it gives off an interosseous branch to the first space, which supplies the metatarso-phalangeal joint of the great toe and sends a filament to the First dorsal interosseous muscle.

The Musculo-cutaneous Nerve (n. peronaeus superficialis) (Fig. 672) supplies the muscles on the fibular side of the leg and the integument of the dorsum of the foot. It passes forward between the Peronei muscles and the Extensor longus digitorum, pierces the deep fascia at the lower third of the leg on its front and outer side, and divides into two branches. This nerve in its course between the muscles gives off muscular branches (rami musculares) to the Peroneus longus and brevis, and cutaneous filaments to the integument of the lower part of the leg.

The medial dorsal cutaneous branch (n. cutaneus dorsalis medialis) of the musculo-cutaneous nerve passes in front of the ankle-joint, and divides into two dorsal digital branches (mn. digitales dorsales pedis), one of which supplies the inner side of the great toe, the other the adjacent sides of the second and third toes. It also supplies the integument of the inner ankle and inner side of the foot, communicating with the saphenous nerve, and joining with the anterior tibial nerve, between the great and second toes.

The intermediate dorsal cutaneous branch (n. cutaneus dorsalis intermedius), the smaller, passes along the outer side of the dorsum of the foot, and divides into two dorsal digital branches, the inner being distributed to the contiguous sides of the third and fourth toes, the outer to the opposed sides of the fourth and fifth toes. It also supplies the integument of the outer ankle and outer side of the foot, communicating with the short saphenous nerve.

The branches of the musculo-cutaneous nerve supply all the toes excepting the outer side of the little toe, which is supplied by the small saphenous nerve. The adjoining sides of the great toe or second toe are also supplied by the internal branch of the anterior tibial. It frequently happens that some of the outer branches of the musculo-cutaneous are absent, their place being then taken by branches of the small saphenous nerve.

The Coccygeal Plexus.

The coccygeal plexus is a subdivision of the pudendal plexus, formed chiefly by the anterior division of the fifth sacral nerve, sometimes the fourth also, and the coccygeal nerve. From this plexus arise the anococcygeal nerves which pierce the great sacrosciatic ligament and supply the integument over the coccyx.

Surgical Anatomy.—The lumbar plexus passes through the Psoas muscle, and, therefore, in psoas abscess any or all of its branches may be irritated, causing severe pain in the parts to which the irritated nerves are distributed. The genito-femoral nerve is the one which is most frequently implicated. This nerve is also of importance, as it is concerned in one of the reflexes employed in the investigation of diseases of the spine. If the skin over the inner side of the thigh just below Poupart's ligament, the part supplied by the femoral branch of the genito-
The femoral nerve, being, by gentle tickling in a male child, the testicle will be noticed to be drawn upward through the action of the cremaster muscle, which is supplied by the genital branch of the same nerve. The same result may occasionally be noticed in adults, and can almost always be produced by severe stimulation. This reflex, when present, shows that the portion of the cord from which the first and second lumbar nerves are derived is in a normal condition.

The femoral or anterior crural nerve is in danger of being injured in fractures of the true pelvis, since the fracture most commonly takes place through the ascending rami of the os pubis, at or near the point where this nerve crosses the bone. It is also liable to be injured in fractures and dislocations of the femur, and is likely to be pressed upon, and its functions impaired, in some tumors growing in the pelvis. Moreover, on account of its superficial position, it is exposed to injury in wounds and stabs in the groin. When this nerve is paralyzed, the patient is unable to flex his hip completely, on account of the loss of motion in the iliacus; or to extend the knee on the thigh, on account of paralysis of the quadriceps extensor cruris; there are complete paralysis of the Sartorius and partial paralysis of the Pectineus. There is loss of sensation down the front and inner side of the thigh, except in that part supplied by the femoral branch of the genito-femoral nerve, and by the ilio-inguinal nerve. There is also loss of sensation down the inner side of the leg and foot as far as the ball of the great toe.

The obturator nerve is of special surgical interest. It is rarely paralyzed alone, but occasionally is paralyzed in association with the femoral. The principal interest attached to it is in connection with its supply to the knee; pain in the knee being symptomatic of many diseases in which the trunk of this nerve, or one of its branches, is irritated. Thus it is well known that in the earlier stages of hip-joint disease the patient does not complain of pain in that articulation, but on the inner side of the knee, or in the knee-joint itself, both these articulations being supplied by the obturator nerve, the final distribution of the nerve being to the knee-joint. Again, the same thing occurs in sacro-iliac disease: pain is complained of in the knee-joint or on its inner side. The obturator nerve is in close relationship with the sacro-iliac articulation, passing over it, and, according to some anatomists, distributing filaments to it. Again, in cancer of the sigmoid flexure, and even in cases where masses of hardened faeces are impacted in this portion of the gut, pain is complained of in the knee. The left obturator nerve lies beneath the sigmoid flexure, and is readily pressed upon and irritated when disease exists in this part of the intestine. Finally, pain in the knee forms an important diagnostic sign in obturator hernia. The hernial protrusion as it passes out through the opening in the obturator membrane presses upon the nerve and causes pain in the parts supplied by its peripheral filaments. When the obturator nerve is paralyzed, the patient is unable to press his knees together or to cross one leg over the other, on account of paralysis of the Adductor muscles. Rotation outward of the thigh is impaired from paralysis of the Obturator externus. Sometimes there is loss of sensation in the upper half of the inner side of the thigh.

The great sciatic nerve is liable to be pressed upon by various pelvic tumors, giving rise to pain along its trunk, to which the term sciatica is applied. Tumors growing from the pelvic viscerum, or bones, aneurisms of some of the branches of the internal iliac artery, calculus in the bladder when of large size, accumulation of faeces in the rectum, may all cause pressure on the nerve inside the pelvis, and give rise to sciatica. Outside the pelvis exposure to cold, violent movements of the hip-joint, exostoses or other tumors growing from the margin of the sacro-scatic foramen, may also give rise to the same condition. When paralyzed there is loss of motion in all the muscles below the knee, and loss of sensation in the same situation, except the upper half of the back of the leg, supplied by the small sciatic and the upper half of the inner side of the leg, when the communicating branch of the obturator is large.

The sciatic nerve has been frequently cut down upon and stretched, or has been acupuncture for the relief of sciatica. The nerve has also been stretched in cases of locomotor ataxia, the anaesthesia of leprosy, etc. In order to define it on the surface, a point is taken at the junction of the middle and lower third of a line stretching from the posterior superior spine of the ilium to the outer part of the tuber ischii, and a line is drawn from this point to the middle of the upper part of the popliteal space. This line must be slightly curved with its convexity outward, and as it passes downward to the lower border of the Gluteus maximus is slightly nearer the tuberosity of the ischium than to the great trochanter, as it crosses a line drawn between these two points. The operation of stretching the sciatic nerve is performed by making an incision over the course of the nerve about the centre of the thigh. The skin, superficial structures, and deep fascia having been divided, the interval between the inner and outer hamstrings is to be defined, and these muscles respectively pulled inward and outward with retractors. The nerve will be found a little to the inner side of the Biceps. It is to be separated from the surrounding structures, hooked up with the finger, and stretched by steady and continuous traction for two or three minutes. The sciatic nerve may also be stretched by what is known as the "dry" plan. The patient is laid on his back, the foot is extended, the leg flexed on the thigh, and the thigh strongly flexed on the abdomen. While the thigh is maintained in this position the leg is forcibly extended to its full extent, and the foot as fully flexed on the leg. This last-named method is uncertain.

The position of the external popliteal nerve, close behind the tendon of the Biceps on the outer side of the ham, should be remembered in subcutaneous division of the tendon. After it is divided,
THE CRANIAL NERVES (NERVI CEREBRALES).

The irregularities of origin and distribution of the cranial nerves, as compared with the relatively simple spinal nerves, is so great and their functions were formerly so little known that the older anatomists contented themselves with numbering them in order, beginning at the cephalic end of the brain, and named them with reference to their anatomical connections. The enumeration of the cranial nerves was as variously given, almost, as there were writers upon the subject; the systems of Willis and of Sömmering were most in vogue for a time, but the latter prevails to-day. In Sömmering’s arrangement twelve pairs of cranial nerves are recognized, but, on morphological and functional grounds, the nerves of the seventh and eighth pairs should each be considered as being composed of two nerves, the eleventh pair should be included with the nerves of the tenth, and the optic “nerve” is rather a diverticulum of the brain itself than a nerve in the strict sense. Furthermore, while some of the nerves are sensor or motor in a sense strictly comparable with the spinal nerves, others are “mixed” in function, and yet others constitute nerves of special sense, lacking general sensibility. The numerical names, based upon the order in which they pass through the foramina in the base of the cranium, are being abandoned gradually for the more appropriate functional names, but not yet entirely so. Thus glossopharyngeal has not yet given way to “gustatory;” “vagus” is shorter than “pneumogastric”—a term which is misleading for a nerve which is distributed not only to lungs and stomach, but also to the meninges, the pharynx and oesophagus, larynx and trachea, heart and pericardium, liver and spleen.

The cranial nerves, as usually enumerated, together with their superficial “origin” or attachment to the brain and their foramina of exit from the skull, are tabulated on p. 866. The central olfactory pathway is described on p. 938, and the central connections of the optic tracts are given on p. 921. The central connections of the remaining cranial nerves are described on pp. 892 to 914.

The following is a brief summary of the twelve pairs of cranial nerves, indicating their functional nature:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Functional nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Olfactory (fila)</td>
<td>Smell-sense</td>
</tr>
<tr>
<td>II.</td>
<td>Optic</td>
<td>Visual-sense</td>
</tr>
<tr>
<td>III.</td>
<td>Oculomotor</td>
<td>Motor to muscles of eyeball and orbit</td>
</tr>
<tr>
<td>IV.</td>
<td>Trochlear</td>
<td>Motor to Superior oblique muscles of eyeball</td>
</tr>
<tr>
<td>V.</td>
<td>Trigeminal</td>
<td>Mixed: Sensor to face, tongue, and teeth; motor to muscles of mastication.</td>
</tr>
<tr>
<td>VI.</td>
<td>Abductent</td>
<td>Motor to External rectus muscle of eyeball</td>
</tr>
<tr>
<td>VII.</td>
<td>Facial</td>
<td>Motor to muscles of scalp and face</td>
</tr>
<tr>
<td></td>
<td>Nervus intermedius</td>
<td>Mixed: Sensor (gustatory) to tongue; excitoglandular to submaxillary and sublingual salivary glands.</td>
</tr>
<tr>
<td>VIII.</td>
<td>Acoustic</td>
<td>Hearing-sense</td>
</tr>
<tr>
<td></td>
<td>I. Cochlearis</td>
<td>Equilibratory-sense</td>
</tr>
<tr>
<td></td>
<td>II. Vestibularis</td>
<td>Mixed: Sensor (and gustatory) to tongue and pharynx; motor (?) to Stylopharyngeus muscle.</td>
</tr>
<tr>
<td>IX.</td>
<td>Glossopharyngeal</td>
<td>Mixed: Sensory-motor to respiratory tract and part of alimentary tract.</td>
</tr>
<tr>
<td>X.</td>
<td>Vagus</td>
<td></td>
</tr>
<tr>
<td>XI.</td>
<td>Accessory</td>
<td>Motor to muscles of palate, pharynx, etc.; respiratory organs; inhibitory to heart.</td>
</tr>
<tr>
<td></td>
<td>I. Accessory to vagus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II. Spinal part</td>
<td>Motor to Trapezius and Sternomastoid muscles.</td>
</tr>
<tr>
<td>XII.</td>
<td>Hypoglossal</td>
<td>Motor to muscles of tongue.</td>
</tr>
</tbody>
</table>
THE FIRST OR OLFACTORY NERVE (N. OLFACTORIUS).

The olfactory nerves or fila are the special nerves of the sense of smell, and are about twenty in number on each side. These filaments constitute the first or olfactory nerves and are the axones of the olfactory cells, lying in the small olfactory region in the upper part of the superior concha and corresponding portion of the septum and are macroscopically differentiated from the respiratory region in being of a more brownish hue (Fig. 680). The olfactory fila are amyelinic and exhibit a plexiform arrangement in the deeper layers. After piercing the cribrosa (cribriform plate) of the ethmoid they become attached to the under surface of the olfactory bulb, an oval mass of a grayish color, which rests on the cribiform plate of the ethmoid bone and forms the anterior expanded extremity or a slender process of brain-substance, named the olfactory tract. The olfactory tract and bulb have already been described (p. 935). The olfactory tubercle (trigonum olfactorium) is a small triangular mass of gray substance between the diverging roots of the optic tract (p. 935).

Each nerve is surrounded by tubular prolongations from the dura and pia, the former being lost on the periosteum lining the nose, the latter in the neurilemma of the nerve. The nerves, as they enter the nares, are divisible into two groups: an inner group, larger than those on the outer wall, spread out over the upper third of the septum; and an outer set, which is distributed over the superior turbinated bone, and the surface of the ethmoid in front of it. As the filaments descend, they unite in a plexiform network, and are believed by most observers to terminate by becoming continuous with the deep extremities of the olfactory cells.

The olfactory nerves differ in structure from other nerves in being composed exclusively of non-medullated (amyelinic fibres). They are deficient in the white substance of Schwann, and consist of axones with a distinct nucleated sheath, in which there are, however, fewer nuclei than in ordinary amyelinic fibres.

The central olfactory pathways are described on p. 964.
Surgical Anatomy.—Destruction of the olfactory tract of one side causes loss of smell (anosmia) on the side of the injury, because the olfactory tract is practically uncrossed. In severe injuries to the head the olfactory bulb may become separated from the olfactory nerves, thus producing loss of the sense of smell, and with this a considerable loss in the sense of taste, as much of the perfection of the sense of taste is due to the soluble substances, being also odorous and simultaneously exciting the sense of smell. When the sense of smell is lost, an individual cannot distinguish the flavor of food, but he can distinguish that a substance is salt, or sweet, or bitter, or acid. The most usual cause of injury to the olfactory nerve is fracture of the base of the skull the line of fracture passing through the cribriform plate of the ethmoid bone, but a blow upon the face, forehead, or back of the head, which does not produce fracture may injure the nerve.

THE SECOND OR OPTIC NERVE (N. OPTICUS).

The fibres of the optic nerve, the special nerve of the sense of sight, are the central processes of the retinal ganglion cells which, after converging to the optic papilla, leave the eyeball by piercing its fibrous and vascular tunics as a rounded cord. The point of emergence is situated a little mesad (3 to 4 mm.) of the central axis of the globe. Behind the eyeball the nerve passes backward and inward through the orbital fat and optic foramen to enter the middle fossa of the cranium. The total length of the nerve averages 45 to 50 mm. The two nerves converge to decussate partially, forming the chiasm.

The Chiasm (chiasma opticum) (Figs. 681 and 682 and p. 919).—The chiasm is somewhat quadrilateral in form, rests upon the olivary eminence and on the anterior part of the diaphragma sellae, being bounded above by the terma; behind by the tuber; on either side by the preperforatum. Within the commissure, the optic nerves of the two sides undergo a partial decussation (Figs. 594 and 682) described in detail on pp. 918 and 919.

From the chiasm the optic tracts wind as flattened bands obliquely caudo-laterad around the crura to subdivide, each into two bands, one (mesial root) passing to the postgeniculum and not a true continuation of the optic path (see Gudden’s commissure, p. 919), the other (lateral root) passing to the pregeniculm, the pulvinar, and the pregeninum (p. 919).

The optic path has been described on p. 917.

Surgical Anatomy.—The optic nerve is peculiarly liable to become the seat of neuritis or undergo atrophy in affections of the central nerve system, and, as a rule, the pathologic relationship between the two affections is exceedingly difficult to trace. There are, however, certain points in connection with the anatomy of this nerve which tend to throw light upon the frequent association of these affections with intracranial disease: (1) From its mode of development and from its structure the optic nerve must be regarded as a prolongation of the brain-substance, rather than as an ordinary cerebro-spinal nerve. (2) As it passes from the brain it receives sheaths from the three cerebral membranes—a perineurial sheath from the pia, an intermediate sheath from the arachnoid, and an outer sheath from the dura, which is also connected with the periosteum as it passes through the optic foramen. These sheaths are
THE THIRD OR OCULOMOTOR NERVE

Separated from each other by spaces which communicate with the subdural and subarachnoid spaces respectively. The innermost or perineural sheath sends a process around the arteria centralis retinae into the interior of the nerve, and enters intimately into its structure. Thus inflammatory infections of the meninges or of the brain may readily extend themselves along these spaces or along the interstitial connective tissue in the nerve.

The course of the fibres in the optic commissure has an important pathologic bearing, and has been the subject of much controversy. Microscopic examination, experiments; and pathology all seem to point to the fact that there is a partial decussation of the fibres, each tract supplying the corresponding half of each eye, so that the right tract supplies the right half of each eye, and the left tract the left half of each eye. At the same time, Charcot believes—and his view has met with general acceptance—that the fibres which do not decussate at the optic commissure will decussate in the corpora quadrigemina, so that lesion of the cerebral centre of one side causes complete blindness of the opposite eye, because both sets of decussating fibres are destroyed. Whereas should one tract—say the right—be destroyed by disease, there will be blindness of the right half of both retina.

A sagittal section through the commissure would divide the decussating fibres, and would therefore produce blindness of the inner half of each eye; while a section at the margin of the side of the optic commissure would produce blindness of the external half of the retina of the same side.

The optic nerve may also be affected in injuries or diseases involving the orbit, in fractures of the anterior fossa of the base of the skull, in tumors of the orbit itself, or those invading this cavity from neighboring parts.

THE THIRD OR OCULOMOTOR NERVE (N. OCULOMOTORIUS)
(Figs. 683, 684, 687).

The third or oculomotor nerve supplies all the muscles of the orbit except the Superior oblique and External rectus; it also supplies, through its connection with the ciliary ganglion, the Sphincter muscle of the iris and the Ciliary muscle. It is rather a large nerve, of rounded form and firm texture.

Its apparent origin is from the oculomotor groove along the ventro-mesal border of the crus. The deep origin may be traced through the substantia nigra and tegmentum of the crus to a nucleus situated on either side of the median line beneath the floor of the aqueduct. The nucleus of the oculomotor nerve also receives fibres from the abducent nerve of the opposite side. The nucleus of the oculomotor nerve, considered from a physiological standpoint, can be subdivided into several smaller groups of cells, each group controlling a particular muscle (see p. 911). The nerves to the different muscles appear to take their origin from before backward, as follows: Inferior oblique, Inferior rectus, Superior rectus and Levator palpebrae, Internal rectus; while from the cephalic end of the nucleus the fibres for accommodation and for the Sphincter pupillic take their origin.

On emerging from the brain, the nerve is invested with a sheath of pia, and enclosed in a prolongation from the arachnoid. It passes between precerebellar and postcerebral arteries, and then pierces the dura in front of and external to the posterior clinoid process, passing between the two processes from the free and attached borders of the tentorium, which are prolonged forward to be connected with the anterior and posterior clinoid processes of the sphenoid bone. It passes along the outer wall of the cavernous sinus (Figs. 454 and 455); above the other orbital nerves, receiving in its course one or two filaments from the cavernous plexus of the sympathetic, and a communicating branch from the first division of the trigeminal nerve. It then divides into two branches, which enter the orbit through the sphenoidal fissure, between the two heads of the External rectus muscle (Fig. 683). On passing through the fissure, the nerve is placed below the trochlear nerve and the frontal and lacrimal branches of the ophthalmic nerve, and has passing between its two divisions the nasal nerve (Fig. 692).

The Superior Division (ramus superior) (Fig. 684).—The superior division, the smaller, passes inward over the optic nerve, and supplies the Superior rectus and Levator palpebrae.
The Inferior Division (ramus inferior) (Fig. 684).—The inferior division, the larger, divides into three branches. One passes beneath the optic nerve to the Internal rectus; another, to the Inferior rectus; and the third, the longest of the three, passes forward between the Inferior and External recti to the Inferior oblique. From this latter a short, thick branch, radix brevis ganglii ciliaris, is given off to the lower part of the ciliary or lenticular ganglion and forms its short or motor root (Figs. 684 and 687). It also gives off one or two filaments to the Inferior rectus. All these branches enter the muscles on their ocular surface, except that to the Inferior oblique, which enters its posterior border.

Surgical Anatomy.—Paralysis of the oculomotor nerve may be the result of many causes: as cerebral disease; conditions causing pressure on the cavernous sinus; periostitis of the bone entering into the formation of the sphenoidal fissure; fracture of the orbit. It results, when complete, in (1) ptosis, or drooping of the upper eyelid, in consequence of the Levator palpebræ being paralyzed; (2) external strabismus, on account of the unopposed action of the External rectus muscle, which is not supplied by the oculomotor nerve, and is therefore paralyzed; (3) dilatation of the pupil, because the sphincter fibres of the iris are paralyzed; (4) loss of power of accommodation, as the Sphincter pupille, the Ciliary muscle, and the Internal rectus are paralyzed; (5) slight prominence of the eyeball, owing to most of its muscles being relaxed. Occasionally paralysis may affect only a part of the nerve; that is to say, there may be, for example, a dilated and fixed pupil, with ptosis, but no other signs. Irritation of the nerve causes spasm of one or other of the muscles supplied by it; thus, there may be internal strabismus from spasm of the Internal rectus; accommodation for near objects only from spasm of the Ciliary muscle, or contraction of the pupil (myosis), from irritation of the sphincter of the pupil.
THE FOURTH OR TROCHLEAR NERVE (N. TROCHLEARIS) (Figs. 683 and 687).

The fourth or trochlear nerve or patheticus, with the exception of the n. intermedius, the smallest of the cranial nerves, supplies the Superior oblique muscle.

The apparent origin, at the base of the brain, is on the outer side of the crus cerebri, just in front of the pons, but the fibres can be traced backward behind the quadrigemina to the valvula, on the upper surface of which the two nerves decussate, decussatio nervorum trochlearium. Its deep origin may be traced to a nucleus in the floor of the aqueduct immediately below that of the oculomotor nerve, with which it is continuous (Fig. 578).

Emerging from the valvula, the nerve is directed outward across the prepeduncle of the cerebellum, and then winds forward around the outer side of the crus cerebri, immediately above the pons, pierces the dura in the free border of the tentorium, just behind, and external to, the posterior clinoid process, and passes forward in the outer wall of the cavernous sinus, between the oculomotor nerve and the ophthalmic division of the trigeminal nerve (Figs. 454 and 455). It crosses the oculomotor nerve and enters the orbit through the sphenoidal fissure (Fig. 692). It now becomes the highest of all the nerves, lying at the inner extremity of the fissure internal to the frontal nerve. In the orbit it passes inward, above the origin of the Levator palpebrae, and finally enters the orbital surface of the Superior oblique muscle. In the outer wall of the cavernous sinus this nerve is not infrequently blended with the ophthalmic division of the trigeminal nerve.

Branches of Communication.—In the outer wall of the cavernous sinus it receives some filaments from the cavernous plexus of the sympathetic. In the sphenoidal fissure it occasionally gives off a branch to assist in the formation of the lacrimal nerve.

Branches of Distribution.—It gives off a recurrent branch, which passes backward between the layers of the tentorium, dividing into two or three filaments which may be traced as far back as the wall of the lateral sinus.

Surgical Anatomy.—The trochlear nerve when paralyzed causes loss of function in the Superior oblique, so that the patient is unable to turn his eye downward and outward. Should the patient attempt to do this, the eye on the affected side is twisted inward, producing diplopia or double vision. Accordingly, it is said that the first symptom of this disease which presents itself is giddiness when going down hill or in descending stairs, owing to the double vision induced by the patient looking at his steps while descending.

THE FIFTH, TRIGEMINAL OR TRIFACIAL NERVE (N. TRIGEMINUS) (Figs. 683, 685, 686, 687, 688, 689, 690, 691).

The fifth or trigeminal or trifacial nerve is the largest cranial nerve. It resembles a spinal nerve (1) in having two roots; (2) in having a ganglion developed on its dorsal root; and (3) in its function, since it is a compound nerve. It is the great sensor nerve of the head and face and the motor nerve of the muscles of mastication. Its upper two divisions, portio major, are entirely sensor, the third division, portio minor, is partly sensor and partly motor. It arises by two roots: of these the ventral is the smaller, and is the motor root (Fig. 578); the dorsal, the larger and sensor root. Its superficial origin is from the side of the pons nearer to the upper than the lower border (Fig. 578). The smaller root consists of three or four bundles; the larger root consists of numerous bundles of fibres, varying in number from seventy to a hundred. The two roots are separated from one another by a few of the transverse fibres of the pons. The
deep termination of the larger or sensor root is chiefly in a long tract in the oblongata, the lower sensor nucleus, which is continuous below with the glosia or substantia gelatinosa of Rolando. The fibres from this nucleus form the so-called ascending root of the fifth nerve; they pass upward through the pons and join with fibres from the locus cereuleus or upper sensor nucleus (Fig. 578), which is situated to the outer side of the nucleus, from which the lower part of the motor root takes origin. The deep origin of the smaller or motor root is derived partly from a nucleus embedded in the gray substance of the upper part of the floor of the fourth ventricle and partly from a collection of nerve-cells situated at the side of the aqueduct from which the fibres pass caudad under the name of the descending root of the fifth nerve (Fig. 578).

The two roots of the nerve pass forward below the tentorium as it bridges over the notch on the inner part of the superior border of the petrous portion of the temporal bone (Fig. 686); they then run between the bone and the dura to the apex of the petrous portion of the temporal bone, where the fibres of the sensor root appear to enter into the formation of the large semilunar or Gasserian ganglion (Figs. 685 and 686), while the motor root passes beneath the ganglion without having any connection with it, and joins outside the cranium with one of the trunks derived from it (Figs. 685 and 686).

![Diagram of the Nerve System](image_url)

Fig. 685.—The right semilunar or Gasserian ganglion, viewed from the medial side. (Spalteholz.)

The Gasserian or Semilunar Ganglion¹ (ganglion semilunare) (Figs. 685, 686, 687, 688, 689, and 690).—The Gasserian or semilunar ganglion is lodged in an osteo-fibrous space, the cavum Meckelli (Figs. 644 and 686), near the apex of the petrous portion of the temporal bone. The ganglion is of somewhat crescentic form, with its convexity turned forward. Its upper surface is intimately adherent to the dura. Besides the small or motor root, the large superficial petrosal nerve lies underneath the ganglion.

Branches of Communication.—This ganglion receives on its inner side filaments from the carotid plexus of the sympathetic.

Branches of Distribution.—It gives off minute branches to the tentorium and the dura in the middle fossa of the cranium. From its anterior border, which is

¹ A Viennese anatomist, Raimund Balthasar Hirsch (1765), was the first who recognized the ganglionic nature of the swelling on the sensory root of the fifth nerve, and called it, in honor of his otherwise unknown teacher, Jon. Laur. Gasser, the "Ganglion Gasseri." Julius Casserius, whose name is given to the musculocutaneous nerve of the arm, was professor at Padua, 1545-1605. (See Hyrtl, Lehrbuch der Anatomie, p. 805 and p. 85.) Ed. of 16th English edition.
directed forward and outward, three large branches proceed—the ophthalmic, superior maxillary, and inferior maxillary. The ophthalmic and superior maxillary consist exclusively of fibres derived from the larger root and ganglion, and are solely nerves of common sensation. The third division, or inferior maxillary, is joined outside the cranium by the motor root. This, therefore, strictly speaking, is the only portion of the trigeminal nerve which can be said to resemble a spinal nerve.

**Ophthalmic Nerve** (*n. ophthalmicus*) (Figs. 683, 685, 686, 687, 688, 689, and 690).—The ophthalmic or first division of the trigeminal is a sensor nerve. It supplies the eyeball, the lacrimal gland, the mucous lining of the eye and nasal fossæ, and the integument of the eyebrow, forehead, and nose (Fig. 691). It is the smallest of the three divisions of the fifth, arising from the upper part of the Gasserian ganglion. It is a short, flattened band, about 2 cm. in length, which passes forward along the outer wall of the cavernous sinus (Figs. 454 and 455), below the other nerves (Fig. 685), and just before entering the orbit, through the sphenoidal fissure, divides into three branches—lacrimal, frontal, and nasal (Figs. 683, 687, and 688).

**Branches of Communication.**—The ophthalmic nerve gives off in the cavernous sinus a branch to the dura (*n. tentorii*), is joined by filaments from the cavernous plexus of the sympathetic, and gives off minute branches to communicate with the oculomotor and abducens nerves, and not infrequently with the trochlear.

**Branches of Distribution.**—It gives off recurrent filaments which pass between the layers of the tentorium, and then divide into—

- **Lacrimal.**
- **Frontal.**
- **Nasal.**

**The Lacrimal Nerve** (*n. lacrimalis*) (Figs. 683, 687, and 688).—The lacrimal is the smallest of the three branches of the ophthalmic. It sometimes receives a filament from the trochlear nerve, but this is possibly derived from the branch of communication which passes from the ophthalmic to the trochlear. It passes forward in a separate tube of dura, and enters the orbit through the narrowest part of the sphenoidal fissure (Fig. 692). In the orbit it runs along the upper border of the External rectus muscle, with the lacrimal artery, and communicates with the temporomalar branch of the superior maxillary nerve. It enters the lacrimal gland and gives off several filaments, which supply the gland and the conjunctiva. Finally, it pierces the superior palpebral ligament, and terminates in the integument of the upper eyelid, joining with filaments of the facial nerve. The lacrimal nerve is occasionally absent, when its place is taken by the temporal branch of the superior maxillary. Sometimes the latter branch is absent, and a continuation of the lacrimal is substituted for it.

**The Frontal Nerve** (*n. frontalis*) (Figs. 683 and 687).—The frontal is the largest division of the ophthalmic, and may be regarded, both from its size and direction, as the continuation of the nerve. It enters the orbit above the muscles, through the sphenoidal fissure (Fig. 692), and runs forward along the middle line, between the Levator palpebrarum and the periosteum. Midway between the apex and the base of the orbit it divides into two branches, supratrochlear and supraorbital.
The **Supratrochlear Branch** (*n. supratrochlearis*) (Fig. 683), the smaller of the two, passes inward, above the pulley of the superior oblique muscle, and gives off a descending filament, which joins with the infratrochlear branch of the nasal nerve. It then escapes from the orbit between the pulley of the Superior oblique and the supraorbital foramen, curves up on to the forehead close to the bone, ascends beneath the Corrugator supercilii and Occipito-frontalis muscles, and, dividing into branches which pierce these muscles, it supplies the integument of the lower part of the forehead on either side of the middle line and sends filaments to the conjunctiva and skin of the upper lid.

The **Supraorbital Branch** (*n. supraorbitalis*) (Fig. 692) passes forward through the supraorbital foramen, and gives off, in this situation, **palpebral filaments** to the upper eyelid. It then ascends upon the forehead, and terminates in **cutaneous and pericranial branches**.

The **cutaneous branches**, two in number, an inner and an outer, supply the integument of the cranium as far back as the vertex. They are at first situated beneath the Occipito-frontalis, the inner branch perforating the frontal portion of the muscle, the outer branch its tendinous aponeurosis.

The **pericranial branches** are distributed to the pericranium over the frontal and parietal bones.

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**The Nasal Nerve** (*n. nasociliaris*) (Figs. 683 and 687).—The nasal nerve is intermediate in size between the frontal and lacrimal, and more deeply placed than the other branches of the ophthalmic. It enters the orbit by way of the sphenoidal fissure (Fig. 692) between the two heads of the External rectus, and passes obliquely inward across the optic nerve, beneath the Superior rectus and Superior oblique muscles, to the inner wall of the orbit, where it passes through the anterior ethmoidal foramen, and, entering the cavity of the cranium, traverses a shallow groove on the front of the cribiform plate of the ethmoid bone, and passes down, through the slit by the side of the crista galli, into the nose (Fig. 689), where it divides into two branches, an **internal** and an **external branch**. The **internal branch** (*rami nasales mediales*) supplies the mucous membrane near the forepart of the septum of the nose. The **external branch** (*rami nasales laterales*) descends in a groove on the inner surface of the nasal bone, and supplies a few filaments to the mucous membrane covering the forepart of the outer wall of the nares as far as the inferior turbinate bone; it then leaves the cavity.
of the nose, between the lower border of the nasal bone and the upper lateral cartilage of the nose, and, passing down beneath the Compressor nasi, supplies the integument of the ala and the tip of the nose, joining with the facial nerve.

Branches.—The branches of the nasal nerve are the ganglionic, ciliary, and infra-trochlear.

The Ganglionic Branch or the long root of the ciliary ganglion (radix longa ganglii ciliaris) (Figs. 684 and 687) is a slender branch, about 1 to 2 cm. in length, which usually arises from the nasal nerve, between the two heads of the External rectus muscle. It passes forward on the outer side of the optic nerve, and enters the postero-superior angle of the ciliary ganglion, forming its long root. It is sometimes joined by a filament from the cavernous plexus of the sympathetic or from the superior division of the third nerve.

The Long Ciliary Nerves (nn. ciliares longi), two or three in number, are given off from the nasal as it crosses the optic nerve. They join the short ciliary nerves (Figs. 684 and 687) from the ciliary ganglion, pierce the posterior part of the sclera, and, running forward between it and the choroid, are distributed to the ciliary muscle, iris, and cornea.

The Infra-trochlear Branch (n. infra-trochlearis) (Fig. 683) is given off just before the nasal nerve passes through the anterior ethmoidal foramen. It runs forward along the upper border of the Internal rectus muscle, and is joined, beneath the pulley of the Superior oblique, by a filament from the supratrochlear nerve. It then passes to the inner angle of the eye, and supplies the integument of the eyelids and side of the nose, the conjunctiva, the lacrimal sac, and the caruncula lacrimalis.

Connected with the three divisions of the trigeminal nerve are four small ganglia. With the first division is connected the ophthalmic ganglion; with the second division, the sphenopalatine or Meckel's ganglion; and with the third, the otic and submaxillary ganglia. All the four receive sensor filaments from the trigeminal nerve, and motor and sympathetic filaments from various sources; these filaments are called the roots of the ganglia.

The Ophthalmic, Lenticular or Ciliary Ganglion (ganglion ciliare) (Figs. 684 and 687) is a small, quadrangular, flattened ganglion, of a reddish-gray color, and about the size of a pin's head, situated at the back part of the orbit between the optic nerve and the External rectus muscle, lying generally on the outer side of the ophthalmic artery. It is enclosed in a quantity of loose fat, which makes its exposure by dissection somewhat difficult.

Its branches of communication or roots are three, all of which enter its posterior border. One, the long or sensor root (radix longa ganglii ciliaris), is derived from the nasal branch of the ophthalmic and joins the superior angle of the ganglion. The second, the short or motor root (radix brevis ganglii ciliaris), is a short, thick nerve, occasionally divided into two parts, which is derived from the branch of the oculomotor to the Inferior oblique muscle, and is connected with the inferior angle of the ganglion. The third, the sympathetic root (radix sympathetic ganglii ciliaris), is a slender filament from the cavernous plexus of the sympathetic. This is frequently blended with the long root, although it sometimes passes to the ganglion separately. The ganglion occasionally receives a filament of communication from the sphenopalatine ganglion.

Its branches of distribution are the short ciliary nerves (nn. ciliares breves) (Figs. 684 and 687). These are delicate filaments, from six to ten in number, which arise from the forepart of the ganglion in two bundles, connected with its superior and inferior angles; the lower bundle is the larger. They run forward with the ciliary arteries in a wavy course, one set above and the other below the optic nerve, and are accompanied by the long ciliary branches of the nasal nerve. They pierce the sclera at the back part of the globe, pass forward in delicate
grooves on its inner surface, and are distributed to the Ciliary muscle, iris, and cornea. One small branch is said to penetrate the optic nerve with the arteria centralis retinae.

The circular fibres of the iris are innervated by the oculomotor nerve; the radiating fibres are innervated by the sympathetic.

The Superior Maxillary Nerve (n. maxillaris) (Figs. 685, 686, 687, and 688).
—The superior maxillary or second division of the trigeminal is a sensor nerve. It is intermediate, both in position and size, between the ophthalmic and inferior maxillary. It commences at the middle of the Gasserian ganglion as a flattened plexiform band (Fig. 685), and, passing horizontally forward, it leaves the skull through the foramen rotundum (Fig. 686), where it becomes more cylindrical in form and firmer in texture. It then crosses the sphenoid-maxillary fossa (Fig. 67) enters the orbit through the sphenoid-maxillary fissure, traverses the infraorbital canal in the floor of the orbit, and appears upon the face at the infraorbital foramen. After it enters the infraorbital canal the nerve is usually called the infraorbital (n. infraorbitalis), and is, therefore, the terminal branch of the superior maxillary nerve (Fig. 688). At its termination the nerve lies beneath the Levator labii superioris muscle, and divides into a leash of branches, which spread out upon the side of the nose, the lower eyelid, and upper lip, joining with filaments of the facial nerve.

Branches of Distribution.—The branches of this nerve may be divided into four groups: 1. Those given off in the cranium. 2. Those given off in the sphenomaxillary fossa. 3. Those in the infraorbital canal. 4. Those on the face.

In the cranium . . . Dural.

Sphenomaxillary fossa . . .

Infraorbital canal . . .

On the face . . .

Dural.

Orbital or temporo-malar.

Spheno-palatine.

Posterior superior dental.

Middle superior dental.

Anterior superior dental.

Palpebral.

Nasal.

Labial.

The Dural Branch (n. meningeus medius).—The dural branch is given off by the superior maxillary nerve directly after its origin from the Gasserian ganglion; it accompanies the medidural artery and supplies the dura of the middle fossa of the base of the skull.

The Orbital or Temporo-malar Branch (n. zygomaticus) (Figs. 687 and 688).—The orbital or temporo-malar branch arises in the sphenomaxillary fossa, enters the orbit by the sphenomaxillary fissure, and divides at the back of that cavity into two branches, temporal and malar.

The Temporal Branch (ramus zygomaticotemporalis) runs in a groove along the outer wall of the orbit (in the malar bone), receives a branch of communication from the lacrimal, and, passing through a foramen in the malar bone, enters the temporal fossa. It ascends between the bone and the substance of the Temporal muscle, pierces this muscle and the temporal fascia about an inch above the zygoma, and is distributed to the integument covering the temple and side of the forehead, communicating with the facial and the auriculo-temporal branch of the inferior maxillary nerve. As it pierces the temporal fascia it gives off a slender twig, which runs between the two layers of the fascia to the outer angle of the orbit.

The Malar Branch (ramus zygomaticofacialis) passes along the external inferior angle of the orbit, emerges upon the face through a foramen in the malar bone, and, perforating the Orbicularis palpebrarum muscle, supplies the skin on the
prominence of the cheek, where it is named the subcutaneus malae. It joins with the facial and the palpebral branches of the superior maxillary.

The Spheno-palatine Branches (nn. sphenopalatini) (Fig. 688).—The sphenopalatine branches, two in number, descend to the spheno-palatine ganglion, of which ganglion they are the sensor or short roots.

The Posterior Superior Dental Branches (rami alveolares superiores posteriores) (Fig. 688).—The posterior superior dental branches arise from the trunk of the nerve just as it is about to enter the infraorbital canal; they are generally two in number, but sometimes arise by a single trunk, and immediately divide and pass downward on the tuberosity of the superior maxillary bone. They give off several twigs to the gums and neighboring parts of the mucous membrane of the cheek, superior gingival branches (rami gingivales superiores). They then enter the posterior dental canals on the zygomatic surface of the superior maxil-
enlargement, which is called the **ganglion of Bochdalek**. Neither of these is a true ganglion.

**The Anterior Superior Dental Branch** (*ramus alveolaris superior anteriores*).—The anterior superior dental branch, of large size, is given off from the superior maxillary nerve just before its exit from the infraorbital foramen; it enters a special canal in the anterior wall of the antrum, and divides into a series of branches which supply the incisor and canine teeth. It communicates with the middle dental nerve by a plexus, and gives off a **nasal branch**, which passes through a minute canal into the nasal fossa, and supplies the mucous membrane of the forepart of the inferior meatus and the floor of the cavity, communicating with the nasal branches from the spheno-palatine ganglion.

The **superior dental plexus** (*plexus dentalis superior*) is formed by twigs of the three superior dental nerves. From the plexus come the nerves which supply the teeth of the upper jaw (*rami dentales superiores*) and the gums (*rami gingivales superiores*).

The branches upon the face are known as the **rami n. infraorbitalis** (Fig. 688). There are three sets of them.

**The Palpebral Branches** (*rami palpebrales inferiores*).—The palpebral branches pass upward beneath the Orbicularis palpebrarum muscle. They supply the integument and conjunctiva of the lower eyelid with sensation, joining at the outer angle of the orbit with the facial nerve and the malar branch of the orbital.

**The Nasal Branches** (*rami nasales interni*).—The nasal branches pass inward; they supply the integument of the side of the nose and join with the nasal branch of the ophthalmic.

**The Labial Branches** (*rami labiales superiores*).—The labial branches, the largest and most numerous, descend beneath the Levator labii superioris muscle, and are distributed to the integument of the upper lip, the mucous membrane of the mouth, and the labial glands.

All these branches are joined, immediately beneath the orbit, by filaments from the facial nerve, forming an intricate plexus, the **infraorbital plexus**.

**The Spheno-palatine or Meckel's Ganglion** (*ganglion sphenopalatinum*) (Fig. 689).—The sphenopalatine ganglion, the largest of the cranial ganglia, is deeply placed in the sphenomaxillary fossa, close to the spheno-palatine foramen. It is triangular or heart-shaped, of a reddish-gray color, and is situated just below the superior maxillary nerve as it crosses the fossa.

**Branches of Communication.**—Like the other ganglia of the trigeminal nerve, it possesses a motor, a sensor, and a sympathetic root. Its **sensor root** is derived from the superior maxillary nerve through its two sphenopalatine branches (p. 1047). These branches of the nerve are given off in the sphenomaxillary fossa and descend to the ganglion. Their fibres, for the most part, pass in front of the ganglion, as they proceed to their destination, in the palate and nasal fossa, and are not incorporated in the ganglionic mass; some few of the fibres, however, enter the ganglion, constituting its sensor root. Its **motor root** is derived from the facial nerve through the large superficial petrosal nerve, and its **sympathetic root** from the carotid plexus, through the large deep petrosal nerve. These two nerves join together before their entrance into the ganglion to form a single nerve, the **Vidian**.

The **Large or Great Superficial Petrosal Branch** (*n. petrosus superficialis major*) (Fig. 693) is given off from the **geniculate ganglion** of the facial nerve in the aqueductus Fallopii; it passes through the hiatus Fallopii; enters the cranial cavity, and runs forward, being contained in a groove on the anterior surface of the petrous portion of the temporal bone and lies beneath the dura. It then enters the cartilaginous substance which fills in the foramen lacerum medium basis cranii, and, joining with the large deep petrosal branch, forms the Vidian nerve.
The **Large or Great Deep Petrosal Branch** (*n. petrosus profundus*) (Fig. 694) is given off from the carotid plexus of the sympathetic upon the internal carotid artery, and runs through the carotid canal on the outer side of the internal carotid artery. It then enters the cartilaginous substance which fills in the foramen lacerum medium basis crani, and joins with the large superficial petrosal nerve to form the Vidian.

The **Vidian Nerve** (*n. canalis pterygoidei*) (Fig. 689), formed in the cartilaginous substance which fills in the middle lacerated foramen by the junction of the two preceding nerves, passes forward, through the Vidian canal, with the artery of the same name, and is joined by a small ascending nervous branch, the **sphenoidal branch**, from the otic ganglion. Finally, it enters the spheno-maxillary fossa, and joins the posterior angle of the spheno-palatine ganglion.

**Branches of Distribution of the Spheno-palatine Ganglion.**—Its branches of distribution are divisible into four groups: **ascending**, which pass to the orbit; **descending**, to the palate; **internal**, to the nose; and **posterior branches**, to the pharynx and nasal fossæ.

The **Ascending Branches** (*rami orbitales*) are two or three delicate filaments which enter the orbit by the spheno-maxillary fissure, and supply the peristeum. According to Luschka, some filaments pass through foramina in the suture between the os planum of the ethmoid and frontal bones to supply the mucous membrane of the posterior ethmoidal and sphenoidal sinuses.

The **Descending or Palatine Branches** (*nn. palatini*) (Fig. 689) are distributed to the roof of the mouth, the soft palate, tonsil, and lining membrane of the nose. They are almost a direct continuation of the spheno-palatine branches of the superior maxillary nerve, and are three in number—**anterior**, **middle**, and **posterior**.

The **anterior or large palatine nerve** (*n. palatinus anterior*) descends through the **large posterior palatine canal**, emerges upon the hard palate at the posterior palatine foramen, and passes forward through a groove in the hard palate nearly
as far as the incisor teeth. It supplies the gums, the mucous membrane and glands of the hard palate, and communicates in front with the termination of the naso-palatine nerve (see below). While in the posterior palatine canal it gives off inferior nasal branches (rami nasales posteriores inferiores), which enter the nose through openings in the palate bone, and ramify over the inferior turbinate bone, the middle and the inferior meatus; and at its exit from the canal a palatine branch is distributed to both surfaces of the soft palate.

The middle or external palatine nerve (n. palatinus medius) descends through one of the accessory palatine canals, distributing branches to the uvula, tonsil, and soft palate. It is occasionally wanting.

The posterior or small palatine nerve (n. palatinus posterior) descends with a minute artery through the small posterior palatine canal, emerging by a separate opening behind the posterior palatine foramen. It supplies the Levator palatini and Azygos uvulae muscles, the soft palate, tonsil, and uvula. The middle and posterior palatine join with the tonsillar branches of the glosso-pharyngeal to form the plexus around the tonsil, the circulus tonsillaris.

The Internal Branches are distributed to the septum and outer wall of the nasal fossa. They are the posterior superior nasal and the naso-palatine.

The posterior superior nasal branches (rami nasales posteriores superiores), three in number, enter the back part of the nasal fossa by the sphenopalatine foramen. They supply the mucous membrane covering the superior and middle spongy bones, and that lining the posterior ethmoidal cells, a few being prolonged to the upper and back part of the septum.

The naso-palatine nerve (n. nasopalatinus) has been called the nerve of Scarpa and also the nerve of Cotunnius. It enters the nasal fossa through the sphenopalatine foramen, and passes inward across the roof of the nose, below the orifice of the sphenoidal sinus, to reach the septum; it then runs obliquely downward and forward along the lower part of the septum, to the anterior palatine foramen, lying between the peristeum and mucous membrane. It descends to the roof of the mouth through the anterior palatine canal (Fig. 689). The two nerves are here contained in separate and distinct canals, situated in the intermaxillary suture, and termed the foramina of Scarpa, the left nerve being usually anterior to the right one. In the mouth they become united, supply the mucous membrane behind the incisor teeth, and join with the anterior palatine nerve. The naso-palatine nerve furnishes a few small filaments to the mucous membrane of the septum.

The Posterior Branches are the pharyngeal or pterygo-palatine and the upper posterior nasal branches.

The pharyngeal or pterygo-palatine nerve (Fig. 689) is a small branch arising from the back part of the sphenopalatine ganglion, being generally blended with the Vidian nerve. It passes through the pterygo-palatine canal with the pterygo-palatine artery, and is distributed to the mucous membrane of the upper part of the pharynx, behind the Eustachian tube.

The upper posterior nasal branches are a few twigs given off from the posterior part of the sphenopalatine ganglion, which run backward in the sheath of the Vidian nerve to the mucous membrane at the back part of the roof, septum, and superior meatus of the nose and that covering the end of the Eustachian tube.

The Mandibular or Inferior Maxillary Nerve (n. mandibularis) (Figs. 685, 687, and 688).—The inferior maxillary or third division of the trigeminal nerve distributes branches to the teeth and gums of the lower jaw, the integument of the temple and external ear, the lower part of the face and lower lip, and the muscles of mastication; it also supplies the tongue with a large branch. It is the largest of the three divisions of the trigeminal, and is made up of two roots: a large or sensor

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1 It is probable that this is not the true motor supply to these muscles, but that they are supplied by the accessory nerve through the pharyngeal plexus.—Ed. of 18th English edition.
root, proceeding from the inferior angle of the Gasserian ganglion; and a small or motor root, which passes beneath the ganglion and unites with the sensor root just after its exit from the skull through the foramen ovale (Figs. 685, 686, and 688). Immediately beneath the base of the skull this nerve divides into two trunks, anterior and posterior. Previous to its division the primary trunk gives off from its inner side a recurrent branch and the nerve to the Internal pterygoid muscle.

The Recurrent or Meningeal Branch (n. spinosus).—The recurrent or meningeal branch is given off directly after the exit of the mandibular nerve from the foramen ovale. It passes backward into the skull through the foramen spinosum with the medidural artery. It divides into two branches, anterior and posterior, which accompany the main divisions of the artery and supply the dura. The posterior branch also supplies the mucous lining of the mastoid cells. The anterior branch communicates with the dural branch of the superior maxillary nerve.

The Internal Pterygoid Nerve (n. pterygoideus internus).—The internal pterygoid nerve, given off from the inferior maxillary previous to its division, is intimately connected at its origin with the otic ganglion. It is a long and slender branch, which passes inward to enter the deep surface of the Internal pterygoid muscle.

The anterior and smaller division of the inferior maxillary nerve, which receives nearly the whole of the motor root of the trigeminal nerve, divides into branches which supply the muscles of mastication. They are the masseteric, deep temporal, buccal, and external pterygoid branches (Fig. 688).

The Masseteric Branch (n. massetericus) passes outward, above the External pterygoid muscle, in front of the temporo-mandibular articulation and behind the tendon of the temporal muscle; it crosses the sigmoid notch with the masseteric artery, to the deep surface of the Masseter muscle, in which it ramifies nearly as far as its anterior border. It occasionally gives a branch to the Temporal muscle, and a filament to the articulation of the jaw.

The Deep Temporal Branches (nn. temporales profundi), two in number, anterior and posterior, supply the deep surface of the Temporal muscle. The posterior branch (n. temporalis profundus posterior), of small size, is placed at the back of the temporal fossa. It is sometimes joined with the masateric branch. The anterior branch (n. temporalis profundus anterior) is frequently given off from the buccal nerve; it is reflected upward, at the pterygoid ridge of the sphenoid, to the front of the temporal fossa. Sometimes there are three deep temporal branches, and if this maintains the third branch, the middle deep temporal, passes outward above the External pterygoid muscle, and runs upward on the bone to enter the deep surface of the Temporal muscle.

The Buccal or Buccinator Branch (n. buccinatorius) passes forward between the two heads of the External pterygoid, and downward beneath the inner surface of the coronoid processes of the lower jaw, or through the fibres of the Temporal muscle, to reach the surface of the Buccinator muscle, upon which it divides into a superior and an inferior branch. It gives a branch to the External pterygoid during its passage through that muscle, and a few ascending filaments to the Temporal muscle, one of which occasionally joins with the anterior branch of the deep temporal nerve. The superior or upper branch supplies the integument and upper part of the Buccinator muscle, joining with the facial nerve around the facial vein. The inferior or lower branch passes forward to the angle of the mouth; it supplies the integument and Buccinator muscle, as well as the mucous membrane lining the inner surface of that muscle, and joins the facial nerve.1

The External Pterygoid Nerve (n. pterygoideus externus) is most frequently derived from the buccal, but it may be given off separately from the anterior trunk of the mandibular nerve. It enters the muscle on its inner surface.

1 There seems to be no reason to doubt that the branch supplying the Buccinator muscle is entirely a nerve of ordinary sensation, and that the true motor supply of this muscle is from the facial.—Eo. of 16th English edition.
The posterior and larger division of the inferior maxillary nerve is for the most part sensor, but receives a few filaments from the motor root. It divides into three branches: auriculotemporal, lingual (gustatory), and inferior dental (Fig. 688).

The Auriculotemporal Nerve (n. auriculotemporalis) (Fig. 690) generally arises by two roots, between which the medidural artery passes. It runs backward beneath the External pterygoid muscle to the inner side of the neck of the lower jaw. It then turns upward with the temporal artery, between the external ear and the condyle of the jaw, under cover of the parotid gland, and, escaping from beneath this structure, ascends over the zygoma and divides into two temporal branches.

The branches of communication are with the facial and with the otic ganglion. The branches of communication with the facial (rami anastomotici cum n. facialis), usually two in number, pass forward from behind the neck of the condyle of the jaw, to join this nerve at the posterior border of the Masseter muscle. They form one of the principal branches of communication between the facial and the trigeminal nerve. The filaments of communication with the otic ganglion are derived from the commencement of the auriculotemporal nerve.

The branches of distribution are—

- Anterior auricular.
- Branches to the meatus auditorius.
- Articular.
- Parotid.
- Superficial temporal.

The anterior auricular branches (rami auriculares anteriores) are usually two in number. They supply the front of the upper part of the pinna, being distributed principally to the skin covering the front of the helix and tragus.

A branch to the external auditory meatus (n. meatus auditorii externi) divides into two. The two nerves enter the canal between the bony and cartilaginous portion of the meatus. They supply the skin lining the meatus; the upper one sending a filament to the membrana tympani (ramus membranae tympani).

A branch to the temporo-mandibular articulation, the articular branch, is usually derived from the auriculotemporal nerve.

The parotid branches (rami parotidei) supply the parotid gland.

The superficial temporal branches (rami temporales superficiales) accompany the temporal artery to the vertex of the skull, and supply the integument of the temporal region, communicating with the facial nerve, and with the temporal branch of the temporo-malar from the superior maxillary.

The Lingual Nerve (n. lingualis) (Fig. 688).—The lingual nerve supplies the papilla and mucous membrane of the anterior two-thirds of the tongue. It is deeply placed throughout the whole of its course. It lies at first beneath the External pterygoid muscle, together with the inferior dental nerve, being placed to the inner side of this nerve, and is occasionally joined to it by a branch which may cross the internal maxillary artery. The chorda tympani nerve also joins it at an acute angle in this situation. The nerve then passes between the Internal pterygoid muscle and the inner side of the ramus of the jaw, and crosses obliquely to the side of the tongue over the Superior constrictor of the pharynx and the Stylo-glossus muscles, and then between the Hyo-glossus muscle and the deep part of the submaxillary gland; the nerve finally runs across Wharton’s duct, and along the side of the tongue to its apex, lying immediately beneath the mucous membrane.

The branches of communication are with the inferior dental and hypoglossal nerves, and the submaxillary ganglion, and, apparently only, with the facial through the chorda. The chorda tympani branch of the facial joins the lingual nerve under the external pterygoid muscle and is distributed with the lingual to the tongue.
The hypoglossal nerve and the lingual nerve lie near together, over the Hyo-glossus muscle, and the two nerves are joined by loops (rami anastomotici cum n. hypoglosso). The branches to the submaxillary ganglion are two or three in number; those connected with the hypoglossal nerve form a plexus at the anterior margin of the Hyo-glossus muscle.

The branches of distribution supply the mucous membrane of the mouth, the gums, the sublingual gland, the filiform and fungiform papillae and mucous membrane of the tongue; the terminal filaments communicate, at the tip of the tongue, with the hypoglossal nerve. The lingual fibres are fibres of common sensation. The chorda tympani fibres which join the lingual nerve are probably taste-fibres and exo-glandular for the submaxillary and sublingual salivary glands.

The Inferior Dental Nerve (n. alveolaris inferior) (Fig. 688).—The inferior dental is the largest of the branches of the inferior maxillary nerve. It passes downward with the inferior dental artery, at first beneath the External pterygoid muscle, and then between the internal lateral ligament and the ramus of the jaw to the dental foramen. It then passes forward in the dental canal of the inferior maxillary bone, lying beneath the teeth, as far as the mental foramen, where it divides into two terminal branches, incisor and mental.

The Branches of the inferior dental are: the mylo-hyoid, dental, incisor, and mental.

The Mylo-hyoid (n. mylohyoideus) is derived from the inferior dental just as that nerve is about to enter the dental foramen. It descends in a groove on the inner surface of the ramus of the jaw, in which it is retained by a process of fibrous membrane. It reaches the under surface of the Mylo-hyoid muscle, and supplies it and the anterior belly of the Digastric.

The Dental Branches supply the molar and bicuspid teeth. They correspond in number to the fangs of those teeth: each nerve entering the orifice at the point of the fang and supplying the pulp of the tooth.

The Incisor Branch is continued onward within the bone to the middle line, and supplies the canine and incisor teeth.

The dental branches and the incisor branch form a plexus (plexus dentalis inferior), and from this plexus come the branches to the teeth (rami dentales inferiores) and to the gums (rami gingivales inferiores).

The Mental Branch (n. mentalis) emerges from the bone at the mental foramen, and divides beneath the Depressor anguli oris muscle into two or three branches; one descends to supply the skin of the chin, and another (sometimes two) ascends to supply the skin and mucous membrane of the lower lip. These branches communicate freely with the facial nerve.

Two small ganglia are connected with the inferior maxillary nerve—the otic with the trunk of the nerve, and the submaxillary with its lingual branch.

Otic or Arnold’s Ganglion (ganglion oticum) (Fig. 690).—The otic or Arnold’s ganglion is a small, oval-shaped, flattened ganglion of a reddish-gray color, situated immediately below the foramen ovale, on the inner surface of the inferior maxillary nerve, and round the origin of the internal pterygoid nerve. It is in relation, externally, with the trunk of the inferior maxillary nerve, at the point where the motor root joins the sensor portion; internally, with the cartilaginous part of the Eustachian tube, and the origin of the Tensor palati muscle; behind, it lies in relation with the medidural artery.

Branches of Communication.—This ganglion is connected with the internal pterygoid branch of the inferior maxillary nerve by two or three short delicate filaments. From this nerve the ganglion may obtain a motor root, and possibly also a sensor root, as these filaments from the nerve to the Internal pterygoid perhaps contain sensor fibres. The otic ganglion communicates with the glossopharyngeal and facial nerves through the small superficial petrosal nerve (Figs. 690
and 603) continued from the tympanic plexus, and through this communication it probably receives its sensor root from the glossopharyngeal and its motor root from the facial; its communication with the sympathetic is effected by a filament from the plexus surrounding the medidural artery. The ganglion also communicates with the auriculo-temporal nerve (ramus anastomoticus cum n. auriculotemporalis). This communicating filament is probably a branch from the glossopharyngeal which passes to the ganglion, and through it and the auriculo-temporal nerve to the parotid gland. A slender filament, the sphenoidal, ascends from it to the Vidian nerve.

**Branches of Distribution.**—Its branches of distribution are a filament to the Tensor tympani (n. tensoris tympani) and one to the Tensor palati (n. tensoris veli palatini). The former passes backward on the outer side of the Eustachian tube; the latter arises from the ganglion, near the origin of the internal pterygoid nerve, and passes forward. The fibres of these nerves are, however, mainly derived from the nerve to the Internal pterygoid muscle. It also gives off a small communicating branch to the chorda tympani (ramus anastomoticus cum n. chorda tympani).

![Fig. 690.—The otic ganglion and its branches.](image)

**The Submaxillary Ganglion** (ganglion submaxillare) (Fig. 688).—The submaxillary ganglion is of small size, fusiform in shape, and situated above the deep portion of the submaxillary gland, near the posterior border of the Mylo-hyoid muscle, being connected by filaments with the lower border of the lingual nerve.

**Branches of Communication.**—This ganglion is connected with the lingual nerve by a few filaments (rami communicantes cum n. lingualis), which join it separately at its fore and back part. It also receives a branch from the chorda tympani, by which it communicates with the facial, and communicates with the sympathetic by filaments from the sympathetic plexus around the facial artery.

**Branches of Distribution.**—These are five or six in number; they arise from the lower part of the ganglion, and supply the mucous membrane of the mouth and Wharton’s duct, some being lost in the submaxillary gland (rami submaxillares). The branch of communication from the lingual nerve to the forepart of the ganglion is by some regarded as a branch of distribution, by which filaments of the chorda tympani pass from the ganglion to the lingual nerve, and by it are conveyed to the sublingual gland and the tongue.
Summary of the Distribution and Connections of the Trigeminal Nerve.—It is the chief sensor nerve of the face, the anterior half of the scalp, the mouth, nasal cavity, lips, teeth, anterior two-thirds of the tongue, orbit, and eyeball. The clearly defined cutaneous distributions of the branches are shown in Fig. 691. The motor portion of the nerve supplies the muscles of mastication, the mylo-hyoid, and the anterior belly of the digastric. By way of branches from the otic ganglion it supplies the Tensor tympani and Tensor palati muscles, and by way of branches from the sphenopalatine ganglion perhaps supplies the Levator palati and Azygos uvulae muscles, although it is more probable that these muscles receive their motor influence by the accessory nerves through the pharyngeal plexus. The ganglia associated with the nerve create communications with the sympathetic, the motor oculi, the facial, and the glosso-pharyngeal, and through these ganglia, as Prof. Cunningham says, “important organs, areas, and muscles” are innervated. The trigeminal communicates many times with the facial, and thus gives sensor fibres to the “muscles of expression supplied by the facial nerve.”

1 Cunningham’s Text-book of Anatomy.
injury to the sensor root there is anaesthesia of the half of the face on the side of the lesion, with the exception of the skin over the parotid gland; insensibility of the conjunctiva, followed, if the eye is not temporarily protected with a watch-glass, by destructive inflammation of the cornea, partly, it is held, from loss of trophic influence, and partly, it is certain, from the irritation produced by the presence of foreign bodies on it, which are not perceived by the patient, and therefore not expelled by the act of winking; dryness of the nose, loss to a considerable extent of the sense of taste, and diminished secretion of the lacrimal and salivary glands. In injury to the motor root there is impaired action of the lower jaw from paralysis of the muscles of mastication on the affected side.

The trigeminal nerve is often the seat of neuralgia, and each of the three divisions has been divided or a portion of the nerve excised for this affection. The supraorbital nerve may be exposed by making an incision an inch and a half in length along the supraorbital margin below the eyebrow, which is to be drawn upward, the centre of the incision corresponding to the supraorbital notch. The skin and Orbicularis palpebrarum having been divided, the nerve can be easily found emerging from the notch and lying in some loose cellular tissue. It should be drawn up by a blunt hook and divided, or, what is better, a portion of it should be removed. The infraorbital nerve has been divided at its exit by an incision on the cheek; or the floor of the orbit has been exposed, the infraorbital canal opened up, and the anterior part of the nerve resected; or the whole nerve, together with Meckel's ganglion as far back as the foramen rotundum, has been removed. This latter operation, though undoubtedly a severe proceeding, appears to have been followed by better results than has nerve resection. The operation is performed as follows: The superior maxillary bone is first exposed by a T-shaped incision, one limb of the incision passing along the lower margin of the orbit, the other from the centre of the first cut vertically down the cheek toward the angle of the mouth. The nerve is then found, is divided, and a piece of silk is tied to it as a guide. A small trephine (one-half inch) is then applied to the bone below, but including the infraorbital foramen, and the antrum opened. The trephine is now applied to the posterior wall of the antrum, and the sphenomaxillary fossa exposed. The infraorbital canal is now opened up from below by fine cutting-pliers or a chisel, and the nerve drawn down into the trephine hole, it being held on the stretch by means of the piece of silk; it is severed with fine curved scissors as near the foramen rotundum as possible, any branches coming off from the ganglion being also divided. The mental branch of the inferior dental nerve may be divided at its exit from the foramen through an incision made through the mucous membrane where it is reflected from the alveolar process on to the lower lip; or a portion of the trunk of the inferior dental nerve may be resected through an incision on the cheek through the Masseter muscle, exposing the outer surface of the ramus of the jaw. A trephine is then applied over the position of the inferior dental foramen and the outer table removed, so as to expose the inferior dental canal. The nerve is dissected out of the portion of the canal exposed, and, having been divided after its exit from the mental foramen, it is by traction on the end exposed in the trephine-hole, drawn out entire, and cut off as high up as possible. The inferior dental nerve has also been divided through an incision within the mouth, the bony point guarding the inferior dental foramen forming the guide to the nerve. The buccal nerve may be divided by an incision through the mucous membrane of the mouth and the Buc- cinator muscle just in front of the anterior border of the ramus of the lower jaw (Stimson).

In invertebral neuralgia of one or two of the branches of the trigeminal nerve a peripheral operation may cure the case, but seldom does. It often gives relief, perhaps for months. In neuralgia of the second division or third division, or of the second division and third division, Abbe, of New York, opens the skull and divides the nerve or nerves by an intracranial operation, removes a piece of nerve so as the foramen of exit is empty, and covers the foramen with rubber tissue, to hinder regrowth of the nerve. Other operators, after removing a piece from each nerve, have plugged the foramina of the exit with dentists' cement or silver-filler.

Rose's method of neurectomy is very valuable for neuralgia of the second division. It is a modification of the Braun-Lossen method. The infraorbital nerve is exposed, a ligature is tied about it, the roof of the infraorbital canal is chiselled open, and the nerve is freed as far back as possible. An incision is made from below the external angular process outward along the zygoma to in front of the lobule of the ear, downward to just above the angle of the jaw, and forward for two inches. The flap is raised and the zygoma is exposed. The root of the zygoma is drilled at two points, and the zygomatic process of the temporal bone is drilled at two points. The bone is sawed in two places between the drill-holes. The freed arch is lifted down and back, the tendon of the temporal muscle is drawn backward, and the pterygo-maxillary fossa is thus exposed. The internal maxillary artery is divided between two ligatures. The External pterygoid muscle is separated from the greater wing of the sphenoid and from the root of the external pterygoid process. The superior maxillary nerve is grasped and twisted off as near the ganglion as possible. The entire nerve is then drawn back from the infraorbital foramen and removed. The wound is then closed. If the third division is also haunted by neuralgia, it too should be removed a few weeks after the performance of Rose's operation.

1 Carnochan, American Journal of the Medical Sciences, 1858, p. 136.
If a peripheral operation fails, or if all the branches of the trigeminal are involved, the Gasserian ganglion must be removed or the sensor root of the trigeminal must be divided, as suggested by Frazier and Spiller.

Removal of the Gasserian ganglion was suggested by J. Ewing Mears in 1884, and was first carried out by Rose in 1890.

The method chiefly in vogue was devised by Hartley, and was first performed by him in 1891. An osteoplastie flap is made in front of the ear, the dura is exposed and lifted. Following Krause’s advice, the third division is exposed and clamped. The second division is exposed and clamped. The nerves are loosened from their beds and then are rolled about the clamps. This twisting pulls out the ganglion intact along with the motor root, and also the sensor root from the pons.

A difficulty in the Hartley operation is the danger of division of the dural artery. If this happens, the surgeon may be able to arrest bleeding and proceed with the operation. If the vessel is torn off at the foramen spinosum, it will be necessary to pack the wound and postpone any further operative manipulation for forty-eight hours.

Dr. Harvey Cushing has modified Hartley’s operation by trephining the wall of the temporal fossa very low down. He opens the skull below the arch of the dural vessels, and thus avoids the medidural at the foramen spinosum, and also the sulcus arteriosus of the parietal bone.

After the removal of the ganglion, Professor Keen, in order to prevent undue inflammation of the eye, sews the eyelids of the affected side together, leaving a space open at each angle, and covers the eye with a watch-crystal. Boric acid solution is flushed into the opening at the external angle at frequent intervals. The stitches are removed from the lid in from eight to ten days.

The lingual nerve is occasionally divided with the view of relieving the pain in cancerous disease of the tongue. This may be done in that part of its course where it lies below and behind the last molar tooth. If a line is drawn from the middle of the crown of the last molar tooth to the angle of the jaw, it will cross the nerve, which lies about half an inch behind the tooth, parallel to the bulging alveolar ridge on the inner side of the body of the bone. If the knife is entered three-quarters of an inch behind and below the last molar tooth and carried down to the bone, the nerve will be divided. Hilton divided it opposite the second molar tooth, where it is covered only by the mucous membrane, and Lucas pulls the tongue forward and over to the opposite side, when the nerve can be seen standing out as a firm cord under the mucous membrane by the side of the tongue and can be easily seized with a sharp hook and divided or a portion excised. This is a simple enough operation on the cadaver, but when the disease is extensive and has extended to the floor of the mouth, as is generally the case when division of the nerve is thought of, the operation is not practicable.

THE SIXTH OR ABDUCENT NERVE (N. ABDUCENS) (Fig. 687).

The sixth or abducens nerve supplies the External rectus muscle. Its superficial origin is by several filaments from the postpontile groove, between pons and pyramid. Its deep origin is from the upper part of the floor of the fourth ventricle, close to the median line, beneath the eminentia abducens (Fig. 578).

From the nucleus of the abducens nerve some fibres are supposed to pass through the medial longitudinal bundle to the oculomotor nucleus of the opposite side and into the oculomotor nerve, along which they are carried to the Internal rectus muscle. The External rectus of one eye and the Internal rectus of the other may therefore be said to receive their nerves from the same nucleus—a factor of great importance in connection with the conjugate movements of the eyeball, and one that may explain certain paralytic phenomena of the Recti muscles, which are often associated with lesions in the pons.

The nerve pierces the dura on the basilar surface of the sphenoid bone, runs through a notch immediately below the posterior clinoid process, and enters the cavernous sinus. It passes forward through the sinus, lying on the outer side of the internal carotid artery (Fig. 454). It enters the orbit through the sphenoid fissure, and lies above the ophthalmic vein, from which it is separated by a lamina of dura (Fig. 692). It then passes between the two heads of the External rectus muscle, and is distributed to that muscle on its ocular surface.

Branches of Communication.—It is joined by several filaments from the carotid and cavernous plexuses, and by one from the ophthalmic nerve.
Relations to Each Other of the Oculomotor, Trochlear, Ophthalmic Division of the Trigeminal and Abducent Nerves as they Pass to the Orbit.—The oculomotor, trochlear, the ophthalmic division of the trigeminal, and the abducent nerves, as they pass to the orbit, bear a certain relation to one another in the cavernous sinus, at the sphenoidal fissure, and in the cavity of the orbit, which will now be described.

In the Cavernous Sinus (Figs. 454 and 455) the oculomotor, trochlear, and ophthalmic division of the trigeminal are placed on the outer wall of the sinus, in their numerical order, both from above downward and from within outward. The abducent nerve lies at the outer side of the internal carotid artery. As these nerves pass forward to the sphenoidal fissure, the oculomotor and trigeminal nerves become divided into branches, and the abducent nerve approaches the rest, so that their relative position becomes considerably changed.

In the Sphenoidal Fissure (Fig. 692) the trochlear nerve and the frontal and lacrimal branches of the ophthalmic division of the trigeminal lie upon the same plane, the former being most internal, the latter external, and they enter the cavity of the orbit above the muscles. The remaining nerves enter the orbit between the two heads of the External rectus muscle. The superior division of the oculomotor nerve is the highest of these; beneath this lies the nasal branch of the ophthalmic nerve; then the inferior division of the oculomotor nerve; and the abducent nerve lowest of all.

In the Orbit (Figs. 683 and 687) the trochlear nerve and the frontal and lacrimal divisions of the ophthalmic nerve lie on the same plane immediately beneath the periosteum, the trochlear nerve being internal and resting on the Superior oblique muscle, the frontal nerve resting on the Levator palpebrae muscle, and the lacrimal nerve on the External rectus muscle. Next in order comes the superior division of the oculomotor nerve, lying immediately beneath the Superior rectus muscle, and then the nasal branch of the ophthalmic nerve, crossing the optic nerve from the outer to the inner side of the orbit. Beneath these is found the optic nerve, surrounded in front by the ciliary nerves, and having the ciliary ganglion on its outer side, between it and the External rectus muscle. Below the optic nerve is the inferior division of the oculomotor nerve and the abducent nerve, which lies on the outer side of the orbit.

Surgical Anatomy.—It is often stated that the abducent nerve is more frequently involved in fractures of the base of the skull than any other of the cranial nerves. As a matter of fact, however, it is injured in only about 2 per cent. of cases of fracture of the skull (Putscher). Cases have been reported in which the nerve was actually ruptured. The nerve may be injured by traction, pressure of a blood clot, of a tumor, or of an arterio-venous aneurism. The result of paralysis of this nerve is internal or convergent squint. When injured so that its function is destroyed, there is, in addition to the paralysis of the External rectus muscle, often a certain amount of contraction of the pupil, because some of the sympathetic fibres to the radiating muscle of the iris pass along with this nerve.
THE SEVENTH OR FACIAL NERVE (N. FACIALIS) (Figs. 693, 694, 695).

The seventh or facial nerve is the motor nerve of all the muscles of expression in the face, and of the Platysma and Buceinator; the muscles of the External ear; the posterior belly of the Digastric, and the Stylo-hyoid. The chorda tympani (or nervus intermedius) is referred to as the sensor portion of the facial.

Its superficial origin is from the upper end of the oblongata, in the groove between the olive and rectis. Its deep origin is from a nucleus situated in the floor of the fourth ventricle, beneath the superior fovea (Fig. 578). The facial nucleus is deeply placed in the reticular formation of the lower part of the preoblongata, a little external and ventral to the nucleus of the abducent nerve. From this origin the fibres pursue a curved course in the substance of the preoblongata. They first pass backward and inward, and then turn upward and forward, forming the fasciculus teres, which with the nucleus abducentis produces an eminence, the eminentia abducentis, on the floor of the fourth ventricle, and finally bend sharply downward and outward around the upper end of the nucleus of origin of the abducent nerve, to reach their superficial origin between the olive and rectis. From the nucleus of the oculomotor nerve some fibres arise which descend in the medial longitudinal bundle and join the facial just before it leaves the preoblongata; these fibres are said to supply the anterior belly of the Occipitofrontalis, the Orbicularis palpebrarum, and the Corrugator supercilii, as these muscles have been observed to escape paralysis in lesions of the nucleus of the facial nerve.

The acoustic or auditory nerve lies to the outer side of the facial nerve; and between the two is a small fasciculus, the nervus intermedius or pars intermedia of Wrisberg, which apparently arises from the oblongata and joins the facial nerve in the internal auditory meatus. The central processes of the ganglion cells, known as the nervus intermedius, end in the upper end of the nucleus of the glosso-pharyngeal nerve.

The nervus intermedius may be regarded as the sensor root of the facial nerve, analogous to the sensor root of the trigeminal, and its real nucleus of origin consists of the geniculate ganglion (see p. 894).

The facial nerve, firmer, rounder, and smaller than the auditory, passes forward and outward upon the medipeduncle of the cerebellum, and enters the internal auditory meatus with the auditory nerve. Within the meatus the facial nerve lies in a groove along the upper and anterior part of the auditory nerve, and the nervus intermedius is placed between the two and joins the inner angle of the geniculate ganglion. Beyond the ganglion its fibres are generally regarded as forming the chorda tympani (see p. 894).

At the bottom of the meatus the facial nerve enters the aqueductus Fallopii and follows the course of that canal through the petrous portion of the temporal bone, from its commencement at the internal meatus to its termination at the stylo mastoid foramen (Figs. 49 and 693). It is at first directed outward between the cochlea and vestibule toward the inner wall of the tympanum; it then bends suddenly backward and arches downward behind the tympanum to the stylo mastoid foramen. At the point in the aqueduct of Fallopii where the nerve changes its direction (geniculum n. facialis), it presents a reddish, gangliform swelling, the geniculate ganglion (ganglion geniculi), which is also called the intumescentia ganglio-
The geniculate ganglion receives a branch from the vestibular division of the auditory nerve. On emerging from the stylo-mastoid foramen the facial nerve runs forward in the substance of the parotid gland, crosses the external carotid artery, and divides behind the ramus of the lower jaw into two primary branches, temporo-facial and cervico-facial, from which numerous offsets are distributed over the side of the head, face, and upper part of the neck, supplying the superficial muscles in these regions. As the primary branches and their offsets diverge from each other, they present somewhat the appearance of a bird's claw; hence the name of pes anserinus is given to the divisions of the facial nerve in and near the parotid gland.

Branches of Communication (Fig. 694).—The communications of the facial nerve may be thus arranged:

In the internal auditory meatus.

From the geniculate ganglion.

In the Fallopian aqueduct.

At its exit from the stylomastoid foramen.

Behind the ear.

On the face.

In the neck.

With the acoustic nerve. The nervus intermedius, which is between the facial and acoustic, is supposed to give branches to both. The branch given to the acoustic accompanies it for a certain distance, and then departs from it to join the geniculate ganglion.

With the acoustic as explained above.

With the sterno-mastoid ganglion by the large superficial petrosal nerve.

With the otic ganglion by the small superficial petrosal nerve.

With the sympathetic on the mediodural artery by the external superficial petrosal nerve.

With the auricular branch of the vagus.

With the glosso-pharyngeal.

With the vagus.

With the auricularis magnus.

With the auriculotemporal.

With the small occipital.

With the superficial cervical.

In the internal auditory meatus some minute filaments pass between the facial and acoustic nerves.

Opposite the hiatus Fallopian the gangliform enlargement on the facial nerve communicates with the sphenopalatine ganglion by means of the large superficial petrosal nerve, which forms its motor root; with the otic ganglion, by the small superficial petrosal nerve; and with the sympathetic filaments accompanying the mediodural artery, by the external petrosal nerve (Bidder). From the gangliform enlargement, according to Arnold, a twig is sent back to the acoustic nerve. Just before the facial nerve emerges from the stylo-mastoid foramen it generally receives a twig of communication from the auricular branch of the vagus.

After its exit from the stylo-mastoid foramen, it sends a twig to the glosso-pharyngeal, another to the vagus nerve, and communicates with the great auricular branch of the cervical plexus, with the auriculo-temporal branch of the inferior maxillary nerve in the parotid gland, with the small occipital nerve behind the ear, on the face with the terminal branches of the three divisions of the trigeminal, and in the neck with the transverse cervical.

Branches of Distribution (Fig. 694).—The branches of distribution of the facial nerves may be thus arranged:
Within the aquaeductus Fallopii.

At its exit from the stylo-mastoid foramen.

On the face.

The branches of the two terminal divisions form the parotid plexus (plexus parotideus).

The Tympanic Branch (n. stapedius) (Fig. 694).—The tympanic branch arises from the nerve opposite the pyramid; it passes through a small canal in the pyramid and supplies the Stapedius muscle.

The Chorda Tympani (Figs. 688, 693, and 694).—The chorda tympani is apparently given off from the facial as it passes vertically downward at the back of the tympanum, about 5 mm. before its exit from the stylo-mastoid foramen. It passes from below upward and forward in a distinct canal, and enters the cavity of the tympanum through an aperture (iter chordae posterius) on its posterior wall between the opening of the mastoid cells and the attachment of the membrana tympani, and becomes invested with mucous membrane. It passes forward through the cavity of the tympanum, between the fibrous and mucous layers of the membrana tympani, and over the handle of the malleus, emerging from that cavity
through a foramen at the inner end of the Glaserian fissure, which is called the canal of Huguen (iter chordae anterius). It then descends between the two Pterygoid muscles, meets the lingual nerve at an acute angle, and accompanies it to the submaxillary gland; part of it then joins the submaxillary ganglion; the rest is continued onward through the muscular substance of the tongue to the mucous membrane covering its anterior two-thirds. A few of its fibres probably pass through the submaxillary ganglion to the sublingual gland. Before joining the lingual nerve it receives a small communicating branch from the otic ganglion. As already stated, the chorda tympani nerve is regarded as the peripheral continuation of the nervus intermedius (see p. 894).

The Posterior Auricular Nerve (n. auricularis posterior) (Figs. 655, 694, and 695).—The posterior auricular nerve arises close to the stylo-mastoid foramen, and passes upward in front of the mastoid process and between the mastoid process and the external ear, where it is joined by a filament from the auricular branch of the vagus, and communicates with the mastoid branch of the great auricular and with the small occipital. As it ascends between the external auditory meatus and the mastoid process it divides into two branches, the auricular and the occipital branches.

The Auricular Branch supplies the Retrahens auriculam and the small muscles on the cranial surface of the pinna.

The Occipital Branch (ramus occipitalis), the larger, passes backward along the superior curved line of the occipital bone, and supplies the occipital portion of the Occipito-frontalis.

The Digastric Branch of the Facial Nerve (ramus digastricus).—The digastric branch usually arises by a common trunk with the Stylo-hyoid branch; it divides into several filaments, which supply the posterior belly of the Digastric; one of these perforates that muscle to join the glossopharyngeal nerve (ramus anastomoticus cum n. glossopharyngeo).

The Stylo-hyoid Branch (ramus stylohyoidus).—The stylo-hyoid branch is a long, slender branch, which passes inward, entering the Stylo-hyoid muscle about its middle.

The Temporo-facial Division (Figs. 694 and 695).—The temporo-facial, the larger of the two terminal branches of the facial, passes upward and forward through the parotid gland, crosses the external carotid artery and temporo-maxillary vein, and passes over the neck of the condyle of the jaw, being connected in this situation with the auriculo-temporal branch of the inferior maxillary nerve, and divides into branches which are distributed over the temple and upper part of the face; these are divided into three sets—temporal, malar, and infraorbital.

The Temporal Branches (rami temporales) cross the zygoma to the temporal region, supplying the Attrahens and Attollens auriculam muscles, and join with the temporal branch of the temporo-malar division of the superior maxillary, and with the auriculo-temporal branch of the inferior maxillary. The more anterior branches supply the frontal portion of the Occipito-frontalis, the Orbicularis palpebrarum, and Corrugator supercilii muscles, joining with the supraorbital and lacrimal branches of the ophthalmic.

The Malar Branches (rami zygomatici) pass across the malar bone to the outer angle of the orbit, where they supply the Orbicularis palpebrarum muscle, joining with filaments from the lacrimal nerve; others supply the lower eyelid, joining with filaments of the malar branch (subcutaneous mala) of the superior maxillary nerve.

The Infraorbital Branches (rami buccales), of larger size than the rest of the malar branches, pass horizontally forward to be distributed between the lower margin of the orbit and the mouth. The superficial branches run beneath the skin and above the superficial muscles of the face, which they supply; some branches are
distributed to the Pyramidalis nasi, joining at the inner angle of the orbit with the infratrochlear and nasal branches of the ophthalmic. The deep branches pass beneath the Zygomatici and the Levator labii superioris, supplying the Levator anguli oris, the Levator labii superioris alaeque nasi and the small muscles of the nose, and form a plexus, infraorbital plexus, by joining with the branches of the infraorbital branch of the superior maxillary nerve and the buccal branches of the cervico-facial.

The Cervico-facial Division.—The cervico-facial division of the facial nerve passes obliquely downward and forward through the parotid gland, crossing the external carotid artery. In this situation it is joined by branches from the great auricular nerve. Opposite the angle of the lower jaw it divides into branches which are distributed on the lower half of the face and upper part of the neck. These may be divided into three sets—buccal, supramaxillary, and inframaxillary.

The Buccal Branches (rami buccales) cross the Masseter muscle. They supply the Buccinator and Orbicularis oris, and join with the infraorbital branches of the temporo-facial division of the nerve, and with filaments of the buccal branch of the inferior maxillary nerve.

The Supramaxillary or Supramandibular Branch (ramus marginalis mandibulae) passes forward beneath the Platysma and Depressor anguli oris, supplying the
muscles of the lower lip and chin, and communicating with the mental branch of the inferior dental nerve.

The **Inframandibular**, **Inframanidibular** or **Cervical Branch** (ramus collis) runs forward beneath the Platysma, and forms a series of arches across the side of the neck over the suprahyoid region. A branch descends vertically to join with the superficial cervical nerve from the cervical plexus; others supply the Platysma.

**Surgical Anatomy.**—The facial nerve is more frequently paralyzed than any of the other of the cranial nerves. The paralysis may depend either upon (1) central causes—i. e., blood-clots or intracranial tumors pressing on the nerve before its entrance into the internal auditory meatus. It is also one of the nerves involved in bulb bar paralysis. Or (2) it may be paralyzed in its passage through the petrous bone by damage due to middle-ear disease or by fractures of the base. Or (3) it may be affected at or after its exit from the stylo-mastoid foramen. This is commonly known as Bell's paralysis. It may be due to exposure to cold or to injury of the nerve, either from accidental wounds of the face or during some surgical operation, as removal of parotid tumors, opening of abscesses, or operations on the lower jaw.

When the cause is central, the a bellent nerve is usually paralyzed as well, and there is also hemiplegia on the opposite side. In these cases the electric reactions are the same as in health; whereas, when the paralysis is due to a lesion in the course of the nerve, the reactions of degeneration develop. When the nerve is paralyzed in the petrous bone, in addition to the paralysis of the muscles of expression, there is loss of taste in the anterior part of the tongue, and the patient is unable to recognize the difference between bitters and sweets, acids and salines, from involvement of the chorda tympani. The mouth is dry, because the salivary glands are not secreting; the sense of hearing is affected from paralysis of the Stapedius, but there is no hemiplegia. When the cause of the paralysis is from fracture of the base of the skull, the acoustic nerve and the petrosal nerves, which are connected with the intumescentia ganglioformis, are also involved. When the injury to the nerve is after its exit from the stylo-mastoid foramen, all the muscles of expression except the Levator palpebrae, together with the posterior belly of the Digastric and Stylo-hyoid, are paralyzed. There is smoothness of the forehead, and the patient is unable to frown; the eyelids cannot be closed, and the lower lid droops, so that the punctum is no longer in contact with the globe, and the tears run down the cheek; there is smoothness of the cheek and loss of the nasolabial furrow; the nostril of the paralyzed side cannot be dilated; the mouth is drawn to the sound side, and there is inability to whistle; food collects between the cheek and gum from paralysis of the Buccinator.

The facial nerve is at fault in cases of so-called histrionic spasm, which consists in an almost constant and uncontrollable twitching of the muscles of the face. This twitching is sometimes so severe as to cause great discomfort and annoyance to the patient and to interfere with sleep, and for its relief the facial nerve has been stretched. The operation is performed by making an incision behind the ear from the root of the mastoid process to the angle of the jaw. The parotid is turned forward, and the dissection carried along the anterior border of the Sterno-mastoid muscle and mastoid process until the upper border of the posterior belly of the Digastric is found. The nerve is parallel to this on about a level with the middle of the mastoid process. When found, the nerve may be stretched by passing a blunt hook beneath it and pulling it forward and outward. Too great force must not be used, for fear of permanent injury to the nerve. In facial palsy of extracerebral origin it may be advisable to expose the nerve, cut it across, and anastomose the distal end of the paralyzed nerve to the accessory nerve or, better, to the hypoglossal nerve (facio-accessory anastomosis or facio-hypoglossal anastomosis). The idea was first proposed by Ballance, and has been put in practice by Ballance and Stewart, Keen, Cushing, Faure, Kennedy, and others.

**The Eighth or Acoustic Nerve** (N. Acusticus) (Fig. 696).

The **eight or acoustic or auditory nerve** comprises two distinct sets of fibres which, although both are devoted to the transmission of afferent impulses, differ in their peripheral distribution and in their central connections. The two divisions appear blended in the interval between the oblongata and the internal auditory meatus, running oblique latero-frontal in company with the facial nerve and internal auditory artery. At the internal auditory meatus the two divisions of the nerve are separable, the vestibular division above, the cochlear below.

**The Cochlear Nerve** (radix cochlearis).—The cochlear nerve is the true nerve of hearing, lacking general sensibility, however, and therefore a nerve of special sense.
The fibres of this division arise from the cells of the spiral ganglion of the cochlear as axones of bipolar cells whose dendrites or peripheral processes terminate about the (auditory) hair-cells of the organ of Corti. The central connections of the cochlear division are described on p. 892.

**The Vestibular Nerve** (radix vestibularis).—The vestibular nerve conducts impulses of equilibratory-sense from the semicircular canals, utricle, and saccule to the vestibular nuclei. The ganglion of origin of this nerve differs from ordinary sensor ganglia in that its cells are of bipolar structure, having retained this embryonic characteristic of the ganglion-cells throughout life. The central processes of the cells of the vestibular ganglion (or ganglion of Scarpa) enter the oblongata with the trunk of the cochlear nerve in the postpontile groove, laterad of the facial nerve, to establish central connections already described on p. 893. The peripheral processes constitute the two main branches of the nerve, viz., (a) the utriculo-ampullar and (b) the sacculo-ampullar.

![Distribution of the acoustic nerve](image)

The upper or **utriculo-ampullar branch** divides into:

(a) The **Utricular Branch**, passing through the superior macula cribrosa of the vestibule to end in the macula acustica of the utricle.

(b) The **Superior Ampullar Branch**, accompanying the utricular branch, to end in the crista acustica of the ampulla of the superior semicircular canal.

(c) The **Lateral Ampullar**, to the ampulla of the lateral semicircular canal. The lower or **sacculo-ampullar branch** is somewhat longer and divides into:

(a) The **Posterior Ampullar**, passing through the foramen singulare and the inferior macula cribrosa to end in the ampulla of the posterior semicircular canal.

(b) The **Saccular Branch**, passing through the middle macula cribrosa to end in the macula acustica of the sacculus.

**Surgical Anatomy.**—The acoustic nerve is frequently injured, together with the facial nerve, in fractures of the middle fossa of the base of the skull implicating the internal auditory meatus. The nerve may be either torn across, producing permanent deafness, it may be bruised or it may be pressed upon by extravasated blood or inflammatory exudation, when the deafness will in all probability be temporary. The nerve may also be injured by violent blows on the head without
Fracture, and deafness may follow loud explosions of dynamite, etc., probably from some lesion of this nerve, which is more liable to be injured than the other cranial nerves on account of its structure. The test that the nerve is destroyed and that the deafness is not due to some lesion of the auditory apparatus is obtained by placing a vibrating tuning-fork on the head. The vibrations will be heard in cases where the auditory apparatus is at fault, but not in cases of destruction of the auditory nerve.

THE NINTH OR GLOSSO-PHARYNGEAL NERVE (N. GLOSSOPHARYNGEUS) (Figs. 697 and 698).

The ninth or glosso-pharyngeal nerve is distributed, as its name implies, to the tongue and pharynx, being the nerve of ordinary sensation to the mucous membrane of the pharynx, fauces, and tonsil; and the nerve of taste to all parts of the tongue to which it is distributed.

Its (apparent) superficial origin is by three or four filaments, closely connected together, from the upper part of the oblongata, in the dorso-lateral groove (Fig. 697). The central connections are described on p. 590. The small motor component arises from cells in the nucleus ambiguous. The real origin of the sensor fibres of the glosso-pharyngeal must be looked for in the jugular and petrosal ganglia which are developed from the neural crest.

From its superficial origin it passes outward across the flocculus, and leaves the skull at the central part of the jugular foramen, in a separate sheath of the dura external to and in front of the vagus and accessory nerves (Fig. 698). In its passage through the jugular foramen it grooves the lower border of the petrous portion of the temporal bone, and at its exit from the skull passes forward between the jugular vein and internal carotid artery, and descends ventrad of the latter vessel, and beneath the styloid process of the temporal bone and the muscles connected with it, to the lower border of the Stylo-pharyngeus muscle. The nerve now curves inward, forming an arch on the side of the neck, and lying upon the Stylo-pharyngeus muscle and the Middle constrictor of the pharynx. It then passes beneath the Hyo-glossus muscle, and is finally distributed to the mucous membrane of the fauces and base of the tongue, and the mucous glands of the mouth and tonsil.

In passing through the jugular foramen the nerve presents, in succession, two gangliform enlargements. The superior and smaller is called the jugular ganglion; the inferior and larger, the petrous ganglion or the ganglion of Andersch.

The Superior or Jugular Ganglion (Ganglion Superius n. Glossopharyngei).

The superior or jugular ganglion is situated in the upper part of the groove in which the nerve is lodged during its passage through the jugular foramen. It is of very small size, and involves only the lower part of the trunk of the nerve. It is usually regarded as a segmentation from the lower ganglion.

The Inferior or Petrous Ganglion (Ganglion Petrosum n. Glossopharyngei) (Fig. 697).

The inferior or petrous ganglion is situated in a depression in the lower border of the petrous portion of the temporal bone; it is larger than the superior ganglion and involves the whole of the fibres of the nerve. From this ganglion arise those filaments which connect the glosso-pharyngeal with the vagus and sympathetic nerves.
Branches of Communication.—The branches of communication are with the vagus, sympathetic, and facial.

The branches to the vagus are two filaments, arising from the petrous ganglion, one of which passes to the auricular branch of the vagus, and one to the upper ganglion of the vagus.

The branch to the sympathetic, also arising from the petrous ganglion, is connected with the superior cervical ganglion.

The branch of communication with the facial perforates the posterior belly of the Digastric muscle. It arises from the trunk of the nerve below the petrous ganglion, and joins the facial just after its exit from the stylo-mastoid foramen.

Branches of Distribution.—The branches of distribution are the tympanic, carotid, pharyngeal, muscular, tonsillar, and lingual.

The Tympanic Branch or Jacobson's Nerve (n. tympanicus).—The tympanic branch or Jacobson's nerve arises from the petrous ganglion, and enters a small bony canal in the lower surface of the petrous portion of the temporal bone, the lower opening of which is situated on the bony ridge which separates the carotid canal from the jugular fossa. It ascends to the tympanum, enters that cavity by an aperture in its floor close to the inner wall, and divides into branches which are contained in grooves upon the surface of the promontory. These branches form a tympanic plexus (plexus tympanicus). This plexus gives off (1) the greater part of the small superficial petrosal nerve (Fig. 694); (2) a branch to join the great superficial petrosal nerve; and (3) branches to the tympanic cavity, all of which will be described in connection with the anatomy of the ear.

The Carotid Branches (n. caroticotympanicus superior and n. caroticotympanicus inferior).—The carotid branches descend along the trunk of the internal carotid artery as far as its commencement, communicating with the pharyngeal branch of the vagus and with branches of the sympathetic.

The Pharyngeal Branches (rami pharynges).—The pharyngeal branches are three or four filaments which unite opposite the Middle constrictor of the pharynx with the pharyngeal branches of the vagus and sympathetic nerves to form the pharyngeal plexus, branches from which perforate the muscular coat of the pharynx to supply the muscles and mucous membrane.

The Muscular Branch (ramus stylopharyngeus).—The muscular branch is distributed to the Stylo-pharyngeus muscle.

The Tonsillar Branches (rami tonsillares).—The tonsillar branches supply the tonsil, forming a plexus (circulus tonsilaris) around this body, from which branches are distributed to the soft palate and fauces, where they communicate with the palatine nerves.

The Lingual Branches (rami linguales).—The lingual branches are two in number: one supplies the circumvallate papillae and the mucous membrane covering the surface of the base of the tongue; the other perforates its substance, and supplies the mucous membrane and follicular glands of the posterior one-third of the tongue and communicates with the lingual nerve.

The Gustatory Path.—The impressions of taste reach the glosso-pharyngeal nucleus in the oblongata in two ways. From the posterior one-third of the tongue and from the palate they reach the nucleus by the glosso-pharyngeal nerve. From the anterior two-thirds of the tongue impulses of taste are conveyed by the chorda tympani and nervus intermedius. From the glosso-pharyngeal nucleus gustatory impressions pass by way of the medial fillet to the thalamus of the opposite side, and from the thalamus through ventral thalamo-cortical radiation to the gyrus hippocampi, where the cortical gustatory centre is situated.

Surgical Anatomy.—Injury may produce hemorrhage about the roots of the nerve. Bergmann reported such a case. The patient died from edema of the glottis after presenting evidences of disorder of speech and difficulty in swallowing.
THE TENTH, VAGUS OR PNEUMOGASTRIC NERVE (N. VAGUS).
(Figs. 697 and 698).

The tenth, vagus or pneumogastric nerve has a more extensive distribution than any of the other cranial nerves, passing through the neck and thorax to the upper part of the abdomen. It is composed of both motor and sensor fibres. It supplies the organs of voice and respiration with motor and sensor fibres, and the pharynx, oesophagus, stomach, and heart with motor fibres. Its superficial origin (Fig. 697) is by eight or ten filaments from the groove between the olive and the restis below the glossopharyngeal; its central connections are described on p. 890.

The real origin of the sensor fibres of the vagus is to be found in the cells of the ganglia on the nerve—viz., the ganglion of the root and the ganglion of the trunk. The filaments become united and form a flat cord, which passes outward beneath the flocculus to the jugular foramen, through which it emerges from the cranium (Fig. 698). In passing through this opening the vagus accompanies the accessory nerve, being contained in the same sheath of dura with it, a membranous septum separating them from the glossopharyngeal, which lies in front (Fig. 698). The nerve in this situation presents a well-marked ganglionic enlargement, which is called the superior ganglion, or jugular ganglion; to it the vagal accessory part of the accessory nerve is connected by one or two filaments. After the exit of the nerve from the jugular foramen the nerve is joined by the accessory portion of the accessory nerve and enlarges into a second gangliform swelling, called the inferior ganglion or the ganglion of the trunk of the nerve, through which the fibres of the accessory nerve pass unchanged, being
principally distributed to the pharyngeal and superior laryngeal branches of the vagus; but some of the filaments from it are continued into the trunk of the vagus below the ganglion to be distributed with the recurrent laryngeal nerve, and probably also with the cardiac nerves. The vagus nerve passes vertically down the neck within the sheath of the carotid vessels lying between the internal carotid artery and the internal jugular vein as far as the thyroid cartilage, and then between the same vein and the common carotid to the root of the neck (Fig. 698). From here the course of the nerve differs on the two sides of the body.

On the right side (Fig. 698) the nerve passes across the subclavian artery between it and the right innominate vein, and descends by the side of the trachea to the back part of the root of the lung, where it spreads out in a plexiform network, the dorsal pulmonary plexus (plexus pulmonalis posterior), from the lower part of which two cords descend upon the oesophagus, on which tube they divide, forming, with branches from the opposite nerve, the esophageal plexus (plexus gulae); below, these branches are collected into a single cord, which runs along the back part of the oesophagus, enters the abdomen, and is distributed to the dorsal surface of the stomach, joining the left side of the solar plexus, and sending filaments to the splenic plexus and a considerable branch to the coeliac plexus.

On the left side the vagus nerve enters the chest between the left carotid and subclavian arteries, behind the left innominate vein. It crosses the arch of the aorta and descends behind the root of the left lung, forming the ventral pulmonary plexus (plexus pulmonalis anterior), and along the ventral surface of the oesophagus, where it unites with the nerve of the right side in forming the esophageal plexus. It passes to the stomach, distributing branches over the ventral surface of that viscus, some extending over the great cul-de-sac, and others along the lesser curvature. Filaments from these branches enter the gastro-hepatic omentum and join the hepatic plexus.

The Ganglion of the Root of the Vagus Nerve (Ganglion Jugulare).

The ganglion of the root or the jugular ganglion is of a grayish color, circular in form, about two lines in diameter, and resembles the ganglion on the larger root of the fifth nerve.

Connecting Branches.—To this ganglion the accessory portion of the accessory nerve is connected by several delicate filaments; it also has a communicating twig with the petrous ganglion of the glosso-pharyngeal, with the facial nerve by means of its (the ganglion’s) auricular branch, and with the sympathetic by means of an ascending filament from the superior cervical ganglion.

The Ganglion of the Trunk of the Vagus Nerve (Ganglion Nodosum).

The ganglion of the trunk or the inferior ganglion is a plexiform cord, cylindrical in form, of a reddish color, and about an inch (2 cm.) in length; it involves the whole of the fibres of the nerve, and passing through it is the accessory portion of the accessory nerve, which blends with the vagus below the ganglion, to be then continued principally into its pharyngeal and superior laryngeal branches.

Connecting Branches.—This ganglion is connected with the hypoglossal, the superior cervical ganglion of the sympathetic, and the loop between the first and second cervical nerves.
The branches of the vagus are—

- In the jugular fossa
  - Dural
  - Auricular
  - Pharyngeal
  - Superior laryngeal
  - Recurrent laryngeal
  - Cervical cardiac
  - Thoracic cardiac
  - Ventral pulmonary
  - Dorsal pulmonary
  - Esophageal
  - Gastric

The Dural Branch (*ramus meningeus*).—The dural branch is a recurrent filament given off from the ganglion of the root in the jugular foramen. It passes backward and is distributed to the dura lining the posterior fossa of the base of the skull.

The Auricular Branch or Arnold's Nerve (*ramus auricularis*) (Fig. 699).—The auricular branch or Arnold's nerve arises from the ganglion of the root, and is joined soon after its origin by a filament from the petrous ganglion of the glosso-pharyngeal; it passes outward behind the jugular vein, and enters a small canal on the outer wall of the jugular fossa. Traversing the substance of the temporal bone, it crosses the aqueductus Fallopii about two lines above its termination at the stylo-mastoid foramen; here it gives off an ascending branch, which joins the facial; the continuation of the nerve reaches the surface by passing through the auricular fissure between the mastoid process and the external auditory meatus, and divides into two branches, one of which communicates with the posterior auricular nerve, while the other supplies the integument at the back part of the pinna and the dorsal part of the external auditory meatus.

The Pharyngeal Branch (*ramus pharyngeus*).

-The pharyngeal branch, the principal motor nerve of the pharynx, arises from the upper part of the ganglion of the trunk of the vagus. It consists principally of filaments from the accessory portion of the accessory nerve; it passes across the internal carotid artery to the upper border of the Middle constrictor of the pharynx, where it divides into numerous filaments which join with those from the glosso-pharyngeal, the superior laryngeal (its external branch), and sympathetic, to form the pharyngeal plexus (*plexus pharyngeus*),
from which branches are distributed to the muscles and mucous membrane of the pharynx and the muscles of the soft palate. From the pharyngeal plexus a minute filament is given off, which descends and joins the hypoglossal nerve as it winds around the occipital artery.

**The Superior Laryngeal Nerve (n. laryngeus superior) (Figs. 697 and 698).**—It is larger than the preceding, and arises partly from the middle of the ganglion of the trunk of the vagus. It consists principally of filaments from the accessory nerve. In its course it receives a branch from the superior cervical ganglion of the sympathetic. It descends by the side of the pharynx behind the internal carotid artery, where it divides into two branches, the external and internal laryngeal. This nerve is the nerve of sensation of the larynx, and also supplies the crico-thyroid muscle. Exner has pointed out that the superior laryngeal nerve innervates to some extent the muscles supplied by the inferior laryngeal, and this fact explains why division of the inferior laryngeal nerve is not of necessity followed by complete paralysis of the muscles it supplies.

The **External Laryngeal Branch of the Superior Laryngeal (ramus externus) (Fig. 698),** the smaller, descends by the side of the larynx, beneath the Sterno-thyroid, to supply the Crico-thyroid muscle. It gives branches to the pharyngeal plexus and the Inferior constrictor, and communicates with the superior cardiac nerve, behind the common carotid.

The **Internal Laryngeal Branch of the Superior Laryngeal (ramus internus)** descends to the opening in the thyro-hyoid membrane, through which it passes with the superior laryngeal artery, and is distributed to the mucous membrane of the larynx. A small branch communicates with the recurrent laryngeal nerve. The branches to the mucous membrane are distributed, some in front to the epiglottis, the base of the tongue, and the epiglottidean glands; while others pass backward, in the aryteno-epiglottidean fold, to supply the mucous membrane surrounding the superior orifice of the larynx, as well as the membrane which lines the cavity of the larynx as low down as the vocal cord. The filament which joins with the recurrent laryngeal descends beneath the mucous membrane on the inner surface of the thyroid cartilage, where the two nerves become united.

The **Inferior or Recurrent Laryngeal Branch of the Vagus (n. laryngeus inferior) (Figs. 698 and 700).**—The inferior or recurrent laryngeal branch, so called from its reflected course, is the motor nerve of the larynx. It arises on the right side, in front of the subclavian-artery; winds from before backward around that vessel, and ascends obliquely to the side of the trachea, behind the common carotid artery and behind or in front of the inferior thyroid artery. On the left side it arises in front of the arch of the aorta, and winds from before backward around the aorta at the point where the remains of the ductus arteriosus are connected with it, and then ascends to the side of the trachea. The nerve on each side ascends in the groove between the trachea and oesophagus, and, passing under the lower border of the Inferior constrictor muscle, enters the larynx behind the articulation of the inferior cornu of the thyroid cartilage with the cricoid, being distributed to all the muscles of the larynx except the Crico-thyroid. It communicates with the superior laryngeal nerve and gives off a few filaments to the mucous membrane of the lower part of the larynx.

The recurrent laryngeal, as it winds around the subclavian artery and aorta, gives off several cardiac filaments, which unite with the cardiac branches from the vagus and sympathetic. As it ascends in the neck it gives off oesophageal branches, more numerous on the left than on the right side, which supply the mucous membrane and muscular coat of the oesophagus; tracheal branches to the mucous membrane and muscular fibres of the trachea; and some pharyngeal filaments to the Inferior constrictor of the pharynx.
The Cervical Cardiac Branches (rami cardiaci superiores).—The cervical cardiac branches, two or three in number, arise from the vagus, at the upper and lower part of the neck.

The Superior Branches are small, and communicate with the cardiac branches of the sympathetic. They can be traced to the great or deep cardiac plexus.

The Inferior Branches, one on each side, arise at the lower part of the neck, just above the first rib. On the right side this branch passes ventral or by the side of the arteria innominata, and communicates with one of the cardiac nerves proceeding to the great or deep cardiac plexus. On the left side it passes ventral of the arch of the aorta and joins the superficial cardiac plexus.

The Thoracic Cardiac Branches (rami cardiaci inferiores).—The thoracic cardiac branches, on the right side, arise from the trunk of the vagus as it lies by the side of the trachea, and from its recurrent laryngeal branch, but on the left side from the recurrent nerve only; passing inward, they terminate in the deep cardiac plexus.

The Ventral Pulmonary Branches.—The ventral pulmonary branches, two or three in number, and of small size, are distributed on the ventral aspect of the root of the lungs. They join with filaments of the sympathetic, and form the ventral pulmonary plexus (plexus pulmonalis anterior).

The Dorsal Pulmonary Branches.—The dorsal pulmonary branches, more numerous and larger than the ventral, are distributed on the dorsal aspect of the root of the lung; they are joined by filaments from the third and fourth (sometimes also from the first and second) thoracic ganglia of the sympathetic, and form the dorsal pulmonary plexus (plexus pulmonalis posterior). Branches from both plexuses accompany the ramification of the air-tubes through the substance of the lungs (rami bronchiae anteriores and rami bronchiae posteriores).

The Oesophageal Branches (rami oesophagei).—The oesophageal branches are given off from the vagus both above and below the pulmonary branches. The lower are more numerous and larger than the upper. They form, together with branches from the opposite nerve, the oesophageal plexus. From this plexus branches are distributed to the back of the pericardium.

The Gastric Branches (rami gastrici) (Fig. 698).—The gastric branches are the terminal filaments of the vagus nerve. The nerve on the right side is distributed to the posterior surface of the stomach. The right vagus sends branches to the coeliac plexus (rami coeliaci), to the splenic plexus (rami lienales), and to the renal plexus (rami renales). The nerve on the left side is distributed over the anterior surface of the stomach, some filaments (rami hepatici) passing across the great cul-de-sac, and others along the lesser curvature. They unite with branches of the right nerve and with the sympathetic, some filaments passing through the lesser omentum to the hepatic plexus.

Surgical Anatomy.—The laryngeal nerves are of considerable importance in considering some of the morbid conditions of the larynx. When the peripheral terminations of the superior laryngeal nerve are irritated by some foreign body passing over them, reflex spasm of the glottis is the result. When the trunk of the same nerve is pressed upon by, for instance, a goitre or an aneurism of the upper part of the carotid, we have a peculiar dry, brassy cough. When the nerve is paralyzed, we have anesthesia of the mucous membrane of the larynx, so that foreign bodies can readily enter the cavity, and, in consequence of its supplying the crico-thyroid muscle, the vocal cords cannot be made tense, and the voice is deep and hoarse. Paralysis of the superior laryngeal nerves may be the result of bulbar paralysis, may be a sequel to diphtheria, when both nerves are usually involved, or it may, though less commonly, be caused by the pressure of tumors or aneurisms, when the paralysis is generally unilateral. Irritation of the inferior laryngeal nerves produces spasm of the muscles of the larynx. When both the recurrent nerves are paralyzed, the vocal cords are motionless in the so-called cadaveric position—that is to say, in the position in which they are found in ordinary tranquil respiration—neither closed as in phonation, nor open as in deep inspiratory effort. When one recurrent nerve is paralyzed, the cord of the same side is motionless, while the opposite cord crosses the middle line to accommodate itself to the affected one; hence phonation is present, but the voice is altered and weak in timbre. The recurrent laryngeal nerves may be paralyzed in bulbar paralysis or after diph-
therapy, when the paralysis usually affects both sides; or they may be affected by the pressure of aneurisms of the aorta, innominate or subclavian arteries; by mediastinal tumors; by bronchocle; or by cancer of the upper part of the oesophagus, when the paralysis is often unilateral. The nerve may be accidentally divided during the operation for goitre.

It is a well-recognized fact that disease or injury of the vagus may induce serious symptoms. Bruising may cause such symptoms; so may injury of the nerve by a stab, a bullet, or during surgical operations. Either accidental ligation or crushing with clamp forceps is particularly dangerous. Michaux accidentally ligated the vagus, and the patient became comatose and ceased to breathe, but was restored on removing the ligature. Tillmanns, while removing a cancer, accidentally caught and crushed a portion of the nerve in a clamp, and both pulse and respiration ceased. The clamp was removed, the patient was restored with difficulty, and the nerve was sutured. Recovery followed. It thus becomes evident that division of the vagus on one side is not, as was so long taught, a necessarily fatal accident; in fact, it is sometimes undertaken deliberately in removing tumors adherent to the nerve. Division of a nerve which has been long compressed is probably not so dangerous as division of a healthy nerve, as in the former case the opposite vagus has probably assumed some of its colleague’s duties. A number of cases of deliberate division have been reported. Twenty-three cases are referred to in the system of surgery by von Bergmann and Mikulicz, and twelve of them died, but in none of the deaths was the removal of the vagus the apparent cause of the fatality. The editor of this American edition of “Gray” has seen three cases: One was operated upon by Dr. W. Joseph Hearn, one by Dr. Melvin Franklin, and one by the editor. All three recovered, and not one presented any serious disturbance, although each had hoarseness and weakness of voice.

One would assume that after division of the vagus below the superior laryngeal nerve and above the recurrent laryngeal nerve (the region usually attacked) that there would be paralysis of all the muscles of one side of the larynx, except the crico-thyroid, and widespread aberration evinced by disturbances of the heart, stomach, and lungs. As a matter of fact, this has not been the case. It might be and probably would be the case, were a healthy nerve divided; but the surgeon who deliberately divides the nerve does so during the removal of a tumor which has long made pressure. In most cases there is no change in the pulse or respiration. In some cases dysphagia and pneumonia arise, but they may be due to other causes than vagus-nerve injury (the formidable nature and the duration of the operation—the ligation of vessels of large size—the age of the subject).

Laryngeal symptoms, to a greater or less degree, are always noted. The difference in the degree of the palsy is explainable when we recall Exner’s statement that the muscles supplied by the recurrent laryngeal also receive some innervation from the superior laryngeal. In fact, Mills points out that a portion of the recurrent laryngeal has been resected without completely paralyzing the muscles supposed to be supplied solely by the recurrent laryngeal. The laryngeal symptoms result from unilateral laryngeal paralysis, in which there is paralysis of the muscles which open the glottis. The voice may be lost or may be hoarse. Usually, after a time, this is, to a great extent, compensated for by the opposite vocal cord, although the voice may always remain weak, and the patient will tire easily on talking. If both vagi were to be divided death would ensue.

THE ELEVENTH OR ACCESSORY NERVE (N. ACCESSORIUS)
(Figs. 697 and 698).

The eleventh, accessory, or spinal accessory nerve consists of two parts: one the accessory part to the vagus, and the other the spinal portion.

The Bulbar or Vagal Accessory Part of the Accessory Nerve (Ramus Internus).

The bulbar or vagal accessory part is the smaller of the two. It is accessory to the vagus. Its superficial origin (Fig. 697) is by four or five delicate filaments from the side of the oblongata, below the roots of the vagus. Its deep origin is described in detail on page 890. It passes outward to the jugular foramen, where it interchanges fibres with the spinal portion or becomes united to it for a short distance; it is also connected, in the foramen, with the upper ganglion of the vagus by one or two filaments. It then passes through the foramen (Fig. 698), and becoming again separated from the spinal portion it is continued over the surface.
of the ganglion of the trunk of the vagus, being adherent to its surface, and is
distributed principally to the pharyngeal and superior laryngeal branches of the
vagus. Through the pharyngeal branch it probably supplies the muscles of the soft
palate. Some few filaments from it are continued into the trunk of the vagus below
the ganglion, to be distributed with the recurrent laryngeal nerve to supply most
of the laryngeal muscle, and probably also with the cardiac nerves.

The Spinal Portion of the Accessory Nerve (Ramus Externus).

The spinal portion is firm in texture. Its superficial origin (Fig. 697) is by
several filaments or rootlets from the lateral tract of the cord, as low down as
the sixth cervical nerve. Its deep origin (Fig 578) may be traced to the inter-
medio-lateral tract of the gray substance of the cord. The rootlets of origin join and
form a trunk which ascends in the subdural space between the ligamentum den-
ticulatum and the ventral roots of the spinal nerves, enters the skull through the
foramen magnum, and is then directed outward to the jugular foramen, through
which it passes, lying in the same sheath as the vagus, but separated from it by a
fold of the arachnoid. In the jugular foramen it receives one or two filaments
from the vagal accessory portion. At its exit from the jugular foramen it passes
into the neck and becomes the external branch (Figs. 655 and 698). It passes
backward, either in front of or behind the internal jugular vein, and descends
obliquely behind the Digastric and Stylo-hyoid muscles to the upper part of the
Sterno-mastoid muscle. It pierces that muscle, and passes obliquely across the
posterior triangle, to terminate in the deep surface of the Trapezius muscle.
This nerve gives several branches to the Sterno-mastoid muscle during its passage
through it, and joins in its substance with branches from the second cervical, which
supply the muscle. In the posterior triangle it joins with the second and
third cervical nerves, while beneath the Trapezius it forms a sort of plexus with
the third and fourth cervical nerves, and from this plexus fibres are distributed
to the muscle.

Surgical Anatomy.—Division of the external branch of the accessory nerve causes paralysis
of the Sterno-clido-mastoid and Trapezius muscles; not absolute paralysis, for these muscles
also receive nerves from the cervical plexus. In cases of spasmodic torticollis in which all
palliative treatment has failed division or excision of a portion of the external branch of the
accessory nerve has been suggested by Keen. This may be done either along the anterior or
posterior border of the Sterno-mastoid muscle. The former operation is performed by making
an incision from the apex of the mastoid process, three inches in length, along the anterior border of
the Sterno-mastoid muscle. The anterior border of the muscle is defined and pulled back-
ward, so as to stretch the nerve, which is then to be sought for beneath the Digastric muscle,
about two inches below the apex of the mastoid process. The other operation consists in
making an incision along the posterior border of the muscle, so that the centre of the incision
corresponds to the middle of this border of the muscle. The superficial structures having been
divided and the border of the muscle defined, the nerve is to be sought for as it emerges from
the muscle to cross the occipital triangle. When found, it is to be traced upward through the
muscle, and a portion of it is excised above the point where it gives off its branches to the Sterno-
mastoid. In this operation one of the descending branches of the superficial cervical plexus is
liable to be mistaken for the nerve.

THE TWELFTH OR HYPOGLOSSAL NERVE (N. HYPOGLOSSUS)
(Figs. 701 and 702).

The twelfth or hypoglossal nerve is the motor nerve of the tongue. Its superficial origin is by several filaments, from ten to fifteen in number, from the groove
between the pyramidal and olivary bodies of the oblongata, in a continuous line
with the ventral roots of the spinal nerves. Its deep origin can be traced to a
nucleus of gray substance (nucleus hypoglossi) in the floor of the fourth ventricle described on p. 890.

The filaments of this nerve are collected into two bundles, which perforate the dura separately, opposite the anterior condyloid foramen, and unite together after their passage through it. In those cases in which the anterior condyloid

or hypoglossal foramen in the occipital bone is double, these two portions of the nerve are separated by the small piece of bone which divides the foramen. The nerve descends almost vertically to a point corresponding with the angle of the jaw. It is at first deeply seated beneath the internal carotid artery and internal jugular vein, and is intimately connected with the vagus nerve (Fig. 702); it then passes forward between the vein and artery, and lower down in the neck becomes superficial below the Digastric muscle. The nerve then loops around the occipital artery, and crosses the external carotid and its lingual branch below the tendon of the Digastric muscle. It passes beneath the tendon of the Digastric, the Stylohyoid, and the Mylo-hyoid muscles, lying between the last-named muscle and the Hyoglossus (Fig. 702), and communicates at the anterior border of the Hyoglossus with the lingual nerve (Fig. 701); it is then continued forward in the fibres of the Genio-hyglossus muscle as far as the tip of the tongue, distributing branches to its muscular substance.

Branches of Communication (Fig. 701).—The branches of communication are with the

Vagus. First and Second Cervical Nerves.
Sympathetic. Lingual (gustatory).
The first mentioned takes place close to the exit of the nerve from the skull, numerous filaments passing between the hypoglossal and the ganglion of the trunk of the vagus through the mass of connective tissue which here unites the two nerves. It also communicates with the pharyngeal plexus by a minute filament as it winds around the occipital artery.

The communication with the sympathetic takes place opposite the atlas vertebra by branches derived from the superior cervical ganglion, and in the same situation the nerve is joined by filaments derived from the loop connecting the first two cervical nerves.

The communication with the lingual nerve takes place near the anterior border of the Hypoglossus muscle by numerous filaments which ascend upon it.

**Fig. 702.**—Hypoglossal nerve, cervical plexus, and their branches.

**Branches of Distribution** (Fig. 701).—The branches of distribution are—the

<table>
<thead>
<tr>
<th>Dural</th>
<th>Thyro-hyoid</th>
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</thead>
<tbody>
<tr>
<td>Descendens hypoglossi</td>
<td>Muscular</td>
</tr>
</tbody>
</table>

**Dural Branches** (Fig. 701).—As the hypoglossal nerve passes through the anterior condyloid foramen it gives off, according to Luschka, several filaments to the dura in the posterior fossa of the base of the skull; these filaments are probably derived from a branch which passes from the first cervical nerve to the hypoglossal nerve.

**The Descendens Hypoglossi** (ramus descendens) (Figs. 701 and 702).—The descendens hypoglossi, long called the descendens noni, is a long slender branch,
which quits the hypo-glossal where it turns around the occipital artery. It consists mainly of fibres which pass to the hypo-glossal from the first and second cervical nerves in the above-mentioned communication. It descends in front of or within the sheath of the common carotid artery, giving off a branch to the anterior belly of the Omo-hyoid, and then joins the communicating branches from the second and third cervical nerves, just below the middle of the neck, to form a loop, the **ansa hypo-glossi**. From the convexity of this loop branches pass to supply the Sterno-hyoid, Sterno-thyroid, and the posterior belly of the Omo-hyoid. According to Arnold, another filament descends in front of the vessels into the chest, and joins the cardiac and phrenic nerves.

The **Thyro-hyoid Branch** (*ramus thyreohyoidens*) (Fig. 701).—The thyro-hyoid is a small branch arising from the hypoglossal near the posterior border of the Hyo-glossus; it passes obliquely across the great cornu of the hyoid bone and supplies the Thyro-hyoid muscle.

The **Muscular Branches** (Fig. 701).—The muscular branches are distributed to the Stylo-glossus, Hyo-glossus, Genio-hyoid, and Genio-hyo-glossus muscles. At the under surface of the tongue numerous slender branches (*rami linguales*) pass upward into the substance of the organ to supply its intrinsic muscles.

**Surgical Anatomy.**—A wound in the submaxillary region may injure the hypoglossal nerve and result in motor paralysis of the corresponding half of the tongue. The hypo-glossal nerve is an important guide in the operation of ligation of the lingual artery (see page 606). It runs forward on the Hyo-glossus muscle just above the great cornu of the hyoid bone, and forms the upper boundary of the triangular space in which the artery is to be sought for by cutting through the fibres of the Hyo-glossus muscle.

THE SYMPATHETIC NERVE SYSTEM (*SYMPATHICUS*) (Fig. 703).

The sympathetic nerve system consists of (1) a series of **ganglia** (*ganglia trunci sympathici*) connected together by a great **ganglionic cord**, the **gangliated cord** (*trunci sympathicus*), extending from the base of the skull to the coccyx, one gangliated cord on each side of the middle line of the body, partly in front and partly on each side of the vertebral column; (2) of three **great gangliated plexuses** (*plexus sympathici*) or aggregations of nerves and ganglia, situated in front of the spine in the thoracic, abdominal, and pelvic cavities respectively; (3) of **smaller or terminal ganglia**, situated in relation with the abdominal viscera; and (4) of numerous **nerve-fibres**. These latter are of two kinds: **communicating**, by which the ganglia communicate with each other and with the cerebro-spinal nerves; and **distributory**, supplying the internal viscera and the coats of the blood-vessels.

Each gangliated cord may be traced upward from the base of the skull into the cranial cavity by an ascending branch, which passes through the carotid canal, forms a plexus on the internal carotid artery and in the cavernous sinus (Fig. 707), and communicates with certain cranial nerves (p. 1084). According to some anatomists, the two cords are joined, at their cephalic extremities, by these ascending branches communicating in a small ganglion, the **ganglion of Ribes**, situated upon the anterior communicating artery. Upon the gangliated cord are ganglia distinguished as **cervical**, **thoracic**, **lumbar**, and **sacral**, and except in the neck they correspond pretty nearly in number to the vertebrae against which they lie. They may be thus arranged:

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of Ganglia</th>
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<tbody>
<tr>
<td>Cervical</td>
<td>3 pairs</td>
</tr>
<tr>
<td>Thoracic</td>
<td>12</td>
</tr>
<tr>
<td>Lumbar</td>
<td>4</td>
</tr>
<tr>
<td>Sacral</td>
<td>4 or 5</td>
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In the neck they are situated in front of the transverse processes of the vertebrae; in the thoracic region, in front of the heads of the ribs; in the lumbar region, on the sides of the bodies of the vertebrae; and in the sacral region, in front of the sacrum. As the two cords pass into the pelvis they converge and unite together in a single ganglion, the coccygeal ganglion or ganglion impar (ganglion coccygeum impar) placed in front of the coccyx. Each ganglion may be regarded as a distinct centre, and, in addition to its branches of distribution, possesses also branches of communication which communicate with other ganglia and with the cerebro-spinal nerves.

The branches of communication between the ganglia (Figs. 704 and 705) are composed of gray nerve-fibres (gray rami communicantes) and white nerve-fibres (white rami communicantes), the latter being continuous with those fibres of the spinal nerves which pass to the ganglia.

The three great gangliated plexuses (collateral ganglia) are situated in front of the spine in the thoracic, abdominal, and pelvic regions, and are named, respectively, the cardiac, the solar or epigastric, and the hypogastric plexus. They consist of collections of nerves and ganglia, the nerves being derived from the gangliated cords and from the cerebro-spinal nerves. They distribute branches to the viscer.

Smaller or Terminal ganglia are also found lying amidst the nerves, some of them of microscopic size, in certain viscer—as, for instance, in the heart, the stomach, and the uterus. They serve as additional centres for the origin of nerve-fibres. There are numerous special ganglia connected with the cranial nerves.

These ganglia have been described in a previous section (see ophthalmic ganglion, otic ganglion, sphenopalatine ganglion, and submaxillary ganglion).

The branches of distribution derived from the gangliated cords, from the prevertebral plexuses, and also from the smaller ganglia, are principally destined...
for the blood-vessels and thoracic and abdominal viscera, supplying the involuntary muscular fibre of the coats of the vessels and the hollow viscera, and the secreting cells, as well as the muscular coats of the vessels in the glandular viscera.

**Structure of the Sympathetic System.**—The sympathetic system is not, as was so long taught, an independent system. It receives fibres from the cerebro-spinal system and arranges them for distribution to the splanchnic blood-vessels and the viscera. It receives fibres from the viscera and transmits them to the cerebro-spinal system, and it transmits fibres by way of the spinal nerves to unstripped muscles, to vessels, and to glands. It is simply an arrangement of spinal nerves to permit of the re-arrangement and transmission of impulses. In order to effect this, the spinal nerves are connected with a series of ganglia, which possess a certain power of government or automatic action. In the sympathetic system amyelinic fibres predominate. The individual nerve-fibres are smaller in diameter than those of the cerebro-spinal system, and the fibres are interrupted by nerve-cells contained in a ganglia chain, known as the gangliated cord, and are also sometimes interrupted in gangliated plexuses and in terminal ganglia. The sympathetic nerves have a notable disposition to form plexuses. It is important to note that not all of the visceral branches of the spinal nerves join the gangliated cord—for instance, the visceral branches of the third and fourth sacral do not. The majority, but not all, of the sympathetic fibres are amyelinic (fibres of Remak), but in the adult true amyelinic fibres are found only in the sympathetic system. These fibres are of smaller diameter than spinal nerve-fibres, and are prolongations of axones of sympathetic ganglia cells. Each fibre is surrounded by connective-tissue structure which resembles the neurilemma, which contains numerous nuclei, and which is a prolongation of the capsule of a sympathetic cell capsule.

A sympathetic nerve consists of numerous amyelinic and some myelinic fibres. The connective tissue which separates the nerve-bundles carries blood-vessels and nervi nervorum, but no lymph vessels.

The **sympathetic ganglia** contain multipolar cells which are smaller than those of the spinal ganglia. Each cell contains two nuclei, and is surrounded by a delicate capsule of connective tissue. The cell gives off one axone and several short dendrites. The axone is amyelinic when it begins and may remain so or may become myelinic. Fibres which take origin from sympathetic axones, the **commissural fibre**, may pass to an adjacent ganglion cell, may pass toward the centre, **central fibre** or **gray ramus communicans**, or may pass toward the periphery, **peripheral fibre**, and reach certain glands, or to unstripped muscle of blood-vessels, intestines, iris, etc. The fibres passing to glands are called **secreter fibres**.

The dendrites of a ganglion cell form arborizations about other ganglion cells. The sympathetic ganglia contains fibres as well as cells. Some of the fibres are myelinic and some are amyelinic, the latter taking origin from the sympathetic ganglion cells, the former being motor and sensor cerebro-spinal fibres which have reached the sympathetic by the rami communicantes.

The **amyelinic fibres**, the **white rami communicantes** or the **visceral branches** of the **spinal nerves** (Figs. 704 and 705), originate from the ventral divisions of certain accessory nerves. Two groups of them can be recognized, one group coming from the nerves from the first or second thoracic to the second or third lumbar nerves; another group from the second or third lumbar to the third or fourth sacral. The visceral branches of the third and fourth sacral do not join the gangliated cord; the other visceral branches do join it. The fibres of the visceral branches of the spinal nerves are derived from both the ventral and the dorsal nerve-roots, but more largely from the ventral than from the dorsal. The visceral fibres of the ventral roots are axones of nerve-cells of the spinal cord, and by way of the white

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1 Histology and Microscopic Anatomy, by Szymonowicz. Translated and edited by John Bruce MacCallum.
rami enter into the sympathetic ganglia. Some of them end and form networks about the ganglia cells. Others pass up or down and end in an adjacent ganglion. Others pass through a ganglion of the gangliated cord and end in a peripheral ganglion with amyelinic fibres, which take origin from ganglia of the gangliated cord. The fibres of the white rami which pass through the ganglion and go to the periphery are known as the splanchnic efferent fibres, and constitute the secretor fibres of the splanchnic glands and the motor fibres of the muscular tissue of splanchnic blood-vessels and viscera. The visceral fibres of the dorsal nerve-roots aid in the formation of the white rami and arise as axones of nerve-cells in the spinal ganglia on the dorsal roots; they then pass through the ganglia of the sympathetic cord, but do not terminate in them, and leave the ganglion directly to pass through a peripheral ganglion to be distributed to the periphery, or ascend, or descend to an adjacent ganglion and pass through this to a collateral ganglion, and thence to the periphery. They constitute the splanchnic afferent fibres, the sensor fibres of the viscera.

The amyelinic fibres take origin from the cells of the sympathetic ganglia and are axones of these cells. Some help to form the commissure, which joins a ganglion to adjacent ganglia and end as networks about the cells of an adjacent ganglion. Others run to the periphery and help to form the splanchnic efferent branches. Some pass from the ganglia to the spinal nerve-roots and to the ventral and dorsal divisions of the nerves. The latter are the gray rami communicantes (Fig. 705), largely composed of amyelinic but containing some myelinic fibres. They give branches to the somatic part of the nerves but not the visceral, and furnish secretor fibres and fibres to unstriated muscle and minute branches to the membranes which enwrap the nerve-roots. The commissures of the gangliated cord are composed of white and gray fibres. The former consist of both splanchnic efferent and splanchnic afferent fibres. The latter are axones from sympathetic ganglion cells, and some of these are truly commissural, but
others pass up or down the cord and through a ganglion and become branches which go to the periphery.

From the above it becomes evident that the peripheral branches of the sympathetic contain white fibres, which are composed of splanchnic efferent and splanchnic afferent branches and also contain splanchnic efferent gray fibres.

These connections will be better understood by examining the plan drawn out in Fig. 704. There a represents a myelinic nerve-fibre from a ventral nerve-root, passing by a white ramus communicans through the ganglion directly connected with that spinal nerve to a ganglion higher up, where it will form an arborization round a nerve-cell, like e; b, a myelinic nerve-fibre forming an arborization round a cell of the ganglion of its own segment; c, a fibre passing through the ganglion without interruption and leaving it by one of its efferent branches to a prevertebral plexus or directly to some viscera; d, a fibre passing through the ganglion to some lower ganglion, there to end round some nerve-cell, or pass out through an efferent ramus; e, a myelinic nerve from a lower ganglion, behaving as a.

The dotted lines are amyelinic nerves. The fibre, f, arises as the axis-cylinder process of a ganglion cell, and passes by a gray ramus communicans along the sheath of the posterior nerve-root to the spinal meninges; g passes by the posterior division to supply sympathetic fibres to its area of distribution; h enters the anterior division and is similarly distributed; k joins the spinal recurrent branch to supply the interior of the vertebral canal, and l passes for a little way along the gray ramus communicans, but leaves it to be distributed to the sides of the vertebral and intercostal or lumbar vessels. Gray fibres to the prevertebral plexuses, vessels, or viscera, are represented by m, m; and n, n are amyelinic fibres joining neighboring ganglia. In addition to these, sensor fibres from the ganglia of the posterior spinal nerve-roots pass through the sympathetic ganglia to viscera without interruption.

THE GANGLIATED CORD (TRUNCUS SYMPATHICUS).

The Cervical Portion (Pars Cervicalis) of the Gangliated Cord.

The cervical portion of the gangliated cord is to be regarded as a prolongation upward of the primitive sympathetic along the great vessels of the neck (Cunningham). It is not connected to the cervical spinal nerves by white rami communicantes. It obtains its spinal fibres from the upper thoracic nerves. These fibres ascend in the commissure of the gangliated cord and join the cells of the cervical ganglia. From the cervical ganglia come fibres to the unstriped muscle (veins and arteries of the head, neck, and limbs, and to the skin of the head and neck, secretor fibres to the salivary glands and fibres to the heart). The fibres to the vessels are called vasomotor nerves, and the fibres to the heart are called cardio-motor nerves. In the neck the gangliated cord is situated behind the carotid vessels and upon the muscles in front of the vertebrae, and runs from the root of the neck to the base of the skull, being continuous below with the thoracic gangliated cord and ending above in the carotid plexus. There are usually three ganglia on each side, each of which is distinguished, according to its position, as the superior, middle, and inferior cervical ganglion.

The Superior Cervical Ganglion (ganglion cervicale superior) (Figs. 705 and 706).—The superior cervical ganglion, the largest of the three, is about three-quarters of an inch in length. It is placed opposite the second and third cervical vertebrae. It is of a reddish-gray color, is usually fusiform in shape, is sometimes broad and flattened, and is occasionally constricted at intervals, so as to give rise to
the opinion that it consists of the coalescence of several smaller ganglia; and it is usually believed that it is formed by the coalescence of the four ganglia correspond-
ing to the four upper cervical nerves. It is in relation, in front, with the sheath of the internal carotid artery and internal jugular vein; behind, it lies on the Rectus capitis anticus major muscle. It is connected to the middle cervical gan-
glion by the commissure of the gangliated cord.  

Branches.—The branches of the superior cervical ganglion are central and peripheral.  

Central or Communicating Branches.—1. Gray rami communicantes arise in the ganglion and pass to the first, second, third, and fourth cervical nerves. 2. Branches are given off to certain cranial nerves in the neck (Fig. 706). What is known as the jugular nerve (n. jugularis) passes to the ganglion on the trunk of the vagus, a branch from the ganglion passes to the ganglia on the root of the vagus and to the petrosal ganglion of the glosso-pharyngeal, and a branch goes to the hypo-glossal.  

Peripheral Branches.—These branches may be divided into superior, internal, and anterior.  

The Superior Branch of the Superior Cervical Ganglion or the Internal Carotid Branch (n. caroticus internus) (Fig. 706) appears to be a direct prolongation of the ganglion. It is soft in texture and of a reddish color. It ascends by the side of the internal carotid artery, and, entering the carotid canal in the temporal bone, divides into two branches, which lie, one on the outer, and the other on the inner, side of that vessel.  

The outer branch, the larger of the two, distributes filaments to the internal carotid artery and forms the internal carotid plexus.  

The inner branch also distributes filaments to the internal carotid, and, continu-
ing onward, forms the cavernous plexus.  

The Internal Carotid Plexus (plexus caroticus internus) (Figs. 705 and 706).—The carotid plexus is situated on the outer side of the internal carotid artery. Filaments from this plexus occasionally form a small gangliform swelling on the under surface of the artery, which is called the carotid ganglion. The internal carotid plexus communicates with the Gassarian ganglion, with the abducent nerve, and the sphenopalatine ganglion, and distributes filaments to the wall of the carotid artery and to the dura (Valentin), while in the carotid canal it communicates with Jacobson's nerve, which is the tympanic branch of the glosso-
pharyngeal.  

The communicating branches to the abducent nerve consist of one or two filaments which join that nerve as it lies upon the outer side of the internal carotid. Other filaments are also connected with the Gasserian ganglion. The communication with the sphenopalatine ganglion is effected by a branch, the large deep petrosal nerve (Fig. 694), which is given off from the plexus on the outer side of the artery, and which passes through the cartilage filling up the foramen lacerum medium, and joins the large superficial petrosal from the facial to form the Vidian nerve (Figs. 689 and 694). The Vidian nerve then proceeds along the pterygoid or Vidian canal to the sphenopalatine ganglion. The com-

munication with Jacobson's nerve is effected by two branches, one of which is called the deep petrosal nerve, and the other the carotico-typanic nerve; the latter may consist of two or three delicate filaments.  

The Cavernous Plexus (plexus cavernosus) (Fig. 706).—The cavernous plexus is situated below and internal to that part of the internal carotid which is placed by the side of the sella cavernous sinus, and is formed chiefly by the internal division of the ascending branch from the superior cervical ganglion. It communicates with the oculomotor, the trochlear, the ophthalmic division of the trigeminal, and the abducent nerves, and with the ophthalmic ganglion, and distributes filaments to the wall of the internal carotid and to the hypophysis.  

The branch of communication with the oculomotor nerve joins it at its point of
division; the branch to the trochlear nerve joins it as it lies on the outer wall of the cavernous sinus; other filaments are connected with the under surface of the trunk of the ophthalmic nerve; and a second filament of communication joins the abducent nerve.

The filament of connection with the ophthalmic ganglion (Fig. 684) arises from the anterior part of the cavernous plexus; it accompanies the nasal nerve or continues forward as a separate branch.

Terminal Branches of the Carotid and Cavernous Plexuses.—The terminal filaments from the carotid and cavernous plexuses are prolonged along the internal carotid, forming plexuses which entwine around the cerebral and ophthalmic arteries; along the former vessels they may be traced on to the pia; along the latter, into the orbit, where they accompany each of the subdivisions of the vessel, a separate plexus passing, with the arteria centralis retinae, into the interior of the eyeball. The filaments prolonged on to the anterior communicating artery form a small ganglion, the ganglion of Ribes,¹ which serves, as mentioned above, to connect the sympathetic nerves of the right and left sides.

The so-called Inferior or Descending Branch of the Superior Cervical Ganglion communicates with the middle cervical ganglion. It is the commissure of the gangliated cord.

The Internal Branches of the Superior Cervical Ganglion are three in number—the pharyngeal, laryngeal, and superior cardiac nerve.

The pharyngeal branches (rami pharyngei) (Fig. 705) pass inward to the side of the pharynx, where they join with branches from the glossopharyngeal, vagus, and external laryngeal nerves to form the pharyngeal plexus.

¹ The existence of this ganglion is doubted by some observers.—En. of 15th English edition.
The laryngeal branches unite with the superior laryngeal nerve and its branches. The superior cardiac nerve or the nervus superficialis cordis (n. cardiacus superior) (Fig. 705) arises by two or more branches from the superior cervical ganglion, and occasionally receives a filament from the cord of communication between the first and second cervical ganglia. It runs down the neck behind the common carotid artery, lying upon the Longus colli muscle, and crosses in front of the inferior thyroid artery and recurrent laryngeal nerve. The right superior cardiac nerve, at the root of the neck, passes either in front of or behind the subclavian artery, and along the arteria innominata, to the back part of the arch of the aorta, where it joins the deep cardiac plexus. This nerve, in its course, is connected with other branches of the sympathetic; about the middle of the neck it receives filaments from the external laryngeal nerve; lower down it obtains one or two twigs from the vagus, and as it enters the thorax it is joined by a filament from the recurrent laryngeal. Filaments from this nerve communicate with the thyroid branches from the middle cervical ganglion. The left superior cardiac nerve, in the chest, runs by the side of the left common carotid artery and in front of the arch of the aorta to the superficial cardiac plexus, but occasionally it passes behind the aorta and terminates in the deep cardiac plexus.

The Anterior Branches of the Superior Cervical Ganglion (nn. carotici externi) (Fig. 707) ramify upon the external carotid artery and its branches, forming around each a delicate plexus, on the nerves composing which small ganglia are occasionally found. The plexuses accompanying some of these arteries have important communications with other nerves. That surrounding the external carotid artery (plexus caroticus externus) is connected with the branch of the facial nerve to the Stylohyoid muscle; that surrounding the facial artery communicates with the submaxillary ganglion by one or two filaments; and that accompanying the medidural artery sends offsets which pass to the otic ganglion and to the genulate ganglion of the facial nerve and constitute the external superficial petrosal nerve (Fig. 694).

The Middle Cervical or Thyroid Ganglion (ganglion cervical medium) (Figs. 705 and 707).—The middle cervical or thyroid ganglion is the smallest of the three cervical ganglia, and is occasionally altogether wanting. It varies somewhat in position, but in most individuals is placed opposite the sixth cervical vertebra, usually upon, or close to, the inferior thyroid artery; hence the name, thyroid ganglion, assigned to it by Haller. It is probably formed by the coalescence of two ganglia corresponding to the fifth and sixth cervical nerves.
It communicates above with the superior cervical ganglion and below with the inferior cervical ganglion by means of the commissure of the gangliated cord.

The Central Communicating Branches.—The central communicating branches are: 1. Gray rami communicantes passing from the ganglion to the anterior divisions of the fifth and sixth cervical nerves. 2. The subclavian loop or the ansa of Vieussens (ansa subclavia) (Fig. 708) arises from the ganglion, passes down over the front and under the subclavian artery and runs back to join the inferior cervical ganglion. It gives branches to the artery. In some cases this nerve takes origin from the sympathetic trunk below the ganglion.

The Peripheral Branches.—The peripheral branches are the thyroid and the middle cardiac nerve.

The Thyroid Branches are small filaments which accompany the inferior thyroid artery to the thyroid gland, forming the inferior thyroid plexus (plexus thyreoideus inferior); they communicate, on the artery, with the superior cardiac nerve, and, in the gland, with branches from the recurrent and external laryngeal nerves.

The Middle or Great Cardiac Nerve (n. cardiacus medius) (Fig. 705), the largest of the three cardiac nerves, arises from the middle cervical ganglion or from the cord between the middle and inferior ganglia. On the right side it descends behind the common carotid artery, and at the root of the neck passes either in front of or behind the subclavian artery; it then descends on the trachea, receives a few filaments from the recurrent laryngeal nerve, and joins the right side of the deep cardiac plexus. In the neck it communicates with the superior cardiac and recurrent laryngeal nerves. On the left side the middle cardiac nerve enters the chest between the left carotid and subclavian arteries, and joins the left side of the deep cardiac plexus. If the middle cervical ganglion is absent, the above-named branches arise from the gangliated cord.

The Inferior Cervical Ganglion (ganglion cervicale inferius) (Figs. 705 and 707).—The inferior cervical ganglion is situated between the base of the transverse process of the last cervical vertebra and the neck of the first rib on the inner side of the superior intercostal artery. Its form is irregular; it is larger in size than the preceding, and is frequently joined to the first thoracic ganglion. It is probably formed by the coalescence of two ganglia which correspond to the two last cervical nerves. It joins the middle ganglion above and the first thoracic ganglion below by means of the commissural cord, and is usually also joined to the middle ganglion by the subclavian loop.

The Central Communicating Branches.—Its central communicating branches are:
1. Gray rami communicantes passing to the anterior divisions of the seventh and eighth cervical nerves (Fig. 707). 2. The subclavian loop (Fig. 708), which has been previously described and which passes under and in front of the subclavian artery to reach the middle cervical ganglion or the commissural cord.

The Peripheral Branches.—The peripheral branches are: 1. Vascular. The vertebral plexus (plexus vertebralis) lies upon the vertebral artery and its branches in the neck and in the cranial cavity. The subclavian plexus (plexus subclavius) arises from the subclavian loop, which may be regarded as a branch of the inferior or of the middle ganglion. 2. Cardiac. The inferior or minor cardiac nerve (n. cardiacus inferior) arises from the inferior cervical or first thoracic ganglion. It passes down behind the subclavian artery and along the front of the trachea to join the deep cardiac plexus. It communicates freely behind the subclavian artery with the recurrent laryngeal and middle cardiac nerves.
Surgical Anatomy. — The situation of the cervical sympathetic makes wounds of it rare. Thirteen cases of sympathetic traumatic injury were collected by Seeligmüller. In ten cases paralysis existed; in three, irritation. Tumors of the neck may cause irritation or paralysis. In irritation of the sympathetic the corresponding side of the face becomes pale, the pupil dilates, the palpebral fissure widens, and the eyeball protrudes. In many cases there is acceleration of the heart beats. In paralysis of the sympathetic the pupil contracts, the palpebral fissure is narrowed by partial ptosis, the corresponding side of the face reddens, there is an increase in the flow of tears, and recession of the eyeball.

The surgeon occasionally resects the sympathetic. Jonnesco recommends bilateral removal of the superior cervical ganglia for glaucoma, and bilateral removal of all the cervical sympathetic ganglia for epilepsy and for exophthalmic goitre.

The Thoracic Portión (Pars Thoracalis) of the Gangliated Cord (Fig. 709).

The thoracic portion of the gangliated cord consists of a series of ganglia which usually correspond in number to that of the vertebrae, but, from the occasional coalescence of two, their number is uncertain. These ganglia are placed on each side of the spine, resting against the heads of the ribs, and are covered by the pleura costalis; the last two ganglia are, however, ventral to the rest, being placed on the side of the bodies of the eleventh and twelfth thoracic vertebrae. The ganglia are small in size and of a grayish color. The first ganglion, larger than the rest, is of an elongated form and is frequently blended with the last cervical ganglion. They are connected together by cord-like prolongations from their substance. In the thorax each thoracic spinal nerve, with occasionally the exception of the first, sends a visceral branch or white ramus communicans to the thoracic gangliated cord (Fig. 709). As Prof. Cunningham points out, the white rami “separate into two main streams in relation to the sympathetic cord. Those of the upper five nerves are, for the most part, directed upward in the gangliated cord to be distributed through the cervical part of the sympathetic in the manner already described. The white rami of the lower thoracic nerves are, for the most part, directed downward in the lower part of the sympathetic cord and its branches, to be distributed to the abdomen; at the same time some of their fibres are directly associated with the supply of certain thoracic viscera—lungs, aorta, œsophagus.” The white rami are composed of splanchnic afferent fibres and somatic and splanchnic efferent fibres.

Central Communicating Branches.—1. White rami communicantes (see above). 2. Gray rami communicantes arise from each one of the thoracic ganglia, pass backward with the white rami, and enter into the ventral divisions of the thoracic nerves.

Peripheral Branches.—1. Aortic Branches come off from the first five or six upper ganglia. They send filaments to the aorta and its branches, to the vertebral bodies, and to the vertebral ligaments. The aortic branches help to form the thoracic aortic plexus (plexus aorticus thoracalis). This plexus is completed by branches from the cardiac plexus.

2. Pulmonary Branches come off from the third and fourth and sometimes from the first and second ganglia.

3. The Splanchnic Nerves (Figs. 705 and 709).—From the six or seven lower ganglia and from the commissural cord a number of large white branches arise. They give filaments to the aorta and unite to form the three splanchnic nerves on each side. These are named the great, the lesser, and the smallest or renal splanchnic.

The superior or great splanchnic nerve (n. splanchnicus major) is of a white color, firm in texture, and presents a marked contrast to the ganglionic nerves. It is formed by branches from the thoracic ganglia between the fifth or sixth and the ninth or tenth, but the fibres in the higher roots may be traced upward in the sympathetic cord as far as the first or second thoracic ganglion. These roots unite to form a large round cord of considerable size. It descends obliquely
inward in front of the bodies of the vertebrae along the posterior mediastinum, perforates the crus of the Diaphragm, and terminates in the **semilunar ganglion of the solar plexus** (Fig. 709), distributing filaments to the **renal and adrenal plexuses**.

The **middle, lesser, or small splanchnic nerve** (*n. splanchnicus minor*) is formed by filaments from the tenth and eleventh ganglia, and from the cord between them. It pierces the Diaphragm with the preceding nerve, and joins the **solar plexus** (Fig. 709). It communicates in the chest with the great splanchnic nerve, and occasionally sends filaments to the renal plexus.

The **inferior, smallest, least, or renal splanchnic nerve** (*n. splanchnicus imus*) arises from the last thoracic ganglion, and, piercing the Diaphragm, terminates in the **renal plexus** and lower part of the **solar plexus**. It occasionally communicates with the preceding nerve.

A striking analogy appears to exist between the splanchnic and the cardiac nerves. The cardiac nerves are three in number; they *arise* from the three **cervical ganglia**, and are distributed to a large and important organ in the thoracic
cavity. The splanchnic nerves, also three in number, are connected probably with all the thoracic ganglia, and are distributed to important organs in the abdominal cavity

The Lumbar Portion (Pars Lumbalis) of the Gangliated Cord (Fig. 705).

The lumbar portion of the gangliated cord is situated in front of the vertebral column along the inner margin of the Psoas muscle. It consists usually of four ganglia, but there may be as many as eight, connected together by interganglionic cords. The ganglia are of small size, of a grayish color, shaped like a barleycorn, and placed much nearer the median line than the thoracic ganglia. Sometimes several ganglia are fused together.

It is connected with the thoracic portion by a thin commissure, which passes back of or through the Diaphragm. It is connected with the sacral portion by a commissure which is under the common iliac artery.

The upper lumbar ganglia or the upper portion of the gangliated cord receives white rami communicantes from the first two or three lumbar spinal nerves.

Central Communicating Branches.—Gray rami communicantes pass irregularly from the gangliated cord to the ventral divisions of the lumbar spinal nerves, the gray rami accompanying the white rami.

From the situation of the lumbar ganglia these branches are longer than in the other regions. They are usually two in number from each ganglion, but their connection with the spinal nerves is not so uniform as in other regions. They accompany the lumbar arteries around the sides of the bodies of the vertebrae, passing beneath the fibrous arches from which some of the fibres of the Psoas muscle arise.

Peripheral Branches.—Some branches pass inward, in front of the aorta, and help to form the abdominal aortic plexus (plexus aorticus abdominalis) (Fig. 705) which plexus is, however, developed chiefly by filaments from the celiac plexus. Other branches descend in front of the common iliac arteries, and join over the promontory of the sacrum, helping to form the hypogastric plexus (plexus hypogastricus) (Fig. 705). Numerous delicate filaments are also distributed to the bodies of the vertebrae and the ligaments connecting them.

Pelvic or Sacral Portion (Pars Sacralis) of the Gangliated Cord (Fig. 705).

The pelvic portion of the gangliated cord is situated in front of the sacrum along the inner side of the ventral sacral foramina. It consists of four or five small ganglia on each side, connected together by interganglionic cords. Below these cords converge and unite on the front of the coccyx by means of a small ganglion, the coccygeal ganglion or ganglion impar (ganglion coccygeum impar (Fig. 705). The commissural cord joins the pelvic portion to the lumbar portion of the gangliated cord. Like the cervical and the lower lumbar divisions the sacral portion receives no white rami communicantes.

The visceral branches of the third sacral, and usually of the second and fourth sacral spinal nerves, are not connected with the ganglionic cord.

Central Communicating Branches.—Gray rami communicantes, which arise in the sacral ganglia and pass to the anterior divisions of the sacral and coccygeal nerves.

Peripheral Branches.—1. Visceral branches arise from the upper portion of the gangliated cord and pass to the pelvic plexus.

2. Parietal branches communicate, on the front of the sacrum, with the corresponding branches from the opposite side; some, from the first two ganglia, pass to
join the pelvic plexus, and others form a plexus which accompanies the middle sacral artery and sends filaments to the coccygeal gland.

THE GREAT PLEXUSES OF THE SYMPATHETIC SYSTEM.

The great plexuses of the sympathetic are the large aggregations of nerves and ganglia, previously alluded to, situated in the thoracic, abdominal, and pelvic cavities respectively. From them are derived the branches which supply the viscera.

The Cardiac Plexus (Plexus Cardiacus) (Fig. 705).

The cardiac plexus is situated at the base of the heart, and is divided into a superficial part, which lies in the concavity of the arch of the aorta, and a deep part, which lies between the trachea and aorta. The two plexuses are, however, closely connected.

The Great or Deep Cardiac Plexus.—The great or deep cardiac plexus, the plexus magnus profundus of Scarpa, is situated in front of the trachea at its bifurcation, above the point of division of the pulmonary artery and behind the arch of the aorta. It is formed by the cardiac nerves derived from the cervical ganglia of the sympathetic and the cardiac branches of the recurrent laryngeal and vagus. The only cardiac nerves which do not enter into the formation of this plexus are the left superior cardiac nerve and the inferior cervical cardiac branch from the left vagus.

The branches from the right side of this plexus pass, some in front of, and others behind, the right pulmonary artery; the former, the more numerous, transmit a few filaments to the ventral pulmonary plexus, and are then continued onward to form part of the left or ventral coronary plexus; those behind the pulmonary artery distribute a few filaments to the right auricle, and are then continued onward to form a part of the right or dorsal coronary plexus.

The branches from the left side of the deep cardiac plexus distribute a few filaments to the superficial cardiac plexus, to the left auricle of the heart, and to the ventral pulmonary plexus, and then pass on to form the greater part of the dorsal coronary plexus.

The Ventral or Left Coronary Plexus (plexus coronarius cordis anterior).—The ventral or left coronary plexus is formed chiefly from the superficial cardiac plexus, but receives filaments from the deep cardiac plexus. Passing forward between the aorta and pulmonary artery, it accompanies the left coronary artery on the ventral surface of the heart.

The Dorsal or Right Coronary Plexus (plexus coronarius cordis posterior).—The dorsal or right coronary plexus is chiefly formed by filaments prolonged from the left side of the deep cardiac plexus, and by a few from the right side. It surrounds the branches of the coronary artery at the back of the heart, and its filaments are distributed with those vessels to the muscular substance of the ventricles.

The Superficial or Ventral Cardiac Plexus.—The superficial or ventral cardiac plexus lies beneath the arch of the aorta, in front of the right pulmonary artery. It is formed by the left superior cardiac nerve, the left (and occasionally also the right) inferior cervical cardiac branches of the vagus, and filaments from the deep cardiac plexus. A small ganglion, the cardiac ganglion of Wrisberg (ganglion cardiaeum [Wrisbergi]) is occasionally found connected with these nerves at their point of junction. This ganglion, when present, is situated immediately beneath the arch of the aorta, on the right side of the ductus arteriosus. The superficial
cardiac plexus forms the chief part of the ventral coronary plexus, and several filaments pass along the pulmonary artery to the left ventral pulmonary plexus.

Valentin has described nerve filaments ramifying under the endocardium; and Remak has found, in several mammalia, numerous small ganglia on the cardiac nerves, both on the surface of the heart and in its muscular substance.

The Pulmonary Plexus (Plexus Pulmonalis).

The larger dorsal pulmonary plexus is situated back of the root of the lung. It is formed by the vagus nerve and branches from the second, third, and fourth thoracic sympathetic ganglia. It sends branches along the bronchi and blood-vessels into the lung and some fibres pass to the front of the root of the lung to form the ventral pulmonary plexus. The smaller ventral pulmonary plexus is in front of and above the root of the lung. It is formed on each side by the fibres from the dorsal pulmonary plexus. The left plexus receives branches from the superficial cardiac plexus. The ventral plexus supplies the structures of the root of the lung.

The Æsophageal Plexus (Plexus Oesophageus).

The Æsophageal plexus is in the dorsal mediastinum and surrounds the Æsophagus. It is formed by the vagus nerves which have come from the dorsal pulmonary plexuses, and by fibres from the great splanchnic nerve and ganglion. The Æsophageal plexus is usually considered as a portion of the vagus nerve (p. 1072).

The Epigastric or Solar Plexus (Plexus Coeliacum) (Figs. 705, 710, 711).

The epigastric or solar plexus supplies all the viscera in the abdominal cavity. It consists of a great network of nerves and ganglia, situated behind the pancreas and the lesser peritoneal cavity and in front of the aorta and crura of the Diaphragm. It surrounds the coeliac axis and root of the superior mesenteric artery, extending downward as low as the pancreas and outward to the suprarenal capsules. This plexus, and the ganglia connected with it, receive the great, the small, and the least splanchnic nerves of both sides, and some filaments from the right vagus nerve. It distributes filaments which accompany, under the name ofplexuses, all the branches from the front of the abdominal aorta.

Of the ganglia of which the solar plexus is partly composed the principal are the two semilunar ganglia (ganglia coeliaca) (Figs. 710 and 711), which are situated one on each side of the plexus, and are the largest ganglia in the body. They are large, irregular, gangliiform masses formed by the aggregation of smaller ganglia, having interspaces between them. They are situated in front of the crura of the diaphragm, close to the suprarenal capsules: the one on the right side lies beneath the postcava; the upper part of each ganglion is joined by the greater splanchnic nerve, and to the inner side of each the branches of the solar plexus are connected.

From the epigastric or solar plexus are derived the following:

- Phrenic or Diaphragmatic plexus.
- Adrenal plexus.
- Renal plexus.
- Spermatic plexus.

Coeliac plexus

{ Gastric plexus.
{ Splenic plexus.
{ Hepatic plexus.

Superior mesenteric plexus.

Aortic plexus.
The Phrenic Plexus (*plexus phrenicus*) (Fig. 710).—The phrenic plexus accompanies the phrenic artery to the Diaphragm, which it supplies, some filaments passing to the adrenal. It arises from the upper part of the semilunar ganglion, and is larger on the right than on the left side. It receives one or two branches from the phrenic nerve. In connection with this plexus, on the right side, at its point of junction with the phrenic nerve, is a small ganglion, the diaphragmatic or phrenic ganglion (*ganglion phrenicum*) (Fig. 711). This ganglion is placed on the under surface of the Diaphragm, near the right adrenal.

Its branches are distributed to the postcava, adrenal, and hepatic plexus. There is no ganglion on the left side.

The Adrenal Plexus (*plexus suprarenalis*) (Fig. 710).—The adrenal plexus is formed by branches from the solar plexus, from the semilunar ganglion, and from the phrenic and great splanchnic nerves, a ganglion being formed at the point of junction of the latter nerve. It supplies the adrenal. The branches of this plexus are remarkable for their large size in comparison with the size of the organ they supply.
The Renal Plexus (*plexus renalis*) (Figs. 710 and 711).—The renal plexus is formed by filaments from the solar plexus, the outer part of the semilunar ganglion, and the aortic plexus. It is also joined by filaments from the lesser and smallest splanchnic nerves. The nerves from these sources, fifteen or twenty in number,
have numerous ganglia developed upon them. They accompany the branches of the renal artery into the kidney, some filaments on the right side being distributed to the postcava, and others, on both sides, to the spermatic plexuses.

**The Spermatic Plexus** (plexus spermaticus) (Fig. 710).—The spermatic plexus is derived from the renal plexus, receiving branches from the aortic plexus. It accompanies the spermatic vessels to the testes.

**The Ovarian Plexus** (plexus arteriae ovariae).—In the female the ovarian plexus is distributed to the ovaries and fundus of the uterus.

**The Cœliac Plexus** (plexus coeliacus).—The coeliac plexus, of large size, is a direct continuation from the solar plexus; it surrounds the celiac axis and subdivides into the gastric, hepatic, and splenic plexuses. It receives branches from the lesser splanchnic nerves, and, on the left side, a filament from the right vagus.

**The Gastric or Coronary Plexus** (plexus gastricus superior) (Fig. 710) accompanies the gastric artery along the lesser curvature of the stomach, and joins with branches from the left vagus nerve. It is distributed to the stomach.

**The Splenic Plexus** (plexus lienalis) (Fig. 710) is formed by branches from the coeliac plexus, the left semilunar ganglion, and from the right vagus nerve. It accompanies the splenic artery and its branches to the substance of the spleen, giving off, in its course, filaments to the pancreas, the pancreatic plexus, and the left gastro-epiploic plexus, which accompanies the gastro-epiploica sinistra artery along the convex border of the stomach.

**The Hepatic Plexus** (plexus hepaticus) (Fig. 710), the largest offset from the coeliac plexus, receives filaments from the left vagus and right phrenic nerves. It accompanies the hepatic artery, ramifying in the substance of the liver upon its branches and upon those of the vena portae.

Branches from this plexus accompany all the divisions of the hepatic artery. Thus there is a pyloric plexus accompanying the pyloric branch of the hepatic, which joins with the gastric plexus and vagus nerves. There is also a gastro-duodenal plexus, which subdivides into the pancreatico-duodenal plexus, which accompanies the pancreatico-duodenal artery, to supply the pancreas and duodenum, joining with branches from the mesenteric plexus. The gastro-epiploic plexus, which accompanies the right gastro-epiploic artery along the greater curvature of the stomach, and which is said to anastomose with branches from the splenicplexus, is in reality derived from the splenic plexus. A cystic plexus, which supplies the gall-bladder, also arises from the hepatic plexus near the liver.

**The Superior Mesenteric Plexus** (plexus mesentericus superior) (Fig. 710).—The superior mesenteric plexus is a continuation of the lower part of the great solar plexus, receiving a branch from the junction of the right vagus nerve with the coeliac plexus. It surrounds the superior mesenteric artery, which it accompanies into the mesentery, and divides into a number of secondary plexuses, which are distributed to all the parts supplied by the artery—viz., pancreatic branches to the pancreas; intestinal branches, which supply the whole of the small intestine; and ileo-colic, right colic, and middle colic branches, which supply the corresponding parts of the large intestine. The nerves composing this plexus are white in color and firm in texture, and have numerous ganglia developed upon them near their origin.

**The Abdominal Aortic Plexus** (plexus aorticus abdominalis) (Figs. 705, 710, and 711).—The abdominal aortic plexus is formed by branches derived, on each side, from the solar plexus and the semilunar ganglia, receiving filaments from some of the lumbar ganglia. It is situated upon the sides and front of the aorta, between the origins of the superior and inferior mesenteric arteries. From this plexus arise part of the spermatic, the inferior mesenteric, and the hypogastric plexuses; and it distributes filaments to the postcava.

**The Inferior Mesenteric Plexus** (plexus mesentericus inferior) (Fig. 710) is derived chiefly from the left side of the aortic plexus. It surrounds the inferior mesenteric
artery, and divides into a number of secondary plexuses, which are distributed to all the parts supplied by the artery—viz., the left colic and sigmoid plexuses, which supply the descending and sigmoid flexure of the colon; and the superior hemorrhoidal plexus (plexus haemorrhoidalis superior), which supplies the upper part of the rectum and joins in the pelvis with branches from the pelvic plexus.

The Hypogastric Plexus (Plexus Hypogastricus) (Figs. 705 and 711).

The hypogastric plexus supplies the viscera of the pelvic cavity. It is situated in front of the promontory of the sacrum, between the two common iliac arteries, and is formed by the union of numerous filaments, which descend on each side from the abdominal aortic plexus and from the lumbar ganglia. This plexus contains no evident ganglia; it bifurcates, below, into two lateral portions, right and left, which form the pelvic plexuses.

The Pelvic or Sacral Plexus (Plexus Sacralis).

Each pelvic plexus, sometimes called the inferior hypogastric, supplies the viscera of the pelvic cavity, is situated at the side of the rectum in the male, while in the female it lies in the base of the broad ligament near the ureters. It is formed by a continuation of the hypogastric plexus, by branches from the second, third, and fourth sacral nerves, and by a few filaments from the first two sacral ganglia. At the points of junction of these nerves small ganglia are found. From this plexus numerous branches are distributed to the rectum and bladder in the male and to the rectum, bladder, uterus, and vagina in the female. They accompany the branches of the internal iliac artery. These secondary plexuses are (1) the inferior hemorrhoidal, (2) vesical, (3) prostatic, (4) vaginal, and (5) uterine plexus.

The Inferior Hemorrhoidal Plexus (plexus haemorrhoidalis inferior).—The inferior hemorrhoidal plexus arises from the back part of the pelvic plexus. It supplies the rectum, joining with branches of the superior hemorrhoidal plexus.

The Vesical Plexus (plexus vesicalis).—The vesical plexus arises from the forepart of the pelvic plexus. The nerves composing it are numerous, and contain a large proportion of spinal nerve-fibres. They accompany the vesical arteries, and are distributed at the side and base of the bladder. Numerous filaments also pass to the vesicule seminales and vasa deferentia; those accompanying the vasa deferens join, on the spermatic cord, with branches from the spermatic plexus.

The Prostatic Plexus (plexus prostaticus).—The prostatic plexus is continued from the lower part of the pelvic plexus. The nerves composing it are of large size. They are distributed to the prostate gland, vesiculae seminales, and erectile structure of the penis. The nerves supplying the erectile structure of the penis consist of two sets, the small and large cavernous nerves. They are slender filaments, which arise from the forepart of the prostatic plexus, and, after joining with branches from the internal pubic nerve, pass forward beneath the pubic arch.

The Small Cavernous Nerve (n. cavernosus penis minor) perforates the fibrous covering of the penis—near its roots.

The Large Cavernous Nerve (n. cavernosus penis major) passes forward along the dorsum of the penis, joins with the dorsal branch of the pudic nerve, and is distributed to the corpora cavernosa and corpus spongiosum.

The uterine and vaginal plexuses in reality constitute one plexus, the uterovaginal plexus (plexus uterovaginalis).

The Vaginal Plexus arises from the lower part of the pelvic plexus. It is lost on the walls of the vagina, being distributed to the erectile tissue at its ventral
part and to the mucous membrane. The nerves composing this plexus contain, like the vesical nerves, a large proportion of spinal nerve-fibres.

The *Uterine Plexus* arises from the upper part of the pelvic plexus above the point where the branches from the sacral nerves join the plexus. Its branches accompany the uterine arteries to the sides of the organ between the layers of the broad ligaments, and are distributed to the cervix and lower part of the body of the uterus, penetrating its substance.

Other filaments pass separately to the body of the uterus and the oviduct.

Branches from the plexus accompany the uterine arteries into the substance of the uterus. Upon these filaments ganglionic enlargements are found.
THE ORGANS OF SPECIAL SENSE.

The Organs of the Senses are five in number—viz., those of Taste, of Smell, of Sight, of Hearing, and of Touch.

THE TONGUE (LINGUA) (Fig. 712).

The tongue is a very mobile muscular organ, undergoing changes in length and width at every contraction of its muscle. It is the organ of the special sense of taste, and is also an organ of speech, mastication, and deglutition. It is situated in the floor of the mouth, in the interval between the two lateral portions of the body of the lower jaw, and when at rest is about three and one-half inches in length. We describe the body, base, apex, dorsum, margin, and inferior surface.

The Body (corpus linguae).—The body forms the great bulk of the organ and is composed of striated muscle.

The Base or Root (radix linguae).—The base or root is directed backward, and connected with the os hyoideum by the Hyo-glossi and Genio-hyo-glossi muscles and the hyo-glossal membrane; with the epiglottis by three folds of mucous membrane, the glosso-epiglottic folds; with the soft palate by means of the anterior pillars of the fauces; and with the pharynx by the Superior constrictors and the mucous membrane.

The Apex or Tip (apex linguae).—The apex or tip is thin and narrow, and is directed forward against the inner surface of the lower incisor teeth.

The Dorsum of the Tongue (dorsum linguae).—The dorsum when the tongue of a living person is at rest is markedly arched from before backward. On the dorsum is a median longitudinal raphe (sulcus medianus linguae). This slight depression terminates posteriorly in the depression known as the foramen caecum (foramen caecum linguae [Morgagnii]), from which a shallow-shaped groove, the sulcus terminalis of His, runs outward and forward on each side to the lateral margin of the tongue. The part of the dorsum of the tongue in front of this groove, known as the anterior or oral part, forming about two-thirds of its upper surface, is rough and covered with papillae; the posterior third of the dorsum is back of the sulcus terminalis, is known as the posterior or pharyngeal portion, is smoother, and contains numerous muciparous glands and lymphoid follicles.

The Margin of the Tongue (margo lateralis linguae).—The margin of the tongue is free in front of the anterior arch of the palate. Just in front of the arch are several vertical folds, the folia linguae.

The Under or Inferior Surface (facies inferior linguae).—The under or inferior surface of the tongue is connected with the lower jaw by the Genio-hyoglossi muscles, from its sides the mucous membrane is reflected to the inner surface of the gums; and from its under surface on to the floor of the mouth, where, in the middle line, it is elevated into a distinct vertical fold, the fraenum linguae (frenulum linguae). To each side of the fraenum is a slight fold of the mucous membrane, the plica fimbriata, the free edge of which exhibits a series of fringe-like processes.

The tip of the tongue, part of the under surface, its sides, and dorsum are free.
Structure of the Tongue.—The tongue is partly invested by mucous membrane and a submucous fibrous layer. It consists of symmetrical halves, separated from each other, in the middle line, by a fibrous septum. Each half is composed of muscular fibres arranged in various directions (page 400), containing much interposed fat, and supplied by vessels and nerves.

The Mucous Membrane (tunica mucosa linguae).—The mucous membrane invests the entire extent of the free surface of the tongue. On the dorsum it is thicker behind than in front, and is continuous with the sheath of the muscles attached to it, through the submucous fibrous layer. On the under surface of the organ, where it is thin and smooth, it can be traced on each side of the fraenum through the ducts of the submaxillary and the sublingual glands. As it passes over the borders of the organ it gradually assumes a papillary character.

Structure.—The structure of the mucous membrane of the tongue differs in different parts. That covering the under surface of the organ is thin, smooth, and identical in structure with that lining the rest of the oral cavity. The mucous membrane covering the tongue behind the foramen caecum and sulcus terminalis is thick and freely movable over the subjacent parts. It contains a large number of lymphoid follicles (folliculi linguales), which together constitute what is sometimes termed the lingual tonsil (tonsilla lingualis). Each follicle forms a rounded eminence, the centre of which is perforated by a minute orifice leading into a
funnel-shaped cavity or recess; around this recess are grouped numerous oval or rounded nodules of lymphoid tissue, each enveloped by a capsule derived from the submucosa, while opening into the bottom of the recesses are also seen the ducts of mucous glands (glandulae linguales). The mucous membrane on the anterior part of the dorsum of the tongue is thin and intimately adherent to the muscular tissue, and covered with minute eminences, the papillae of the tongue. It consists of a layer of connective tissue, the corium or mucosa, supporting numerous papillae, and covered, as well as the papillae, with epithelium.

The epithelium is of the scaly variety, like that of the epidermis. It covers the free surface of the tongue, as may be readily demonstrated by maceration or boiling, when it can be easily detached entire; it is much thinner than that of the skin; the intervals between the large papillae are not filled up by it, but each papilla has a separate investment from root to summit. The deepest cells may sometimes be detached as a separate layer, corresponding to the rete mucosum, but they never contain coloring matter.

The Corium.—The corium consists of a dense feltwork of fibrous connective tissue, with numerous elastic fibres, firmly connected with the fibrous tissue forming the septa between the muscular bundles of the tongue. It contains the ramifications of the numerous vessels (Fig. 713) and nerves from which the papillae are supplied, large plexuses of lymphatic vessels, and the glands of the tongue.

The Papillae of the Tongue (papillae linguales) (Figs. 712, 713, 714, and 715).—These are papillary projections of the corium. They are thickly distributed over the anterior two-thirds of the upper surface of the tongue, giving to it its characteristic roughness. The varieties of papillae met with are—the papillae maximae or circumvallate papillae, papillae mediae or fungiforme papillae, papillae minimae, conical or filiforme papillae, and papillae simplices or simple papillae.

The Papillae Maximae or Circumvallate Papillae (papillae vallatae) (Figs. 712, 713, and 714) are of large size, and vary from eight to twelve in number. They are situated at the back part of the dorsum of the tongue, near its base, in front of the foramen caecum and sulcus terminalis, forming a row on each side, which, running backward and inward, meet in the middle line, like the two lines of the letter V inverted A. Each papilla consists of a projection of mucous membrane from $\frac{1}{20}$ to $\frac{1}{12}$ of an inch wide, attached to the bottom of a cup-shaped depression of the mucous membrane; the papilla is in shape like a truncated cone, the smaller end being directed downward and attached to the tongue, the broader part or base projecting on the surface and being studded with numerous small secondary papillae (Fig. 713), which, however, are covered by a smooth layer of the epithelium. The cup-shaped depression forms a kind of fossa around the papilla, having a circular margin of about the same elevation covered with smaller papillae.
Immediately behind the apex of the V is the foramen cecum, mentioned above. This foramen, according to His, represents the remains of the invagination which forms the median rudiment of the thyroid body, and which for a time opens by a duct, the thyroglossal duct (ductus thyreoglossus), on to the dorsum of the tongue. It may extend downward toward the hyoid bone. Kanthack, however, disputes this view.  

The *Fungiforme Papillae* or *Papillae Mediae* (papillae fungiformes et papillae lenticales) (Fig. 713), more numerous than the preceding, are scattered irregularly and sparingly over the dorsum of the tongue, but are found chiefly at its sides and apex. They are easily recognized among the other papillae, by their large size, rounded eminences, and deep-red color. They are narrow at their attachment to the tongue, but broad and rounded at their free extremities, and are covered with secondary papillae. Their epithelial investment is very thin.

The *Conical* or *Filiform Papillae* or *Papillae Minimae* (papillae conicae et papillae filiformes) (Fig. 713) cover the anterior two-thirds of the dorsum of the tongue. They are very minute, more or less conical or filiform in shape, and arranged in lines corresponding in direction with the two rows of the papillae circumvallatae, excepting at the apex of the organ, where their direction is transverse. Projecting from their apices are numerous filiform processes or secondary papillae; these are of a whitish tint, owing to the thickness and density of the epithelium of which they are composed, and which has here undergone a peculiar modification, the cells having become cornified and elongated into dense, imbricated, brush-like processes. They contain also a number of elastic fibres, which render them firmer and more elastic than the papillae of mucous membrane generally.

*Simple Papillae*, similar to those of the skin, cover the whole of the mucous membrane of the tongue, as well as the larger papillae. They consist of closely set, microscopic elevations of the corium, containing a capillary loop, covered by a layer of epithelium.

*Structure of the Papillae* (Figs. 713 and 714).

The papillae apparently resemble in structure the papillae of the cutis, consisting of a cone-shaped projection of connective tissue, covered with a thick layer of squamous epithelium, and contain one or more capillary loops, amongst which nerves are distributed in great abundance. If the epithelium is removed, it will be found, however, that they are not simple elevations like the papillae of the skin, for the surface of each is studded with minute conical processes of the mucous membrane, which form secondary papillae (Todd and Bowman). In the papillae circumvallatae the nerves are numerous and of large size; in the papillae fungiformes they are also numerous, and terminate in a plexiform network, from which brush-like branches proceed; in the papillae filiformes their mode of termination is uncertain. Buried in the epidermis of the papillae circumvallatae, and in some of the fungiformes, are certain peculiar bodies, called *taste-buds* (Fig. 715). Each is flask-like in shape, the broad base resting on the corium, and the neck opening by an orifice, the *gustatory pore*, between the cells of the epithelium.

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1 Journal of Anatomy and Physiology, 1891.
2 These bodies are also found in considerable numbers at the side of the base of the tongue, just in front of the anterior pillars of the fauces, and also on the posterior surface of the epiglottis and anterior surface of the soft palate.—En. of 16th English edition.
They are formed by two kinds of cells, supporting cells and gustatory cells. The supporting cells are mostly arranged like the staves of a cask, and form an outer envelope for the bud. Some, however, are found in the interior of the bud between the gustatory cells. The gustatory cells occupy the central portion of the bud; they are spindle-shaped, and each possesses a large spherical nucleus near the middle of the cell. Until recently the teaching was as follows: The peripheral end of the cell terminates as the gustatory pore in a fine, hair-like filament, the gustatory hair. The central process passes toward the deep extremity of the bud, and there ends in a single or bifurcated varicose filament, which was formerly supposed to be continuous with the terminal fibril of a nerve; the investigations of Lenhossék and others would seem to prove, however, that this is not so, but that the nerve-fibrils after losing their medullary sheaths enter the taste-bud, and terminate in a fine extremity between the gustatory cells. Other nerve-fibrils may be seen ramifying between the cortical cells and terminating in fine extremities; these, however, are believed to be nerves of ordinary sensation, and not gustatory. It is now not believed that the epithelia of the taste-buds are directly connected with the nerve-fibres by long processes. "The latest researches have shown that dendrites of sensor neurones (sensor nerves) enter the taste-buds and end free in telodendria. The latter surround the neuro-epithelial, and, to some extent, the sustentacular cells, their relations depending on contact."

Glands of the Tongue.—The tongue is provided with mucous and serous glands. The mucous glands are similar in structure to the labial and buccal glands. They are found especially at the back part, behind the circumvallate papillae, but are also present at the apex and marginal parts. In connection with these glands special ones have been described by Blandin and Nuhn. They are known as the glands of Nuhn and Blandin or apical glands (glandulae linguales anteriores of Nuhn and Blandin) (Fig. 716). They are situated near the apex of the tongue on either side of the fraenum, and each is covered over by a fasciculus of muscular fibre derived from the Stylo-glossus and Inferior lingualis muscles. Each gland is from half an inch to nearly an inch long and about the third of an inch broad. It has from four to six ducts, which open on the under surface of the apex.

The Serous Glands or Glands of v. Ebner occur only at the back of the tongue in the neighborhood of the taste-buds, their ducts opening for the most part into the

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fossae of the papillae circumvallatae. These glands are racemose, the duct branching into several minute ducts, which terminate in alveoli lined by a single layer of more or less columnar epithelium. Their secretion is of a watery nature, and probably assists in the distribution of the substance to be tasted over the taste-area (Ebner).

The Hyo-glossal membrane is a strong fibrous lamina which is derived from the septum of the tongue and which connects the under surface of the base of the tongue to the body of the hyoid bone. This membrane receives, in front, some of the posterior fibres of the Genio-hyo-glossi muscles.

The Vessels of the Tongue.—The arteries of the tongue are derived from the lingual, the facial, and ascending pharyngeal. The veins of the tongue open into the internal jugular.

The lingual artery (Fig. 718) on each side passes forward beneath the Hyo-glossus muscle and courses to the apex of the tongue, between the Genio-glossus and the Inferior lingual muscles, about one-eighth of an inch from the surface. It divides into the ranine (Fig. 716) and sublingual (Fig. 718). Near the apex a branch is given off from the ranine artery, which penetrates the septum and joins a like branch from the other side. The dorsalis linguae is a branch of the lingual

supplying the posterior part of the tongue, and rami from the tonsillar branch of the facial go to the same region. A network of capillary vessels is placed beneath the epithelium.

The ranine veins lie to the sides of the fraenum underneath the mucous membrane. Each ranine vein runs backward, superficial to and upon the Hyo-glossus muscle and near to the hypo-glossal nerve. The venae comites of the lingual artery usually join the ranine vein, and the trunk opens into the internal jugular vein, but the vessels may open separately into the jugular (Fig. 445).

The Muscles of the Tongue.—The muscular fibres of the tongue run in various directions. These fibres are divided into two sets, Extrinsic and Intrinsic, which have already been described (pp. 398, 399, 400, 401, and 402).
The Extrinsic come from the Stylo-glossus, Hyo-glossus, Genio-glossus, Palato-glossus, and Chondro-glossus. The Intrinsic muscles are the Superior lingualis (m. longitudinalis superior), the Inferior lingualis (m. longitudinalis inferior), the Transverse lingual (m. transversus linguae), and the Vertical lingual (m. verticalis linguae). The outer or cortical portion of the tongue is composed chiefly of longitudinal fibres. The central or medullary portion is composed chiefly of vertical and transverse fibres and is divided into two parts by a vertical septum (septum linguae), which is a fibrous structure, beginning at the apex and passing back. As it approaches the back it becomes narrower vertically and broadens out transversely to form the hyo-glossal membrane. The fibrous septum is well displayed by making a vertical section of the tongue.

The Lymphatic Vessels of the Tongue (Fig. 490).—The lymphatic vessels from the anterior half of the tongue pass to the submaxillary lymph glands.

Lymph vessels from the posterior half of the tongue are connected with satellite glands on the Hyo-glossus muscle and terminate in the deep cervical glands. The last-named lymph-vessel accompanies the ranine vein. The lingual lymphatics arise from a network beneath the epithelium. Across the anterior two-thirds of the tongue there is little or no lymphatic connection between the two sides; in the posterior one-third there is free connection.

![Diagram of the tongue](image)

**The Nerves of the Tongue** (Fig. 718).—The nerves of the tongue are five in number in each half: the lingual branch of the inferior maxillary division of the trigeminal, which is distributed to the papillae at the forepart and sides of the tongue, and forms the nerve of ordinary sensibility for its anterior two-thirds; the chorda tympani, which runs in the sheath of the lingual, is generally regarded as the nerve of taste for the same area (p. 898); the lingual branch of the glosso-pharyngeal, which is distributed to the mucous membrane at the base and sides of the tongue, and to the papillae circumvallatae, and which supplies both sensory and gustatory filaments to this region; the hypo-glossal nerve, which is the motor nerve to the muscular substance of the tongue; and the internal laryngeal branch of the superior laryngeal, which sends some fine branches to the root near to the epiglottis. Sympathetic filaments also pass to the tongue from the nervi molles on the lingual and other arteries supplying it. Some of the nerves end free between the cells of epithelium; others terminate as end organs (Meissner's corpuscles and the end-bulbs of Krause), and in taste-buds as sensory dendrites (p. 833).

**Surgical Anatomy.**—The diseases to which the tongue is liable are numerous, and its surgical anatomy is of importance, since any or all the structures of which it is composed—muscles, connective tissue, mucous membrane, glands, vessels, nerves, and lymphatics—may be the seat of morbid changes. It is not often the seat of congenital defects, though a few cases of vertical...
cleft have been recorded, and it is occasionally, though much more rarely than is commonly sup-
pposed, the seat of tongue-tie, from shortness of the frenum.

There is, however, one condition which must be regarded as congenital, though not uncom-
monly it does not exhibit the significant changes until a year or two after birth. This is an
enlargement of the tongue which is due primarily to a dilatation of the lymph-channels and a
greatly increased development of the lymphatic tissue throughout the tongue (macroglossia). This
is often aggravated by inflammatory changes induced by injury or exposure, and the tongue may
assume enormous dimensions and hang out of the mouth, giving the child an imbecile expression.
The treatment consists in excising a V-shaped portion and bringing the cut surfaces together
with deeply placed silver sutures. Compression has been resorted to in some cases with occa-
sional success, but it is difficult to apply. Acute inflammation of the tongue (acute glossitis),
which may be caused by injury or the introduction of some septic or irritating matter, and it
is attended by great swelling from infiltration of the connective tissue of the tongue; this con-
nective tissue is present in considerable quantity. The great swelling renders the patient
incapable of swallowing or speaking, and may seriously impede respiration. The condition may
eventuate in suppuration and the formation of an acute abscess. Chronic abscess, which has
been mistaken for cancer, may also occur in the substance of the tongue.

The mucous membrane of the tongue may become chronically inflamed, and presents different
appearances in different stages of the disease, to which the terms leucoplakia, psoriasis, and
ichthyosis have been given.

The tongue, being very vascular, is often the seat of naevoid growths, and these have a tendency
to grow rapidly.

The tongue is frequently the seat of ulceration, which may arise from many causes, as from
the irritation of jagged teeth, dyspepsia, tuberculosis, syphilis, and cancer. Of these the cancerous
ulcer is the most important, and probably also the most common. The variety is the squamous
epithelioma, which soon develops into an ulcer with an indurated base. It produces great pain
which speedily extends to all parts supplied with sensation by the trigeminal nerve, especially to the
The pain in these cases is conducted to the ear and temporal region by the lingual nerve, and from this nerve pain radiates to the other branches of the inferior maxillary nerve, especially the auriculo-temporal. Possibly pain in the ear itself may be due to implication of the fibres of the glosso-pharyngeal nerve, which by its tympanic branch reaches the tympanic plexus. Cancer of the tongue spreads through the organ very rapidly because of the almost constant muscular movements.

Cancer of the tongue may necessitate removal of a part or the whole of the organ, and many different methods have been adopted for its excision. It may be removed from the mouth by the ecraseur or the scissors. The better method is by the scissors, usually known as Whitehead's method. The mouth is widely opened with a gag, the tongue is transfixed with a stout silk ligature, by which to hold and make traction on it and the reflection of mucous membrane from the tongue to the jaw, and the insertion of the Genio-hyo-glossi first divided with a pair of curved blunt scissors. The Palato-glossi are also divided. The tongue can now be pulled well out of the mouth. The base of the tongue is cut through by a series of short snips, each bleeding vessel being dealt with as soon as divided, until the situation of the ranine artery is reached. The remaining undivided portion of tissue is to be seized with a pair of Wells's forceps, the tongue removed, and the vessel secured. In the event of the ranine artery being accidentally injured early in the operation, hemorrhage can be at once controlled by passing two fingers over the dorsum of the tongue as far as the epiglottis and dragging the root of the tongue forcibly forward.

In cases where the disease is confined to one side of the anterior portion of the tongue this operation may be modified by splitting the tongue down the centre and removing only the affected half. If the posterior portion of the tongue is attacked by cancer the entire tongue must be removed, even if but one side of the organ is apparently involved. The exchange of lymph between the halves of the posterior portion of the tongue makes it certain that the opposite half becomes involved soon after the origin of the disease. Whatever operation is performed for cancer of the tongue, the glands must be removed from both sides of the neck. This is to be done, even if but one side of the tongue is removed. Kocher, after performing a preliminary tracheotomy, removes the tongue from the neck; by an incision taken from near the lobe of the ear, down the anterior border of the Sermo-mastoid to the level of the great cornu of the hyoid bone, then forward to the body of the hyoid bone, and upward to near the symphysis of the jaw. The lingual artery is now secured and by a careful dissection the submaxillary lymphatic glands and the tongue removed. Regnoli advocated the removal of the tongue by a semilunar incision in the submaxillary triangle along the line of the lower jaw, and a vertical incision from the centre of the semilunar one backward to the hyoid bone. Care must be taken not to carry the first incision too far backward, so as to wound the facial arteries. The tongue is thus reached through the floor of the mouth pulled out through the external incision, and removed with the knife. The great objection to this operation is that all the muscles which raise the hyoid bone and larynx are divided, and that therefore the movements of deglutition and respiration are interfered with.

Finally, where both sides of the floor of the mouth are involved in the disease, or where very free access is required on account of the extension backward of the disease to the pillars of the fauces and the tonsil, or where the lower jaw is involved, the operation recommended by Syme must be performed. This is done by an incision through the central line of the lip, across the chin, and down as far as the hyoid bone. The lower jaw is sawed through at the symphysis, and the two halves of the bone forcibly separated from each other. The mucous membrane is separated from the bone, and the Genio-hyo-glossi detached from the bone, and the Hyo-glossi divided. The tongue is then drawn forward and removed close to its attachment to the hyoid bone. Adjacent lymph glands can be removed and if the bone is implicated in the disease, it can also be removed by freeing it from the soft parts externally and internally, and making a second section with the saw beyond the diseased part.

Formerly many surgeons before removing the tongue performed a preliminary tracheotomy: (1) to prevent blood entering the air-passages; and (2) to allow the patient to breathe through the tube and not inspire air which had passed over a sloughy wound, and which was loaded with septic organisms and likely to induce septic pneumonia. By operating with the patient in the Trendelenburg position, the blood is caused to flow away from the air-passages. By the judicious use of iodoform the evil mentioned secondly may be obviated, and the preliminary tracheotomy is now usually dispensed with.

THE NOSE.

The nose is the peripheral portion of the organ of smell (organum olfactorius): by means of the peculiar properties of its nerves it protects the lungs from the inhalation of deleterious gases and assists the organ of taste in discriminating the properties of food. The organ of smell consists of two parts; one external, the outer nose; the other internal, the nasal fossae.
THE OUTER NOSE (NASUS EXTERNUS).

The outer nose is the more anterior and prominent part of the organ of smell. Of a triangular form, it is directed downward, and projects from the centre of the face, immediately above the upper lip. Its summit or root (radix nasi) is connected directly with the forehead. Its inferior part or base (basis nasi) presents two elliptical orifices, the nostrils or anterior nares (nares), separated from each other by an antero-posterior septum, the mobile septum or columna nasi (septum mobile nasi). The margins of the nostrils are provided with a number of stiff hairs or vibrissae, which arrest the passage of foreign substances carried with the current of air intended for respiration. The point (apex nasi) is the free extremity of the nose. The lateral surfaces of the nose form, by their union in the middle line, the dorsum (dorsum nasi), the direction of which varies considerably in different individuals. The portion of the dorsum over the nasal bones is the bridge. Each lateral surface terminates below in a rounded eminence, the wing or ala nasi, which, by its lower margin (margo nasi), forms the outer boundary of the corresponding nostril. Above the ala is a depression, the alar sulcus.

Structure.—The nose is composed of a framework of bones and cartilages, the latter being slightly acted upon by certain muscles. It is covered externally by the integument, internally by mucous membrane, and is supplied with vessels and nerves.

The Bony Framework.—The bony framework occupies the upper part of the organ; it consists of the nasal bones and the nasal processes of the superior maxillary bones (pp. 104 and 109).

The Cartilaginous Framework (cartilagines nasi) (Figs. 719 and 720).—The cartilaginous framework consists of five pieces, the two upper and the two lower lateral cartilages and the cartilage of the septum.

The Upper Lateral Cartilage (cartilago nasi lateralis) of each side is situated below the free margin of the nasal bone. It is flattened and triangular in shape. Its anterior margin is thicker than the posterior, and continuous with the cartilage of the septum. Its posterior margin is attached to the nasal process of the superior maxillary and nasal bones. Its inferior margin is connected by fibrous tissue with the lower lateral cartilage; one surface is turned outward, the other inward toward the nasal cavity.
The Lower Lateral Cartilage, the Cartilage of the Aperture or the Greater Alar Cartilage (cartilago alaris major) of each side consists of two thin, flexible plates situated immediately below the preceding, and bent upon themselves in such a manner as to form the inner and outer walls of the orifice of the nostril. The portion which forms the inner wall (crus mediale), thicker than the rest, is loosely connected with the corresponding portion of the opposite cartilage, and forms a small part of the column. Its inferior border, free, rounded, and projecting, forms, with the thickened integument and subjacent tissue and the corresponding parts of the opposite side, the mobile septum. The part of the cartilage which forms the outer wall (crus laterale) is curved to correspond with the ala of the nose; it is oval and flattened, narrow behind, where it is connected with the nasal process of the superior maxilla by a tough fibrous membrane, in which are found three or four small cartilaginous plates, the sesamoid, accessory quadrate or lesser alar cartilages (cartilagines alares minores). Above, it is connected by fibrous tissue to the upper lateral cartilage and front part of the cartilage of the septum; below, it falls short of the margin of the nostril; the ala being formed by dense cellular tissue covered by skin. In front the lower lateral cartilages are separated by a notch which corresponds with the point of the nose.

The Triangular Cartilage of the Septum (cartilago septi nasi) (Figs. 719 and 721) is somewhat quadrilateral in form, thicker at its margins than at its centre, and completes the separation between the nasal fossae in front. Its anterior margin, thickest above, is connected with the nasal bones, and is continuous with the anterior margins of the two upper lateral cartilages. Below, it is connected to the inner portions of the lower lateral cartilages by fibrous tissue. Its posterior margin is connected with the perpendicular lamella of the ethmoid; its inferior margin with the vomer and the palate processes of the superior maxillary bones (Fig. 103).

It may be prolonged backward (especially in children) for some distance between the vomer and perpendicular plate of the ethmoid, forming what is termed the sphenoidal process (processus sphenoidalis septi cartilaginis). The septal cartilage does not reach as far as the lowest part of the nasal septum. This is formed by the inner portions of the lower lateral cartilages and by the skin; it is freely movable, and hence is termed the mobile septum.

Along the lower margin of the anterior half of the cartilage of the septum is another cartilage which is attached to the vomer and is known as the vomerine cartilage or cartilage of Jacobson (cartilago vomeronasalis).

These various cartilages are connected to each other and to the bones by a tough fibrous membrane, which allows the utmost facility of movement between them.

The Muscles of the Nose.—The muscles of the nose are situated beneath the integument; they are (on each side) the Pyramidalis nasi, the Levator labii superiores alacque nasi, the Dilatator naris, anterior and posterior, the Compressor nasi, the Compressor narium minor, and the Depressor alac nasi. They have been previously described (p. 378).

The Integument covering the dorsum and sides of the nose is thin, and loosely connected with the subjacent parts; but the integument of the tip and the alae of
the nose is thicker and more firmly adherent, and is furnished with a large number of sebaceous follicles, the orifices of which are usually very distinct.

The **Mucous Membrane** lining the interior of the nose is continuous with the skin externally and with the mucous membrane which lines the nasal fossae within.

The **Arteries of the Outer Nose**.—The arteries of the nose are the *lateralis nasi from the facial*, and the *inferior artery of the septum from the superior coronary*, which supply the alae and septum, the sides and dorsum being supplied from the *nasal branch of the ophthalmic* and the *infraorbital*.

The **Veins of the Outer Nose**.—The veins of the nose terminate in the *facial* and *ophthalmic*.

The **Lymphatics of the Outer Nose**.—These vessels are shown in Figs. 486, 488, and 489. They empty chiefly into the *submaxillary lymph glands*.

The **Nerves of the Outer Nose**.—The nerves for the muscles of the nose are derived from the *facial*, while the skin receives its branches from the *infraorbital, infra-trochlear*, and nasal branches of the *ophthalmic*.

**THE NASAL FOSSAE (CAVUM NASI).**

The nasal fossae are two irregular cavities situated in the middle of the face, one on each side of the middle line, and extending from before backward. They open in front, when the soft parts are in place, by the two *nostrils* or anterior nares, and terminate, behind, in the naso-pharynx by the *posterior nares*.

![Diagram of the nasal fossae](image)

The **Anterior Nares** (*nares*).—The anterior nares are somewhat pear-shaped apertures, each measuring about one inch antero-posteriorly and half an inch transversely at their widest part. The nasal fossae in the dry skull open in front by the anterior nasal aperture (*apertura pyriformis*).

The **Posterior Nares** (*choanae*).—The posterior nares are two oval openings, which are smaller in the living or recent subject than in the skeleton, because they
are narrowed by the mucous membrane. Each measures an inch in the vertical and half an inch in the transverse direction in a well-developed adult skull.

For the description of the bony boundaries of the nasal fossae see section on Osteology (p. 143).

Inside the aperture of the nostril is a slight dilatation, the vestibule (vestibulum nasi), which extends as a small pouch, the ventricle, toward the point of the nose. Above and behind the vestibule is surrounded by a prominence (limen nasi). Below the prominence the vestibule is lined with skin; above and behind it the fossa is lined with mucous membrane. The fossa, above and behind the vestibule, has been divided into two parts: an olfactory portion (regio olfactoria), a slit-like cavity, comprising the upper and central part of the septum and probably the superior turbinated bone, and a respiratory portion (regio respiratoria), which comprises the rest of the fossa.

Outer Wall (Figs. 722 and 723).—The superior, middle, and inferior meatus (meatus nasi superior, medius, and inferior) are described on pages 144 and 145. The sphenoidal air sinus opens into the sphenoethmoidal recess (recessus sphenoethmoidalis), a narrow recess above the superior turbinated bone (Fig. 722). The posterior ethmoidal cells (cellula ethmoidalis posterior) open into the front and upper part of the superior meatus (Fig. 722). On raising or cutting away the middle turbinated bone the outer wall of the middle meatus is fully exposed (Figs. 722 and 723) and presents: (1) a rounded elevation, termed the bulla ethmoidalis, opening on or immediately above which are the orifices of the middle ethmoidal cells; (2) a
deep, narrow, curved groove, in front of the bulla ethmoidalis, termed the **hiatus semilunaris**, into which the **anterior ethmoidal cells** (*cellula ethmoidalis anterior*) and the **antrum of Highmore** (*sinus maxillaris*) open, the orifice of the latter being placed near the level of its roof. The middle meatus is prolonged, above and in front, into the **infundibulum** (*infundibulum ethmoidale*), which leads into the **frontal sinus** (*sinus frontalis*). The anterior extremity of the meatus is continued into a depressed area which lies above the vestibule and is named the **atrium** (*atrium meatus medii nasi*). The **nasal duct** (*ductus nasalis*) opens into the anterior part of the inferior meatus, the opening being frequently overlapped by a fold of mucous membrane, and from the orifice of the duct a groove leads downward and forward.

**The Inner Wall** (Fig. 723).—The inner wall or septum is frequently more or less deflected from the mesal plane (Figs. 101 and 723), thus limiting the size of one fossa and increasing that of the other. **Ridges** or **spurs of bone** growing outward from the septum are also sometimes present. Immediately over the incisive foramen at the lower edge of the cartilage of the septum a depression, the **nasopalatine recess** (*recessus nasopalatinus*), may be seen. In the septum close to this recess a minute orifice may be discerned; it leads into a blind pouch, the **rudimentary organ of Jacobson** (*organum vomeronasale*), which is well developed in some of the lower animals, but is rudimentary in man. The organ is supported by a plate of cartilage, distinct from the cartilage of the septum, the **cartilage of Jacobson** (p. 1107). The cartilage of Jacobson is to the outer side of the lower edge of the cartilage of the septum. The diverticulum opens anteriorly near the floor of the nose and close by Stenson’s foramen. Just below the opening of the blind pouch is an elevation, the **eminence of Jacobson**.

**The Mucous Membrane** (*membrana mucosa nasi*).—The mucous membrane lining the nasal fossae is called the **pituitary**, from the nature of its secretion; or **Schneiderian**, from Schneider, the first anatomist who showed that the secretion proceeded from the mucous membrane, and not, as was formerly imagined, from the brain. It is intimately adherent to the periosteum or perichondrium, over which it lies. It is continuous externally with the skin through the anterior nares, and with the mucous membrane of the naso-pharynx through the posterior nares. From the nasal fossae its continuity may be traced with the conjunctiva through the nasal duct and lachrymal canals; with the lining membrane of the tympanum and mastoid cells through the Eustachian tube; and with the frontal, ethmoidal, and sphenoidal sinuses, and the antrum of Highmore through the several openings in the meatuses. The mucous membrane is thickest and most vascular over the turbinated bones. It is also thick over the septum, but in the intervals between the spongy bones and on the floor of the nasal fossae it is very thin. Where it lines the various sinuses and the antrum of Highmore it is thin and pale.

Owing to the great thickness of this membrane, the nasal fossae are much narrower, and the turbinated bones, especially the lower ones, appear larger and more prominent than in the skeleton. From the same circumstances also the various apertures communicating with the meatuses are considerably narrowed or completely closed. The vestibule is lined by modified skin, and contains hairs (**vibrissae**) which guard the entrance of the nostril.

**Structure of the Mucous Membrane** (Fig. 724).—The epithelium covering the mucous membrane differs in its character according to the functions of the part of the nose in which it is found. In the respiratory portion of the nasal cavity the epithelium is columnar and ciliated. Interspersed among the columnar ciliated cells are goblet or mucin cells, while between their bases are found smaller pyramidal cells. In this region, beneath the epithelium and its basement membrane, is a fibrous layer infiltrated with lymph-corpuscles, so as to form in many parts
a diffuse adenoid tissue, which is particularly plentiful in children, and beneath this a nearly continuous layer of smaller and larger glands, some mucous and some serous, the ducts of which open upon the surface. In the respiratory portion of the mucous membrane there is an extensive anastomosing plexus of veins, which in some regions forms a distinct cavernous tissue (plexus cavernosus concharium). The cavernous tissue is particularly distinct over the inferior turbinated bones. In the olfactory region the mucous membrane is yellowish in color and the epithelial cells are columnar and non-ciliated; they are of two kinds, supporting cells and olfactory cells.

The Supporting Cells contain oval nuclei, situated in the deeper parts of the cells; the free surface of each cell presents a sharp outline, and its deep extremity is prolonged into a process which runs inward, branching to communicate with similar processes from neighboring cells, so as to form a network in the deep part of the mucous membrane. Lying between these central processes of the supporting cells are a large number of spindle-shaped cells, the olfactory cells, which consist of a large spherical nucleus surrounded by a small amount of granular protoplasm, and possessing two processes, of which one runs outward between the columnar epithelial cells, and projects on the surface of the mucous membrane as a fine, hair-like process, the olfactory hair; the other or deep process runs inward, is frequently beaded like a nerve-fibre, and is believed by most observers to be in connection with one of the terminal filament of the olfactory nerve. Beneath the epithelium, extending through the thickness of the mucous membrane, is a layer of tubular, often branched, glands, the glands of Bowman (glandulae olfactoriae), identical in structure with serous glands.

The Arteries of the Nasal Fossae.—The arteries of the nasal fossae are the anterior and posterior ethmoidal, from the ophthalmic, which supply the ethmoidal cells, frontal sinuses, and roof of the nose; the sphenopalatine, from the internal maxillary, which supplies the mucous membrane covering the spongy bones, the meatuses, and septum; the inferior artery of the septum, from the superior coronary of the facial; and the infraorbital and alveolar branches of the internal maxillary, which supply the lining membrane of the antrum. The ramifications of these vessels form a close, plexiform network, beneath and in the substance of the mucous membrane.

The Veins of the Nasal Fossae.—The veins of the nasal fossae form a close, cavernous-like network beneath the mucous membrane. This cavernous appearance

![Diagram of the olfactory mucous membrane](image-url)
is especially well marked over the lower part of the septum and over the middle and inferior turbinated bones. Some of the veins pass, with those accompanying the sphenopalatine artery, through the sphenopalatine foramen; and others, through the alveolar branch, to join the facial vein; some accompany the ethmoidal arteries, and terminate in the ophthalmic vein; and, lastly, a few communicate with the veins in the interior of the skull, through the foramina in the cribiform plate of the ethmoid bone, and the foramen caecum.

The Lymphatics of the Nasal Fossae.—The lymphatics can be injected from the subdural and subarachnoid spaces, and form a plexus in the superficial portion of the mucous membrane. The lymph is drained partly into one or two glands which lie near the great cornu of the hyoid bone and partly into a gland situated in front of the axis.

The Nerves of the Nasal Fossae.—The nerves are: the olfactory, the nasal branch of the ophthalmic, filaments from the anterior dental branch of the superior maxillary, the Vidian, the naso-palatine, descending anterior palatine, and nasal branches of Meckel's ganglion. The olfactory, the special nerve of the sense of smell, is distributed to the olfactory region, and has been already referred to (p. 1019). The nasal branch of the ophthalmic division of the trigeminal nerve distributes filaments to the floor of the septum and outer wall of the nasal fossae. Filaments from the anterior dental branch of the superior maxillary supply the inferior meatus and inferior turbinated bone. The Vidian nerve supplies the upper and back part of the septum and superior spongy bone, and the upper anterior nasal branches from the sphenopalatine ganglion have a similar distribution. The naso-palatine nerve supplies the middle of the septum. The larger or anterior palatine nerve supplies the lower nasal branches to the middle and lower spongy bones.

Surgical Anatomy.—Instances of congenital deformity of the nose are occasionally met with, such as complete absence of the nose, an aperture only being present; or perfect development on one side, and suppression or malformation on the other; or there may be imperfect apposition of the nasal bones, so that the nose presents a median cleft or furrow. Deformities which have been acquired are much more common, such as flattening of the nose (saddle nose), the result of syphilitic necrosis, imperfect development of the nasal bones in cases of congenital syphilis, or a lateral deviation of the nose the result of fracture.

The skin over the alae and tip of the nose is thick and closely adherent to subjacent parts. Inflammation of this part is therefore very painful, on account of the tension. The skin is largely supplied with blood, and, the circulation here being terminal, vascular engorgement is liable to occur, especially in women at the menopause and in both sexes from disorders of digestion, exposure to cold, etc. The skin of the nose also contains a large number of sebaceous follices, and these, as a result of intemperance, are apt to become affected, and the nose becomes reddened, congested, and irregularly swollen. To this condition the term gorg-blossom is popularly applied. In some of these cases there is enormous hypertrophy of the skin and subcutaneous tissues, producing pendulous masses, termed lipomata nasi. Ordinary epithelioma and rodent ulcer may attack the nose, the latter being the more common of the two. Lupus and syphilitic ulceration frequently attack the nose, and may destroy the whole of the cartilaginous portion. In fact, lupus vulgaris begins more frequently on the ala of the nose than in any other situation.

Cases of congenital occlusion of one or both nostrils, or adhesion between the ala and septum may occur, and may require immediate operation, since the obstruction much interferes with sucking. Bone closure of the posterior nares may also occur.

To examine the nasal cavities, the head should be thrown back and the nose drawn upward, the parts being dilated by some form of speculum. They can also be examined with the little finger or a probe, and in this way foreign bodies detected. A still more extensive examination can be made by Roux's operation, which was introduced for the cure of osseum. This operation enables the surgeon to remove any dead bone which may be present in this disease. The cartilaginous framework of the nose is lifted up by an incision made inside the mouth, through the junction of the upper lip with the bone; the septum nasi and the lateral cartilages are divided with strong scissors till the anterior nares are completely exposed. The posterior nares can be explored by the aid of reflected light from the mouth, by which the posterior nares can be illuminated. The examination is very difficult to carry out, and, as a rule, sufficient information regarding the
presence of foreign bodies or tumors in the naso-pharynx can be obtained by the introduction of the finger behind the soft palate through the mouth. The septum of the nose may be displaced or deviate from the middle line; this may be the result of an injury or from some congenital defect in its development; in the latter case the deviation usually occurs along the line of union of the vomer and mesethmoid, and rarely occurs before the seventh year. Sometimes the deviation may be so great that the septum may come in contact with the outer wall of the naso fossa, and may even become adherent to it, thus producing complete obstruction. Perforation of the septum is not an uncommon affection and may arise from several causes; syphilitic or tuberculous ulceration, blood-tumor or abscess of the septum, and especially in workmen exposed to the vapor of bichromate of potash, from the irritating and corrosive action of fumes. When small, the perforation may cause a peculiar whistling sound during respiration. When large, it may lead to the falling in of the bridge of the nose.

Epistaxis is a very common affection in children. It is rarely of much consequence, and will almost always subside, but in the more violent hemorrhages of later life it may be necessary to plug the posterior nares. In performing this operation it is desirable to remember the size of the posterior nares. A ready method of regulating the size of the plug to fit the opening is to make it of the same size as the terminal phalanx of the thumb of the patient to be operated on.

Nasal polypus is a very common disease, and presents itself in three forms: the gelatinous, the fibrous, and the malignant. The first is by far the most common. It grows from the mucous membrane of the outer wall of the naso fossa, where there is an abundant layer of highly vascular submucous tissue; rarely from the septum, where the mucous membrane is closely adherent to the cartilage and bone, without the intervention of much, if any, submucous tissue. The most common seat of gelatinous polyps is probably the middle turbinate bone. The fibrous polypus generally grows from the base of the skull behind the posterior nares or from the roof of the naso fossae. The malignant polypi, both sarcomatous and carcinomatous, may arise in the nasal cavities and the naso-pharynx; or they may originate in the antrum, and protrude through its inner wall into the naso fossa.

Rhinoliths or nose-stones may sometimes be found in the nasal cavities. They arise from the deposition of phosphate of lime upon either a foreign body or a piece of inspissated secretion. The nasal passages furnish a secretion of their own and receive secretion from other parts (tears and secretions of the accessory sinuses). The nasal cavities contain the ethmoidal labyrinth, the lateral masses of the ethmoid (which form the superior and middle turbinate bones), and the inferior turbinate bones. The nasal cavity is surrounded by three pairs of pneumatic spaces, the accessory sinuses, which are the maxillary sinuses, the frontal sinuses, and the cells of the ethmoidal labyrinth. The lachrymal duct opens into the inferior meatus. Inflammation of the air-cells may follow inflammation of the nasal mucous membrane or bone disease. One set of cells or many may suffer. Suppuration may occur. Pus may be blocked up and retained. Dead bone may form. The most serious conditions may follow (abscess of brain, sinus thrombosis, septicaemia), and an operation is necessary to obtain relief.

THE EYE.

The eyeball or globe (bulbus oculi) (Figs. 725 and 729) is contained in the anterior part of the cavity of the orbit. In this situation it is securely protected from injury, whilst its position is such as to ensure the most extensive range of sight. It is acted upon by numerous muscles, by which it is capable of being directed to different parts; it is supplied by vessels and nerves, and is additionally protected in front by the orbital margins, eyelids, etc.

The eyeball is embedded in the fat of the orbit, but is partly surrounded by a thin membranous sac, the capsule of Ténon, which isolates it, so as to allow of free movement.

The Fascia or Capsule of Ténon (fascia bulbi [Tenoni]) (Figs. 725 and 726).—The fascia or capsule of Ténon consists of a thin membrane which envelopes the eyeball from the optic nerve to the ciliary region, separating it from the orbital fat and forming a socket in which it plays. Its inner surface is smooth, and is in contact with the outer surface of the sclerotic, the perisclerotic or suprasceral lymph-space only intervening. This lymph-space is continuous with the subdural and subarachnoid spaces, and is traversed by delicate bands of con-
The right eye in sagittal section, showing the capsule of Ténon (semidiagrammatic). (Testut.)

The capsule of Ténon forms a flexible pocket, in which the globe rotates. The capsule is perforated behind by the ciliary vessels and nerves and by the optic nerve, being continuous with the sheath of the latter. In front it blends with the ocular conjunctiva, and with it is attached to the ciliary region of the eyeball. It is perforated by the muscles which move the eyeball and on to each muscle it sends a tubular sheath. The sheath of the Superior oblique is carried as far as the fibrous pulley of that muscle; that on the inferior oblique reaches as far as the floor of the orbit, to which it gives off a slip. The sheaths on the recti are gradually lost in the perimysium, but they give off important expansions. The expansion from the Superior rectus blends with the tendon of the Levator palpebrae; that of the Inferior rectus is attached to the inferior tarsal plate. These two recti, therefore, will exercise some influence on the movements of the eyelids. The expansions
from the sheaths of the Internal and External recti are strong, especially the one from the latter muscle, and are attached to the lachrymal and malar bones respectively. As they probably check the action of these two recti, they have been named the internal and external check ligaments.

Lockwood has also described a thickening of the lower part of the capsule of Ténon, which he has named the suspensory ligament of the eye. It is slung like a hammock below the eyeball, being expanded in the centre and narrow at its extremities, which are attached to the malar and lachrymal bones respectively.¹

The anterior one-third of the globe is covered by the conjunctiva, or mucous membrane, reflected from the inner surfaces of the lids (Fig. 728). A lateral view of the globe shows that it is composed of segments of two spheres of different sizes (Figs. 725, 727, 728, and 729). The anterior segment is one of a small sphere, and forms about one-sixth of the eyeball. It is more prominent than the posterior segment, which is one of a much larger sphere, and forms about five-sixths of the globe. The segment of the larger sphere is opaque, and formed by the sclerotic, the tunic of protection to the eyeball; the smaller sphere is transparent, and formed by the cornea. Between the small, anterior or corneal segment, and the large, posterior or scleral segment, is a shallow and narrow groove, the scleral sulcus (sulcus sclerae). The anterior pole is the centre of the anterior portion of the cornea. The posterior pole is the centre of the posterior portion of the sclerotic. A straight line joining these two poles is the sagittal or optic axis (axis optica) (Fig. 727). A line drawn around the eyeball equally distant at all points from the two poles is called the

equatorial diameter or the equator (Fig. 727). The plane of the equator divides the globe in an anterior and a posterior hemisphere. Meridians may be drawn from one pole to the other at right angles to the equator. The visual axis (linea visus) (Fig. 727) passes in a straight line from the first nodal point on the cornea to the fovea centralis of the yellow spot on the retina. A nodal point is the point of intersection of convergent rays with the visual axis. The first nodal point is 6.9685 mm.

Fig. 728.—Diagram of a horizontal section of the right eye, showing the upper surface of the lower segment. (Testut.)

behind the summit of the cornea. The axes of the eyeballs are nearly parallel, and therefore do not correspond to the axes of the orbits, which are directed outward. The optic nerves follow the direction of the axes of the orbits, and are therefore not parallel; each nerve enters its eyeball about 1 mm. below and 3 mm. to the inner or nasal side of the posterior pole (Fig. 727). The eyeball measures rather more in its transverse and antero-posterior diameters than in its vertical diameter, the former amounting to nearly an inch, the latter to about nine-tenths of an inch. The diameters in the female are somewhat less than in the male.

The eyeball is composed of three investing tunics and of three refracting media.
THE TUNICS OF THE EYE.

From without inward the three tunics are:

I. Sclerotic Coat and Cornea.
II. Choroid, Ciliary Body, and Iris.
III. Retina.

I. The Fibrous or External Coat: The Sclerotic and Cornea
(Tunica Fibrosa Oculi).

The sclerotic and cornea (Figs. 727, 728, and 729) form the external tunic of the eyeball; they are essentially fibrous in structure, the sclerotic being opaque, and forming the posterior five-sixths of the globe; the cornea, which forms the remaining sixth, being transparent.

The Sclera or Sclerotic Coat (σκλέρος, hard).—The sclera or sclerotic coat has received its name from its extreme density and hardness; it is a firm, unyielding, opaque, fibrous membrane, forming the posterior five-sixths of the outer coat and serving to maintain the form of the globe. It is much thicker behind than in front. Its external surface is of a white color, and is in contact with the inner surface of the capsule of Ténon, a lymph-space intervening; it is quite smooth, except one-quarter of an inch back of the sclero-corneal junction, at the points where the Recti and Obliqui muscles are inserted into it, and its anterior part is covered by the conjunctival membrane (Fig. 757); hence the whiteness and brilliancy of the front of the eyeball. Its inner surface is stained a brown color, marked by grooves, in which are lodged the ciliary nerves and vessels (Figs. 732, 737, and 738); the inner surface of the sclera is loosely connected by three layers of exceed-
ingly fine cellular pigmented tissue (lamina fusca) with the outer surface of the choroid, an extensive lymph-space, the perichoroidal space (spatium perichorioideale) (Figs. 740 and 757) intervening between the sclerotic and choroid. Behind, the sclera is pierced by the optic nerve (n. opticus), and is continuous with the fibrous sheath of the nerve, which is derived from the dura (Fig. 734). At the point where the optic nerve passes through the sclerotic, the lamina fusca is represented by an arrangement of the fibrous tissue which forms a thin network, the cribiform lamina (lamina cribrosa sclerae) (Fig. 744); the minute orifices in this network serve for the transmission of separate bundles of nervous filaments, and the fibrous septa dividing them from one another are continuous with the membranous processes which separate the bundles of nerve-fibres. One of these openings (porus opticus), larger than the rest, occupies the centre of the lamella; it transmits the arteria centralis retinæ to the interior of the eyeball (Fig. 744). Around the cribiform lamella are numerous small apertures for the transmission of the ciliary nerves and the short ciliary arteries, and about midway between the margin of the cornea and the entrance of the optic nerve are four or five large apertures, for the transmission of veins (venae vorticosae) (Fig. 757). In front, the fibrous tissue of the sclerotic is continuous with the substantia propria of the cornea by direct continuity of tissue (Fig. 757), but the opaque sclerotic slightly overlaps the outer surface of the transparent cornea. In the depths of the line of junction between the cornea and the sclera there is a circular canal, the canal of Schlemm (sinus venosus sclerae) (Figs. 729, 736, 740, and 757). This canal receives the sclera veins (Fig. 736) and communicates internally by numerous minute openings in the pectineal ligament of the iris (Fig. 757) with the anterior chamber of the eyeball. These openings are the spaces of Fontana (Fig. 740).

Structure.—The sclerotic is formed of white fibrous tissue intermixed with fine elastic fibres, and of flattened connective-tissue corpuscles, some of which are pigmented, contained in cell-spaces between the fibres (Figs. 733 and 744). These fibres are aggregated into bundles, some of which are arranged in layers having an equatorial direction, but most of which are arranged in layers lying in meridian lines. The sclera is joined to the choroid by three thin layers of loose connective tissue containing pigment cells, the lamina fusca (lamina fasciae sclerae) (Fig. 737). Where the optic nerve passes through the sclera there is a very thin network to represent the lamina fusca. This network is the lamina cribrosa (Fig. 744). The muscles of the eyeball are attached to the sclera (Figs. 728, 729, and 757), and their tendons enter among the bundles of fibrous connective tissue. The conjunctiva covers the anterior portion of the sclera and is attached to it by submucous tissue (Figs. 728 and 740). The sclera yields gelatin on boiling. Its vessels (Figs. 734 and 736) are not numerous, the capillaries being of small size and uniting at long and wide intervals. It obtains arterial blood from the short posterior ciliary and the anterior ciliary arteries. The venous blood is removed by the venae vorticosae and the anterior ciliary veins. There are lymph-spaces between the cells which empty into the periscleral (Fig. 725 and p. 1114) and perichoroidal lymph-spaces (Fig. 740). Its nerves are derived from the ciliary nerves (Fig. 732). They lose their medullary sheaths and enter among the bundles of fibrous tissue, but it is not known how they terminate.

The Cornea (Figs. 725, 728, and 734).—The cornea is the projecting transparent part of the external tunic of the eyeball, and forms the anterior sixth of the globe. It is almost, but not quite, circular in shape, occasionally a little broader in the transverse than in the vertical direction. It is convex anteriorly, and projects forward from the sclerotic in the same manner that a watch-glass does from the case. Its degree of curvature varies in different individuals, and in the same individual at different periods of life, it being more prominent in youth than in advanced life, when it becomes flattened. Usually the curvature is slightly greater in the vertical plane than in the horizontal plane; at its centre than at its periphery, and at its temporal than at its nasal side. The cornea is dense and of uniform thickness throughout;
its posterior surface is perfectly circular in outline, and exceeds the anterior surface slightly in extent, from the latter being overlapped by the sclerotic. The antérieur surface is covered with conjunctiva (Fig. 740).

**Structure** (Fig. 730).—The cornea consists of five layers—namely: (1) the anterior or epithelial layer; (2) the anterior elastic layer; (3) the substantia propria; (4) the posterior elastic layer; (5) the posterior or endothelial layer.

(1) The **Anterior Layer** (*epithelium corneae*) is composed of stratified epithelium and is continuous with the cells of the conjunctiva at the borders of the cornea. There are from five to eight strata of nucleated cells in the anterior layer. The deepest cells are columnar. Above the columnar cells are several layers of polygonal cells, most of which have finger-like processes and are called **prickle cells**. At the surface the cells and nuclei become flat. The anterior epithelial layer prevents the absorption of the fluid of the tears.

(2) The **Anterior Elastic** or **Anterior Limiting Layer** or **Bowman's Membrane** (*lamina elastica anterior*) is less than half the thickness of the layer of stratified epithelium.
It differs in some essential respects from true elastic tissue. It shows evidences of fibrillar structure, and does not have a tendency to curl inward or to undergo fracture when detached from the other layers of the cornea. It consists of extremely close interwoven fibrils, similar to those found in the rest of the cornea proper, but contains no corneal corpuscles. It ought, therefore, to be regarded as a part of the proper tissue of the cornea.

(3) The Substantia Propria or proper substance of the cornea forms the main thickness of that structure. It is fibrous, tough, unyielding, perfectly transparent, and continuous with the sclerotic. It is composed of about sixty flattened lamellae, superimposed one on another. These lamellae are made up of bundles of modified connective tissue, the fibres of which are directly continuous with the fibres of the sclerotic. The fibres of each lamella are for the most part parallel with each other; those of alternating lamellae at right angles to each other. Fibres, however, frequently pass obliquely from one lamella to the next (fibrae arcuatae).

The lamellae are connected with each other by an interstitial cement-substance, in which are spaces, the corneal spaces, cell spaces or lacunae (Fig. 731). The spaces are stellate in shape, and have numerous offsets or canaliculi (Fig. 731), by which they communicate with each other. Each space contains a cell, the corneal corpuscle (Fig. 731), which resembles in form the space in which it is lodged, but it does not entirely fill it, the remainder of the space containing lymph. In the aged the margin of the cornea becomes opaque gray. This rim is called the arcus senilis, and is due to fat deposit in the lamellae and corneal corpuscles.

(4) The Posterior Elastic Lamina, the Membrane of Descemet, or the Membrane of Demours (lamina elastica posterior), which covers the proper structure of the cornea behind, presents no structure recognizable under the microscope. It consists of an elastic, and perfectly transparent homogeneous membrane, of extreme thinness, which is not rendered opaque by either water, alcohol, or acids. It is very brittle, but its most remarkable property is its extreme elasticity, and the tendency which it presents to curl up, or roll upon itself, with the attached surface innermost, when separated from the proper substance of the cornea. Its use appears to be (as suggested by Dr. Jacob) "to preserve the requisite permanent correct curvature of the flaccid cornea proper."

At the margin of the cornea this posterior elastic membrane breaks up into fibres to form a reticular structure at the outer angle of the anterior chamber, the intervals between the fibres forming small cavernous spaces, the spaces of Fontana (spatia

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Fig. 731.—From a horizontal section of an ox's cornea. Positive picture of the canal system demonstrated by the gold chloride method. X 450. (Szymonowicz.)
anguli iridis) (Fig. 740). These little recesses communicate with a circular canal in the deeper parts of the corneo-scleral junction. This is the canal of Schlemm (Figs. 729, 736, and 740); it communicates internally with the anterior chamber through the spaces of Fontana, and externally with the scleral veins. Some of the fibres of this reticulated structure are continued into the front of the iris, forming the ligamentum pectinatum iridis; while others are connected with the forepart of the sclerotic and choroid.

(5) The Posterior Layer or the Corneal Endothelium (endothelium camerae anterioris) lines the aqueous chamber and prevents the absorption of the aqueous humor. It covers the posterior surface of the elastic lamina, is reflected on to the front of the iris, and also lines the spaces of Fontana. It consists of a single layer of polygonal flattened transparent nucleated cells, similar to those lining other serous cavities.

Arteries and Nerves.—The foetal cornea contains blood-vessels which pass from the margin almost to the centre. The adult cornea contains no blood-vessels, except at its margin. The capillaries from the sclera and conjunctiva form loops at the corneal margin, and many of these loops enter the cornea for a distance of 1 mm. (Fig. 736). The balance of the cornea is non-vascular and obtains its nourishment from the lymph in the lacunae and canaliculi. Lymphatic vessels have not as yet been demonstrated in it, but are represented by the channels in which the bundles of nerves run; these channels are lined by endothelium and are continuous with the cell-spaces. The nerves are numerous, twenty-four to thirty-six in number (Köllicker), forty to forty-five (Waldeyer and Stümisch); they are derived from the ciliary nerves; they form the annular plexus (plexus annularis), at the corneal margin, and enter the laminated tissue of the cornea, lose their medullary sheaths, and ramify throughout the substantia propria as the fundamental plexus or the plexus of the stroma. From this deep plexus come perforating fibres (fibræ perforantes), which pass through the anterior elastic lamina and form the subepithelial plexus, and from it fibrils are given off which ramify between the epithelial cells, forming a network which is termed the intra-epithelial plexus. Nerve-fibres from the annular plexus and from the plexus of the stroma come into close relation with the corneal corpuscles.

Dissection.—In order to separate the sclerotic and cornea, so as to expose the second tunic, the eyeball should be immersed in a small vessel of water and held between the finger and thumb. The sclerotic is then carefully incised, in the equator of the globe, till the choroid is exposed. One blade of a pair of probe-pointed scissors is now introduced through the opening thus made, and the sclerotic divided around its entire circumference, and removed in separate portions. The front segment being then drawn forward, the handle of the scalpel should be pressed gently against it at its connection with the iris, and, these being separated, a quantity of perfectly transparent fluid will escape; this is the aqueous humor. In the course of the dissection the ciliary nerves (Fig. 732) may be seen lying in the loose cellular tissue between the choroid and sclerotic or continued in delicate grooves on the inner surface of the latter membrane.

II. The Choroid, Ciliary Body, and Iris, the Tunica Media, the Uveal Tract (Tunica Vasculosa Oculi) (Figs. 727, 729, 732, 737, 757).

The second or middle tunic of the eye is formed from behind forward by the choroid, the ciliary body, and the iris.

The choroid is the vascular and pigmentary tunic of the eyeball, investing the posterior five-sixths of the globe, and extending as far forward as the ora serrata of the retina; the ciliary body connects the choroid to the circumference of the iris. The iris is the circular muscular septum, which hangs vertically behind the cornea, presenting in its centre a large rounded aperture, the pupil.

The Choroid (chorioides).—The choroid is a thin, highly vascular membrane, of a dark-brown or chocolate color, which invests the posterior five-sixths of the
THE ORGANS OF SPECIAL SENSE

globe, and is pierced behind by the optic nerve, and in this situation is firmly adherent to the sclerotic. It is thicker behind than in front. Externally, it is loosely connected by the lamina fusca with the inner surface of the sclerotic (p. 1118). Its inner surface is attached to the retina.

**Structure** (Fig. 733).—The choroid consists of a dense capillary plexus and of small arteries and veins, carrying the blood to and returning it from this plexus (Fig. 736), and of branched and pigmented cells which lie in connective tissue. There are three layers in the choroid. Named from without inward, they are the lamina suprachorioidea, the choroid proper, and lamina basalis (Fig. 733).

1. The Lamina Suprachorioidea is on the external surface, that is, the surface next to the sclerotic. It resembles the lamina fusca of the sclerotic. It is composed of delicate non-vascular lamellae, each lamella consisting of a network of fine elastic fibres, among which are branched pigment-cells. The spaces between the lamellae are lined by endothelium, and open freely into the perichoroidal lymph-space, which, in its turn, communicates with the periscleral space by the perforations in the sclerotic through which the vessels and nerves are transmitted.

2. The Choroid Proper is internal to the lamina suprachorioidea. In consequence of the small arteries and veins of the choroid proper being arranged on the outer surface of the capillary network, it is customary to describe this as consisting of two layers: the outermost (lamina vasculosa), composed of small arteries and veins, with pigment-cells interspersed between them, and the inner (lamina choriocapillaris), consisting of a capillary plexus. The external layer of the choroid proper or the lamina vasculosa consists, in part, of the larger branches of the short
posterior ciliary arteries (Figs. 734, 736, and 738). which run forward between the veins, before they bend inward to terminate in the capillaries; but this layer is formed principally of veins, which have a whirl-like arrangement and empty into four or five large equidistant trunks, the venae vorticosae (Figs. 734, 735, and 736), which pierce the sclerotic midway between the margin of the cornea and the entrance of the optic nerve. Around the veins are lymph-spaces. Interspersed between the vessels are dark star-shaped pigment-cells, the offsets from which, communicating with similar branchings from neighboring cells, form a delicate network or stroma, which toward the inner surface of the choroid loses its pigmentary character. The internal layer of the choroid proper consists of an exceedingly fine capillary plexus, formed by the short ciliary vessels (Fig. 736), and is known as the tunic of Ruysch (lamina choriocapillaris). The network is close, and finer at the hinder part of the choroid than in front. About half an inch behind the cornea its meshes become larger, and are continuous
with those of the ciliary processes. These two laminae are connected by an intermediate stratum, which is destitute of pigment-cells and consists of fine elastic fibres.

On the inner surface of the lamina choriocapillaris is a very thin, structureless, or, according to Kölliker, faintly fibrous membrane, called the lamina basalis or membrane of Bruch; it is closely connected with the stroma of the choroid, and separates it from the pigmentary layer of the retina.

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**Tapetum (lucidum).—** This name is applied to the iridescent appearance which is seen in the outer and posterior parts of the choroid of many animals, but not in man.

The ciliary body should now be examined. It may be exposed, either by detaching the iris from its connection with the Ciliary muscle, or by making a transverse section of the globe, and examining it from behind.
The Ciliary Body (corpus ciliare) (Fig. 729).—The ciliary body or cyclon joins the choroid to the margin of the iris. It is in reality a process of the choroid or uveal tract and comprises the orbiculus ciliaris, the ciliary processes, and the Ciliary muscle.

The Orbiculus Ciliaris or Annulus Ciliaris (Figs. 737, 739, and 755).—The orbiculus ciliaris is a zone of about one-sixth of an inch in width, directly continuous with the anterior part of the choroid. The lamina basalis presents numerous ridges arranged in a radial manner. The depressions between the ridges are filled with retinal pigment epithelium (Szymonowicz). The orbiculus contains no lamina choriocapillaris.

The Ciliary Processes (processus ciliares) (Figs. 727, 729, 739, and 757).—The ciliary processes are formed by the plaeting and folding inward of the various layers of the choroid—i.e., the choroid proper and the lamina basalis—at its anterior margin, and are received between corresponding foldings of the suspensory ligament of the lens, thus establishing a connection between the choroid and inner tunic of the eye. They are arranged in a circle, and form a sort of plaited frill, the corona ciliaris, behind the iris, round the margin of the lens (Figs. 739 and 757). They vary between sixty and eighty in number, lie side by side, and may be divided into large and small; the latter, consisting of about one-third of the entire number, are situated in the spaces between the former, but without regular alternation. The larger processes are each about one-tenth of an inch in length, and are attached by their periphery to three or four of the ridges of the orbiculus ciliaris, and are continuous with the layers of the choroid; the opposite margin is free, and rests upon the circumference of the lens. Their anterior surface is turned toward the back of the iris, with the circumference of which they are continuous. The posterior surface is connected with the suspensory ligament of the lens.

Structure.—The ciliary processes are similar in structure to the choroid, but the vessels are larger, and have chiefly a longitudinal direction. They are the most vascular portion of the eyeball. The processes are covered on their inner surface by two strata of black pigment-cells, which are continued forward from the retina, and are named the pars ciliaris retinae (Figs. 733 and 740). In the stroma of the ciliary processes there are also stellate pigment-cells, which, however, are not so numerous as in the choroid itself.

The Ciliary Muscle or Bowman's Muscle (m. ciliaris) (Figs. 732, 734, 738, 740, 741, and 742).—The ciliary muscle consists of unstriped fibres; it forms a grayish, semitransparent, circular band, about one-eighth of an inch broad, on the outer surface of the forepart of the choroid, between the choroid and the iris and back of the sclero-corneal junction. It is thickest in front and gradually becomes thinner behind. It consists of two sets of fibres, radiating and circular.

The Radiating Fibres (fibrae meridianales [Bruckei]) (Figs. 740 and 757), much the more numerous, arise at the point of junction of the cornea and sclerotic, and partly also from the ligamentum pectinatum iridis, and, passing backward, are attached to the choroid opposite to the ciliary processes. One bundle, according to Waldeyer, is continued backward to be inserted into the sclerotic.
The **Circular Fibres** (fibrae circulares [Mulleri]) (Figs. 740 and 757) are internal to the radiating ones and to some extent unconnected with them, and have a circular course around the attachment of the iris. They are sometimes called the "ring muscle" of Muller, and were formerly described as the ciliary ligament. They are well developed in hypermetropic, but are rudimentary or absent in myopic eyes.

The **Ciliary muscle** is admitted to be the chief agent in accommodation—i.e., in adjusting the eye to the vision of near objects. Bowman believed that this was effected by its compressing the vitreous body, and so causing the lens to advance. At the present time all agree that the chief element in accommodation is altered curvature of the lens, but there is diversity of opinion as to the manner in which this is accomplished. The view which now prevails is that of Helmholtz. He maintained that in an unaccommodated eye the capsule and suspensory ligament of the lens are tense, and their pressure flattens the anterior surface of the lens, and parallel rays (and rays from objects far off are practically parallel) "are focused on the retina without any sense of effort."

"In accommodation for a near object the meridional or antero-posterior fibres

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1 Stewart, Manual of Physiology.
of the ciliary muscle by their contraction pull forward the choroid and relax the suspensory ligament. The elasticity of the lens at once causes it to bulge forward till it is again checked by the tension of the capsule. The pupil is at the same time slightly contracted.

**The Iris (iris, a rainbow)** (Figs 729, 732, 734, 736, 737, 740, 741, 742, 743, and 757).—The iris has received its name from its various colors in different individuals. It is a thin, circular-shaped, contractile curtain, suspended in the aqueous humor behind the cornea, and in front of the lens, being perforated a little to the nasal side of its centre by a circular aperture, the pupil (pupilla) (Fig. 743), for the transmission of light. The pupil of a living person varies in size under the influence of light and in efforts at accommodation. In looking at a near object the pupil is small; in looking at a distant object it is large. In light the pupil contracts, in darkness it dilates; hence the pupil is a window which permits light to pass into the interior of the eye. The size of this window depends on the contraction or relaxation of the iris. The iris divides the *aqueous chamber* (the space between

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Fig. 740.—Section of the eye, showing the relations of the cornea, sclerotic, and iris, together with the Ciliary muscle and the cavernous spaces near the angle of the anterior chamber. (Waldeyer.)

1 Stewart, Manual of Physiology.
look forward and backward, the anterior toward the cornea, the posterior toward the ciliary processes and lens. The iris is pigmented and the color of an individual's eyes depends upon this pigment. The anterior surface (facies anterior) (Figs. 741 and 757) of the iris is variously colored in different individuals, and is marked by lines which converge toward the pupil. The posterior surface (facies posterior) (Figs. 739 and 757) is of a deep-purple tint, from being covered by two layers of pigmented, columnar epithelium, which layers are continuous posteriorly with the pars ciliaris retinae. This pigmented epithelium is termed the pars iridica retinae, though it is sometimes named uvea, from its resemblance in color to a ripe grape.

**Structure.**—The iris is composed of the following structures:

1. In front is a layer of flattened endothelial cells placed on a delicate hyaline basement-membrane. This layer is continuous with the endothelial layer covering the membrane of Descemet, and in men with dark-colored irides the cells contain pigment-granules.

2. **Stroma** (stroma iridis).—The stroma consists of fibres and cells. The former are made of fine, delicate bundles of fibrous tissue, of which some few fibres have a circular direction at the circumference of the iris, but the chief mass consists of fibres radiating toward the pupil. They form, by their interlacement, a delicate mesh, in which the vessels and nerves are contained. Interspersed between the bundles of connective tissue are numerous branched cells with fine processes. Many of them in dark eyes contain pigment-granules, but in blue eyes and the pink eyes of albinos they are unpigmented.

3. The **Muscular Fibre** is involuntary and consists of circular and radiating fibres. The circular fibres (m. sphincter pupillae) surround the margin of the pupil on the posterior surface of the iris, like a sphincter, forming a narrow band about one-thirtieth of an inch in width, those near the free margin being closely aggregated; those more external somewhat separated, and forming less complete circles. The radiating fibres (m. dilator pupillae) converge from the circumference toward the centre, and blend with the circular fibres near the margin of the pupil. These fibres are regarded by some as elastic, not muscular, but Grunert positively demonstrated them. The fibres are very small and are placed between the stroma and the posterior layer of endothelium.

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1 Von Graefe's Arch. f. Ophthal., Bd. xlvii.
4. **Pigment.**—The situation of the pigment-cells differs in different irides. In the various shades of blue eyes the only pigment-cells are several layers of small round or polyhedral cells filled with dark pigment, situated on the posterior surface of the iris and continuous with the pigmentary lining of the ciliary processes. The color of the eye in these individuals is due to this coloring-matter showing more or less through the texture of the iris. In the albino even this pigment is absent.

In the gray, brown, and black eye there are, as mentioned above, pigment-granules to be found in the cells of the stroma and in the endothelial layers on the front of the iris; to these the dark color of the eye is due.
The Arteries of the Iris (Figs. 736, 738, 740, and 743).—The arteries of the iris are derived from the long posterior ciliary and anterior ciliary and from the vessels of the ciliary processes (see p. 1125). The long posterior ciliary arteries (Figs. 734 and 736), two in number, pass through the sclera, one on the inner and one on the outer side of the optic nerve, and pass forward between the sclera and choroid, and, having reached the attached margin of the iris (Figs. 734 and 743), divide into an upper and a lower branch, and, encircling the iris, anastomose with corresponding branches from the opposite side; into this vascular zone (circulus arteriosus major) (Fig. 757) the anterior ciliary arteries (Fig. 757), from the lachrymal and anterior ciliary from the muscular branches of the ophthalmic, pour their blood. From this zone vessels converge to the free margin of the iris, and these communicate by branches from one to another and thus form a second zone (circulus arteriosus minor) in this situation. The veins pass toward the ciliary margin and communicate with the veins of the ciliary processes and of the canal of Schlemm (Figs. 734 and 736).

The Nerves of the Choroid and Iris (Fig. 732).—The nerves of the choroid and iris are the short ciliary, the ciliary branches of the lenticular ganglion, and the long ciliary from the nasal branch of the ophthalmic division of the trigeminal. They pierce the sclerotic around the entrance of the optic nerve, and run forward in the perichoroidal lymph-space in which they form a plexus, from which plexus filaments pass to supply the blood-vessels of the choroid. After reaching the iris they form a plexus around its attached margin; from this are derived myelinated fibres which terminate in the circular and radiating muscular fibres. Their exact mode of termination has not been ascertained. Other fibres from the plexus terminate in a network on the anterior surface of the iris. The fibres derived from the motor root of the lenticular ganglion (oculomotor nerve) supply the circular fibres, while those derived from the sympathetic supply the radiating fibres.

Membrana Pupillaris.—In the foetus the pupil is closed by a delicate transparent vascular membrane, the membrana pupillaris, which divides the space into which the iris is suspended into two distinct chambers. This membrane contains numerous minute vessels, continued from the margin of the iris to those on the front part of the capsule of the lens. These vessels have a looped arrangement, and converge toward each other without anastomosing. Between the seventh and eighth months the membrane begins to disappear, by gradual absorption from the centre toward the circumference, and at birth only a few fragments remain. It is said sometimes to remain permanent and produce blindness.

III. The Tunica Interna or Retina (Figs. 736, 744, 746).

The retina is a delicate nerve membrane, in which the fibres of the optic nerve are spread out and upon the surface of which the images of external objects are received. Its outer surface is in contact with the choroid; its inner with the vitreous body. Behind, it is continuous with the optic nerve; it gradually diminishes in thickness from behind forward; and, in front, extends nearly as far as the ciliary body, where it appears to terminate in a jagged margin, the ora serrata (Figs. 736, 745, and 757). Here the nerve tissues of the retina end, but a thin prolongation of the membrane extends forward over the back of the ciliary processes and iris, forming the pars ciliaris retinae and pars iridica retinae, already referred to (Figs. 740 and 757). This forward prolongation consists of the pigmented layer of the retina, together with a stratum of columnar epithelium. The portion back of the ora serrata is called the physiological retina (pars optica retinae) (Fig. 757). The retina is soft, semitransparent, and of a purple tint in the fresh state, owing to the presence of a coloring-material named rhodopsin or visual purple; but it soon becomes clouded, opaque, and bleached when exposed to sunlight. Exactly in the centre of the front surface of the posterior part of the retina, corresponding to the visual axis, and at a point in which the sense of vision is most perfect, is an oval yellowish
THE TUNICA INTERNA OR RETINA

1131

spot, called, after its discoverer, the yellow spot of Sömmerring (macula lutea) (Figs. 727 and 746), having a central depression, the fovea centralis. The retina in the situation of the fovea centralis is exceedingly thin, and the dark color of the choroid is distinctly seen through it; so that it presents more the appearance of a foramen, and hence the name foramen of Sömmerring at first given to it. It exists only in man, the quadruped, and some saurian reptiles. About one-eighth of an inch (3 mm.) to the nasal side of the yellow spot and one-twenty-fourth of an inch below it, is the point of entrance of the optic nerve, the optic disk (porus opticus) (Figs. 744 and 746). The circumference of the optic disk is slightly raised so as to form an eminence, the optic papilla (colliculus nervi optici); the central portion is depressed and is called the optic cup (excavatio papillae nervi optici). The arteria centralis retinae pierces its centre. This is the only part of the surface of the retina from which the power of vision is absent, and is termed the blind spot.

![Diagram of the Retina](image)

**Fig. 744.—The terminal portion of the optic nerve and its entrance into the eyeball, in horizontal section. (Toldt.)**

**Structure.**—The optical portion of the retina is an exceedingly complex structure, and, when examined microscopically by means of sections made perpendicularly to its surface, is found to consist of many layers of nerve structure. These nerve structures are bound together and supported by the sustentacular fibres. There are three layers: a middle or neuro-epithelial layer, an inner layer, and an outer or pigmentary layer. The neuro-epithelial layer is subdivided into four, and the middle layer into six layers; hence the retina consists of eleven layers. The layers from within outward are as follows (Figs. 745, 747, 748, and 749):

1. Inner layer

   1. Membrana limitans interna.
   2. Layer of nerve-fibres (stratum opticum).
   3. Ganglionic layer, consisting of nerve-cells.
   4. Inner molecular, or plexiform, layer.
   5. Inner nuclear layer, or layer of inner granules.
   6. Outer molecular, or plexiform, layer.

2. Neuro-epithelial layer

   8. Outer nuclear layer, or layer of outer granules.
   10. Jacob's membrane (layer of rods and cones).

3. Outer layer

   11. Pigmentary layer (tapetum nigrum).
1. The **Membrana Limitans Interna** (Figs. 745, 747, and 748), is the most internal layer of the retina, and is in contact with the hyaloid membrane of the vitreous humor. It is derived from the supporting framework of the retina, with which tissue it will be described.

2. The **Layer of Nerve-fibres** (Figs. 745, 747, and 748) is formed by the expansion of the optic nerve. This nerve passes through all the other layers of the retina, except the membrana limitans interna, to reach its destination. As the nerve passes through the lamina cribrosa of the sclerotic coat, the fibres of which it is composed lose their myelin sheaths and are continued onward, through the choroid and retina, as simple axones. When these amylelinic axones reach the internal surface of the retina, they radiate from their point of entrance over the surface of the retina, become grouped in bundles, and in many places, according to Michel, arranged in plexuses. Most of the axones in this layer are **centripetal**, and are the direct continuations of the axones of the...
cells of the next layer. A few of the axones are centrifugal, which are axones of ganglion-cells within the brain. The centrifugal fibres in the layer of nerve-fibres pass through it and the next succeeding layer to ramify in the inner molecular and inner nuclear layers, where they terminate in enlarged extremities. The layer is thickest at the optic nerve entrance, and gradually diminishes in thickness toward the ora serrata.

3. The Ganglionic Layer or the Inner Ganglionic Layer (Figs. 745, 747, and 748) consists of a single layer of large ganglion-cells; except in the macula lutea, where there are several strata. The cells are somewhat flask-shaped, the rounded internal margin of each cell resting on the preceding layer and sending off an axone which is prolonged as a nerve-fibre into the fibrous layer. From the opposite extremity numerous thicker processes (dendrites) extend into the inner molecular layer, where they branch out into flattened arborizations at different levels. The ganglion-cells vary much in size, and the dendrites of the smaller ones, as a rule,

arborize in the inner molecular layer as soon as they enter it; while the processes of the larger cells ramify close to the inner nuclear layer.

4. The Inner Molecular, the Plexiform or the Inner Reticular Layer (Figs. 745, 747, and 748) is made up of a dense reticulum of minute fibris, formed by the interlacement of the dendrites of the ganglion-cells with those of the cells contained in the next layer, immediately to be described. Within the reticulum formed by these fibris a few branched spongioblasts are sometimes embedded.

5. The Inner Nuclear or Inner Granular Layer (Figs. 745, 747, and 748) is made up of a number of closely packed cells, of which there are three different kinds. (1) A large number of oval cells, which are commonly regarded as bipolar nerve-cells, and are much more numerous than either of the other kind. They each consist of a large oval body placed vertically to the surface, and containing a distinct nucleus. The protoplasm is prolonged into two processes; one of these passes inward into the inner molecular layer, is varicosc in appearance, and ends in a terminal ramification, which is often in close proximity to the ganglion-cells (Fig. 749, 1, c). The outer process passes outward into the outer molecular layer, and there breaks up into a
THE ORGANS OF SPECIAL SENSE

Fig. 725.—Elements of the retina of mammals, displayed by the chronaxie of silver method of Golgi. (Cajal.) (Copied from Quinac's Anatomy.)
number of branches. According to Cajal, there are two varieties of these bipolar cells: one in which the outer process arborizes around the knobbed ends of the rod-fibres, and the inner around the cells of the ganglionic layer; these he calls rod-bipolars (Fig. 749, i); the others are those in which the outer process breaks up in a horizontal ramification, in contact with the end of a cone-fibre; these are the cone-bipolars, and their inner process breaks up into its terminal ramifications in the inner molecular layer (Fig. 749, i). (2) At the innermost part of this inner nuclear layer is a stratum of cells, which are named amacrine cells of Cajal, from the fact that they have no axis-cylinder process, but they give a number of short protoplasmic processes which extend into the inner molecular layer and there ramify (Fig. 749, i). There are also at the outermost part of this layer some cells; the processes of which extend into and ramify in the outer molecular layer. These are the horizontal cells of Cajal. (3) Some few cells are also found in this layer, connected with the fibres of Müller, and will be described with those structures.

6. The Outer Molecular or Outer Reticular Layer or the Plexiform Layer (Figs. 745, 747, and 748) is much thinner than the inner molecular layer; but, like it, consists of a dense network of minute fibrils, derived from the processes of the horizontal cells of the preceding layer and the outer processes of the bipolar cells, which ramify in it, forming arborizations around the ends of the rod-fibres and with the branched foot-plates of the cone-fibres.

7. Henle's Fibre Layer is a non-granular layer in the neighborhood of the macula lutea, and is produced by elongations from the inner segments of rod-fibres and cone-fibres.

8. The Outer Nuclear or Outer Granular Layer (Figs. 745, 747, and 748), like the inner nuclear layer, contains several strata of clear oval nuclear bodies; they are of two kinds, and on account of their being respectively connected with the rods and cones of Jacob's membrane (rod-fibres and cone-fibres) are named rod-granules and cone-granules.

The rod-granules are much the more numerous, and are placed at different levels throughout the layer. Their nuclei present a peculiar cross-striped appearance, and prolonged from either extremity of the granule is a fine process; the outer process is continuous with a single rod of Jacob's membrane; the inner passes inward toward the outer molecular layer and terminates in an enlarged extremity.

DESCRIPTION OF FIG. 749.

I. Section of the dog's retina. a. Cone-fibre. b. Rod-fibre and nucleus. c, d. Bipolar cells (inner granules) with vertical ramification of outer processes destined to receive the enlarged ends of rod-fibres. e. Bipolar with flattened ramification for ends of cone-fibres. f. Giant bipolar with flattened ramifications. g. Cell sending a neurone or nerve-fibre process to the outer molecular layer. h. Amacrine cell with diffuse arborization in inner molecular layer. i. Nerve-fibres passing to outer molecular layer. j. Centrifugal fibres passing from nerve-fibre layer to inner molecular layer. k. Nerve-fibril passing into inner molecular layer. l. Ganglion-cells. m. Amacrine cells.

II. Horizontal or basal cells of the outer molecular layer of the dog's retina. a. Small cell with dense arborization. b. Large cell, lying in inner nuclear layer, but with its processes branching in the outer molecular. c. Its horizontal neurone. d. Medium-sized cell of the same character.

III. Cells from the retina of the ox. a. Rod-bipolars with vertical arborizations. b, c, d, e. Cone-bipolars with horizontal ramification of outer process. f. Cell lying on the outer surface of the outer molecular layer, and ramifying within it. i, j, m. Amacrine cells within the substance of the inner molecular layer.

IV. Neurones or axis-cylinder processes belonging to horizontal cells of the outer molecular layer, one of them, b, ending in a close ramification at a.

V. Nervous elements connected with the inner molecular layer of the ox's retina. a. Amacrine cell, with long processes ramifying in the outermost stratum. b. Large amacrine with thick processes ramifying in second stratum. c. Flattened amacrine with long and fine processes ramifying mainly in the first and fifth strata. d. Amacrine with radiating tuft of fibrils destined for third stratum. e. Large amacrine, with processes ramifying in fifth stratum. f. Small amacrine, branching into second stratum. g. h. Other amacrines destined for fourth stratum. i. Small ganglion-cell sending its processes to fourth stratum. k. A small ganglion-cell with ramifications in three strata. l. A small cell ramifying ultimately in first stratum. m. A medium-sized ganglion-cell ramifying in fourth stratum.

e. Giant-cell, branching in third stratum. f. A bistriated cell ramifying in second and fourth strata.

VI. Amacrines and ganglion-cells from the dog. a. Amacrine with radiating tuft. b. Large amacrine passing to third stratum. c and d. Small amacrines with radiations in second stratum. e. Small amacrine passing to third stratum. f. Amacrine with diffuse arborization. g. Amacrine belonging to fourth stratum. h. i. j. g. Small ganglion-cells ramifying in various strata. k, l, m. Large ganglion-cells showing two different characters of arborization. n. Bistriated cell.

VII. Amacrines from the dog. a. B. c. e. Small amacrines ramifying in middle of molecular layer. b, d, g, h, f. Small ganglion-cells showing various kinds of arborization. j. A larger cell, similar in character to g, but with longer branch. a, c, e. Giant-cells with thick branches ramifying in the first, second, and third layers. k, l. Ends of bipolaris branching over ganglion-cells.
and is embedded in the tuft into which the outer process of the rod-bipolars breaks up. In its course it presents numerous varicosities.

The cone-granules, fewer in number than the rod-granules, are placed close to the membrana limitans externa, through which they are continuous with the cones of Jacob's membrane. They do not present any cross-striping, but contain a pyri-form nucleus which almost completely fills the cell. From their inner extremity a thick process passes inward to the outer molecular layer, upon which it rests by a somewhat pyramidal enlargement, from which are given off numerous fine fibrils, which enter the outer molecular layer, where they come in contact with the outer processes of the cone-bipolars.

9. The Membrana Limitans Externa (Figs. 745, 747, and 748), like the membrana limitans interna, is derived from the fibres of Müller, with which structures it will be described.

10. Jacob's Membrane or the Layer of Rods and Cones (Figs. 745, 747, and 748) consists of visual cells, and the elements which compose it are of two kinds, rod-cells and cone-cells, the former being much more numerous than the latter.

The rod-cells (Fig. 750) are of nearly uniform size, and arranged perpendicularly to the surface. A rod-cell consists of a rod and a rod-fibre, and the fibre contains the nucleus. The rods are cylindrical and each consists of two portions, an outer segment and an inner segment, which are of about equal length. The segments differ from each other as regards refraction and in their behavior with coloring reagents, the inner portion becoming stained by carmine, iodine, etc., the outer portion remaining unstained with these reagents, but staining yellowish-brown with osmic acid. The outer portion of each rod is marked by transverse striae, and is made up of a number of thin disks superimposed on one another. It also

![Figure 750](image-url)
exhibits faint longitudinal markings. The inner portion of each rod, at its deeper part where it is joined to the outer process of the rod-granule, is indistinctly granular; its more superficial part presents a longitudinal striation, being composed of fine, bright, highly refracting fibres. In most vertebrates the outer portion of the inner segment contains a fibrous body, the ellipsoid of Krause. The visual purple, or rhodopsin, is found only in the outer segments of the rods. At its inner end each rod is prolonged into a very fine fibre, the rod-fibre, which contains a nucleus, and which terminates in the outer nuclear layer, being somewhat enlarged at its termination.

The cone-cells (Fig. 751) are conical or flask-shaped, their broad ends resting upon the membrana limitans externa, the narrow pointed extremity being turned to the choroid. Each cone-cell consists of two parts, the cone and the cone-fibre. The cones are shorter than the rods and exhibit an outer and an inner segment.

The outer segment is a short conical process, which, like the outer segment of a rod, presents transverse striae. The inner segment resembles the inner portion of the rods in structure, presenting a superficial striated and deeper granular part; but differs from it in size, being bulged out laterally and presenting a flask shape.

The inner segment of the cone, as does the rod, contains an ellipsoid of Krause. Each cone is prolonged into a cone-fibre, and at the junction of the cone with the fibre is the nucleus of the cone-cell. The cone-fibre passes to the outer nuclear layer, and terminates as an expansion from which very minute fibrils are given off. The chemical and optical characters of the rod-cells and cone-cells are identical.

11. The Pigmentary Layer or Tapetum Nigrum (Fig. 745).—The most external layer of the retina, formerly regarded as a part of the choroid, consists of a single layer of hexagonal epithelial cells, loaded with pigment-granules. Each cell contains a flattened nucleus in the outer portion of the cell which is free from pigment at this point. These cells are smooth externally, where they are in contact with the choroid, but internally they are prolonged into fine, straight processes, which extend between the rods, this being especially the case when the eye is exposed to light. The pigment changes its position under the influence of light, and is distributed through the entire cell. In the eyes of albinos, the cells of the pigmentary layer are present, but they contain no coloring-matter. In the eyes of many mammals also, as in the horse, and many of the carnivora, there is no pigment in the cells of this layer, and the choroid possesses a beautiful iridescent lustre, which is termed the tapetum lucidum.

Supporting Framework of the Retina.—Almost all these layers of the retina are connected together by a supporting framework, formed by the supporting cells or supporting fibres of Müller or radiating fibres, from which the membrana limitans interna et externa are derived. These fibres are found stretched between the two limiting layers (Fig. 745), "like columns between a floor and a roof," and they pass through all the nervous layers except Jacob's membrane. Each commences on the inner surface of the retina by a conical hollow base, which sometimes contains a spheroidal body which stains deeply with haematoxylin, the edges of the bases of adjoining fibres being united and thus forming a boundary line, which is the membrana limitans interna. As they pass through the nerve-fibre and ganglionic layers they give off few lateral branches; in the inner nuclear layer they give off numerous lateral processes for the support of the inner granules, while in the outer nuclear layer they form a network, the fibre-baskets, around the rod and cone-fibrils, and unite to form the external limiting membrane at the bases of the rods and cones. In the inner nuclear layer each fibre of Müller presents a clear oval nucleus, which is sometimes situated at the side of, sometimes altogether within, the fibre. The supporting framework of the retina contains neuroglia cells.

The Path of Light Stimuli.—The stimulus is first received by the rod and cone-cells (the visual cells), and is transmitted to the bipolar cells of the inner nuclear layer and then to the cells of the ganglionic layer, which send fibres by way of the optic nerve to the brain.
Macula Lutea and Fovea Centralis.—The structure of the retina at the yellow spot presents some modifications. In the macula lutea (1) the nerve-fibres are wanting as a continuous layer; (2) the ganglionic layer consists of several strata of cells, instead of a single layer; (3) in Jacob's membrane there are no rods, but only cones, and these are longer and narrower than in other parts; and (4) in the outer nuclear layer there are only cone-fibres, which are very long and arranged in curved lines. At the fovea centralis the only parts which exist are the cones of Jacob's membrane, the outer nuclear layer, the cone-fibres of which are almost horizontal in direction, and an exceedingly thin inner granular layer, the pigmentary layer, which is thicker and its pigment more pronounced than elsewhere. The color of the macula seems to imbue all the layers except Jacob's membrane; it is of a rich yellow, deepest toward the centre, and does not appear to consist of pigment-cells, but simply a staining of the constituent parts.

At the Ora Serrata (Fig. 736) the nerve layers of the retina terminate abruptly, and the retina is continued onward as a single layer of elongated columnar cells covered by the pigmented layer. This prolongation is known as the pars ciliaris retinae (Fig. 740), and can be traced forward from the ciliary processes on to the back of the iris, where it is termed the pars iridica retinae or uvea.

From the description given of the nerve elements of the retina it will be seen that there is no direct continuity between the structures which form its different layers except between the ganglionic and nerve-fibre layers, the majority of the nerve-fibres being formed of the axones of the ganglionic cells. In the inner molecular layer the dendrites of the ganglionic layer interlace with those of the cells of the inner nuclear layer, while in the outer molecular layer alike synapsis occurs between the processes of the inner granules and the rod and cone elements.

The Arteria Centralis Retinae (Figs. 736 and 744) and its accompanying vein, vena centralis retinae, pierce the optic nerve, and enter the globe of the eye through the porus opticus. It immediately bifurcates into an upper and a lower branch, and each of these again divides into an upper or nasal, and an outer or temporal, branch, which at first run between the hyaloid membrane and the nerve layer; but they soon enter the latter, and pass forward, dividing dichotomously. From these branches a minute capillary plexus is given off, which does not extend beyond the inner nuclear layer. The macula receives small twigs from the temporal branches and others directly from the central artery; these do not, however, reach as far as the fovea centralis, which has no blood-vessels. The branches of the arteria centralis retinae do not anastomose with each other—in other words, they are "terminal arteries." In the fœtus, a small vessel passes forward, through the hyaloid canal in the vitreous body, to the posterior surface of the capsule of the lens (Fig. 728).

THE REFRACTING MEDIA.

The Refracting media are three, viz.:

Aqueous humor. 
Vitreous body. 
Crystalline lens.

I. The Aqueous Humor (Humor Aqueus).

The aqueous humor completely fills the lympath space known as the aqueous chamber, the space which is bounded in front by the cornea and behind by the lens and its suspensory ligament and the ciliary body (Fig. 757). The aqueous chamber
THE VITREOUS BODY

is partly divided by the iris into two communicating parts, the anterior and posterior chambers (Figs. 727, 728, and 757). The posterior chamber (cumera oculi posterior) is only a narrow chink between the peripheral part of the iris, the suspensory ligament of the lens, and the ciliary processes. The anterior chamber (cumera oculi anterior) is bounded in front by the cornea and behind by the iris. The external angle of the anterior chamber is bounded by the periphery of the cornea and of the iris. It is called the angle or sinus of the anterior chamber or the filtration angle (angulus iridis). It is by way of the filtration angle that any excess of aqueous humor passes by way of the spaces of Fontana and the canal of Schlemm (Fig. 740) to the anterior ciliary veins and relieves tension. The aqueous humor is small in quantity (scarcely exceeding, according to Petit, four or five grains in weight), has an alkaline reaction, in composition is little more than water, less than one-fiftieth of its weight being solid matter, chiefly chloride of sodium.

In the adult, these two chambers communicate through the pupil; but in the fetus of the seventh month, when the pupil is closed by the membrana pupillaris, the two chambers are quite separate.

II. The Vitreous Body (Corpus Vitreum) (Figs. 725, 728, 752).

The vitreous body forms about four-fifths of the entire globe. It is composed of a jelly-like tissue containing 98 per cent. water, some salts, and a little albumin, and called the vitreous humor (humor vitreus), connective-tissue fibres, and connective-tissue cells. It fills the concavity of the retina, and is hollowed in front, forming a deep concavity, the fossa patellaris (fossa hyaloidea) (Fig. 752), for the reception of the lens. It is perfectly transparent, of the consistence of thin jelly, and is composed of an albuminous fluid enclosed in a delicate transparent membrane, the hyaloid membrane (membrana hyaloidea), the outside of which is in contact with the membrana limitans interna of the retina. It has been supposed by Hannover, that from its inner surface numerous thin lamellae (stroma vitreum) are prolonged inward in a radiating manner, forming spaces in which the fluid is contained. In the adult, these lamellae cannot be detected even after careful microscopic examination in the fresh state, but in preparations hardened in weak chromic acid it is possible to make out a distinct lamellation at the periphery of the body; and in the fetus a peculiar fibrous texture pervades the mass, the fibres joining at the numerous points, and presenting minute nuclear granules at their point of junction. In the centre of the vitreous humor, running from the entrance of the optic nerve to the posterior surface of the lens, is a canal, filled with fluid and lined by a prolongation of the hyaloid membrane. This is the canal of Stilling, the hyaloid canal, or the canal of Cloquet (canalis hyaloides) (Fig. 728), which in the embryonic vitreous humor conveyed the minute vessel from the central artery of the retina to the back of the lens.

The hyaloid membrane encloses the whole of the vitreous humor. In front of the ora serrata it is thickened by the accession of radial fibres and is termed the zonule of Zinn (zonula ciliaris) (Figs. 755 and 757). It presents a series of radially arranged furrows, in which the ciliary processes are accommodated and to which they are adherent, as evidenced by the fact that when removed some of their pigment remains attached to the zonule. The zonule of Zinn splits into two layers, one of which is thin and lines the fossa patellaris; the other is named the suspensory ligament of the lens; it is thicker, and passes over the ciliary body to be attached to the capsule of the lens a short distance in front of its equator. Scattered and delicate fibres are also attached to the region of the equator itself. This ligament retains the lens in position, and is relaxed by the contraction of the radial fibres of the Ciliary muscle, so that the lens is allowed to become more convex. Behind
the suspensory ligament there is a sacculated canal, the canal of Petit (*spatia zonularia*); which enircles the margin of the lens and which can be easily inflated through a fine blow-pipe inserted through the suspensory ligament. It is bounded in front by the anterior layer of the suspensory ligament of the lens, behind by the hyaloidea membrana, and internally by the capsule of the lens. The canal of Petit is a lymph-space. All the spaces of the canal of Petit communicate with the posterior chamber of the eye.

In the fetus, the centre of the vitreous humor presents the hyaloid canal or canal of Stilling, already referred to, which transmits a minute artery, the hyaloid artery, to the capsule of the lens. In the adult, no vessels penetrate its substance, although a lymph channel remains; so that its nutrition must be carried on by the vessels of the retina and ciliary processes, situated upon its exterior.

III. The Crystalline Lens (Lens Crystallina) (Figs. 729, 736, 753, 754, 755, 756, 757).

The crystalline lens, enclosed in its capsule, is situated immediately behind the pupil, in front of the vitreous body, and is encircled by the ciliary processes, which slightly overlap its margin.

The capsule of the lens (capsula lenti) (Fig. 757) is a transparent, highly elastic, and brittle membrane, which closely surrounds the lens, and is composed in part of cuticular and in part of connective tissue. It is not white fibrous tissue, and is not true elastic tissue (Szymonowicz). Its outer surface is composed of lamella and possesses transverse striations. It rests, behind, in the fossa patellaris in the fore-part of the vitreous body (Fig. 752); in front, it is in contact with the free border of the iris, this latter reeding from it at the circumference, thus forming the posterior chamber of the eye (Fig. 757); and it is retained in its position chiefly by the suspensory ligament of the lens, already described (Fig. 757). The capsule is much thicker in front than behind, and when ruptured the edges roll up with the outer surface innermost, like the elastic lamina of the cornea.

The substance of the lens (substantia lenti) is an epithelial structure and takes origin from the ectoderm. It consists early in development of transparent cylindrical cells, which at a later period become higher at the posterior surface of the lens. Eventually very long cells form; they are known as *lens-fibres* (fibrae lenti), and are joined by a cement substance. The adult lens consists of lens-fibres, the anterior surface being covered by one layer of cubical epithelial cells, known as *lens epithelium* (epithelium lenti). This layer extends to the margin of the lens, at which point the cells gain in height and form lens-fibres. The lens-fibres at the margin are nucleated, the others are not. The lens-fibres run as meridians from the anterior surface backward. There is no epithelium on the posterior surface.
In the foetus, a small branch from the arteria centralis retinae runs forward, as already mentioned, through the vitreous humor to the posterior part of the capsule of the lens, where its branches radiate and form a plexiform network, which covers its surface, and they are continuous around the margin of the capsule with the vessels of the pupillary membrane and with those of the iris. In the adult no vessels enter its substance.

Structure.—The lens is a transparent, biconvex body, the convexity being greater on the posterior than on the anterior surface (Fig. 754). The central points of its anterior and posterior surfaces are known as its anterior and posterior poles (polus anterior lentis et polus posterior lentis) (Fig. 754). It measures from 9 to 10 mm. in the transverse diameter, and about 4 mm. in the antero-posterior. It consists of concentric layers (Fig. 753), of which the external in the fresh state are soft and easily detached (substantia corticalis) (Fig. 757); those beneath are firmer, the central ones forming a hardened nucleus (nucleus lentis) (Fig. 753). These laminae are best demonstrated by boiling or immersion in alcohol, and consist of minute parallel fibres, which are hexagonal prisms, the edges being dentated, and the dentations fitting accurately into each other; their breadth is about $\frac{1}{5}$ of an inch. Faint lines radiate from the anterior and posterior poles to the circumference of the lens. In the adult there may be six or more of these, but in the foetus they are only three in number and diverge from each other at angles of $120^\circ$ (Fig. 756). On the anterior surface one line ascends vertically and the other two diverge downward and outward. On the posterior surface one ray descends vertically and the other two diverge upward. They correspond with the free edges of an equal number of septa in the lens, along which the ends of the lens-fibres come into

![Diagram](image-url)

**Fig. 755.**—The zonule of Zinn or the suspensory ligament of the lens viewed from behind in connection with the lens and the ciliary body. (Toldt.)

**Fig. 756.**—Diagram to show the direction and arrangement of the radiating lines on the front and back of the foetal lens. A, from the front; B, from the back.
apposition and are joined together by transparent amorphous substance. The fibres run in a curved manner from the septa on the anterior surface to those on the posterior surface. No fibres pass from pole to pole, but they are arranged in such a way that fibres which commence near the pole on one aspect of the lens terminate near the peripheral extremity of the plane on the other, and vice versa. Each fibre of the outer layers of the lens contains a nucleus, and these nuclei form a layer, the **nuclear layer** on the surface of the lens. The nuclear layer is most distinct toward the circumference of the lens.

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The **changes produced in the lens by age** are the following:

In the **foetus** its form is nearly spherical, its color of a slightly reddish tint, it is not perfectly transparent, and is so soft as to break down readily on the slightest pressure.

In the **adult** the posterior surface is more convex than the anterior; it is colorless, transparent, and firm in texture.

In **old age** it becomes flattened on both surfaces, slightly opaque, of an amber tint, and increases in density.

**Arteries of the Globe of the Eye.**—The arteries of the globe of the eye are the short posterior ciliary, long posterior ciliary, and anterior ciliary arteries, and the **arteria centralis retinae**.
The short posterior ciliary arteries (aa. ciliares posteriores breves) (Figs. 734, 736, and 738) are from eight to sixteen in number. They arise from the ophthalmic branch of the internal carotid, pass through the sclerotic coat near the optic nerve, and are distributed to the choroid.

There are two long posterior ciliary arteries (aa. ciliares posteriores longae) (Figs. 734, 736, and 743), one on each side of the optic nerve. They are branches of the ophthalmic. They pass through the sclerotic external to the short ciliary arteries, and extend forward in the choroid. In the ciliary body they form an anastomosis with the anterior ciliary arteries. The anastomosis is known as the circulum iridis major (Figs. 736 and 757). Branches from this circle pass to the iris, and at the periphery of the sphincter of the iris form the circulum iridis minor. The muscular branches and the lachrymal branch of the ophthalmic give off the anterior ciliary arteries (aa. ciliares anteriores), six or eight in number. They pass along tendons of the muscles of the eyeball, reach the sclera, and pass upon the sclera to the corneal margin (Fig. 743). Branches are given off which pass backward to supply the anterior half of the sclera, and which are known as episcleral arteries (aa. episclerales) (Fig. 736). Two branches are given off which pass forward to the conjunctiva bulbi, which are known as the anterior conjunctival arteries (aa. conjunctivales anteriores), which anastomose with the posterior conjunctival branches from the palpebral arteries, and which give branches to the delicate vascular network of the corneal margin which is in the annulus conjunctivae (Spalteholz). Eight or even more branches form the anterior ciliary arteries. They pass through the sclerotic near the sclero-corneal junction, and participate in the formation of the circulum iridis major.

The Veins of the Globe of the Eye (Figs. 734, 735, and 736).—The veins are seen on the outer surface of the choroid. They have a whorl-like formation and empty into four or five large veins, the venae vorticosae. These four, five, or six equidistant venae vorticosae pierce the sclerotic midway between the margin of the cornea and the entrance of the optic nerve, and empty into the ophthalmic vein. Another set of veins accompany the anterior ciliary arteries, and are known as the anterior ciliary veins (vv. ciliares anteriores). They are derivatives of the venous sinus of the sclera in the canal of Schlemm. They form a circular plexus. They receive vessels, the ciliary muscle, and pass through the sclera close to the corneal margin. Posterior ciliary veins (vv. ciliares posteriores) receive vessels which gather venous blood from the outer surface of the sclera near the optic nerve. The posterior ciliary veins join anteriorly with the venae vorticosae. After emerging from the sclera they receive anterior conjunctival branches, and by means of episcleral veins communicate with the venae vorticosae.

The Lymphatic Passages of the Eyeball.—The conjunctiva contains lymph-vessels. The eyeball contains lymph-spaces, but no lymph-vessels.

There are two sets of lymph-spaces in the eyeball, the anterior and posterior. The anterior lymph-spaces are the spaces of the cornea, of the iris, of the anterior chamber, and of the posterior chamber. The lymph from the intralamellar lymph-spaces of the cornea enters the conjunctival lymphatics at the margin of the cornea.

The lymph-spaces of the iris open into the anterior chamber by the crypts of the iris and at the margin of the iris join the spaces of Fontana. The aqueous humor fills the anterior and posterior chambers, but is furnished by the vessels in the posterior chamber; in part by the vessels of the ciliary body, and in part by the vessels of the posterior surface of the iris. The lymph thus secreted passes by way of the pupil into the anterior chamber, and then is taken up by the spaces of Fontana, the canal of Schlemm, and the anterior ciliary veins.¹

¹ Deaver's Anatomy.
The posterior lymph-spaces are the hyaloid canal, the perichoroidal lymph-space, the space of Ténon, the intervaginal space of the optic nerve, and the supravaginal space (Deaver).

The hyaloid canal (Figs. 725 and 728) passes between the posterior surface of the lens and the optic disk. In the embryo the canal holds an artery; the hyaloid artery. During development the artery disappears, but a lymph channel remains. The hyaloid canal opens into the intervaginal space of the optic nerve. Between the sclerotic and the choroid is the perichoroidal lymph-space (Fig. 757). It is around the choroid vessels and the venae vorticosae, and empties into Ténon's space by means of openings through the sclera about the venae vorticosae.

Ténon's space (Figs. 725 and 726) is between the sclera and the capsule of Ténon. It receives lymph from the perichoroidal space, and empties into the supravaginal space.

The optic nerve (Fig. 744) has a sheath of dura and a sheath of pia, and between these sheaths is the intervaginal lymph-space. It is divided by a prolongation of the cerebral arachnoid into a subdural space and a subarachnoid space, which empty into the corresponding spaces of the membranes of the brain.

The supravaginal space is between the dural portion of the sheath of the optic nerve and a posterior prolongation of Ténon's capsule.1

The Nerves of the Globe of the Eye.—The long ciliary nerves (nn. ciliares longi), two in number, are derived from the nasal branch of the ophthalmic and the short ciliary nerves (nn. ciliares breves), twelve to fifteen in number, are derived from the ciliary or ophthalmic ganglion. Both the long and short ciliary nerves perforate the sclera in the neighborhood of the optic nerve (Fig. 734). They pass along the perichoroidal lymph-space, forming a plexus, and send filaments to the choroid vessels. In front of the Ciliary muscle they form a second plexus, and from it come branches which go to the Ciliary muscle and the muscular fibres and vessels of the iris, sclera, choroid, ciliary body, and iris (Fig. 742). The ciliary nerves supply the cornea. The circular fibers of the iris are innervated by the oculomotor nerve and the radiating fibres by the sympathetic.

Surgical Anatomy.—From a surgical point of view the cornea may be regarded as consisting of three layers: (1) of an external epithelial layer, developed from the epiblast, and continuous with the external epithelial covering of the rest of the body, and therefore in its lesions resembling those of the epidermis; (2) of the cornea proper, derived from the mesoblast, and associated in its diseases with the fibro-vascular structures of the body; and (3) the posterior elastic layer with its endothelium, also derived from the mesoblast and having the characters of a serous membrane, so that inflammation of it resembles inflammation of the other serous and synovial membranes of the body.

The cornea contains no blood-vessels, except at its periphery, where numerous delicate loops, derived from the anterior ciliary arteries, may be demonstrated on the anterior surface of the cornea. The rest of the cornea is nourished by lymph, which gains access to the proper substance of the cornea and the posterior layer through the spaces of Fontana. This lack of a direct blood-supply renders the cornea very apt to inflame in the cachectic and ill-nourished. In spite of the absence of blood-vessels, wounds of the cornea usually heal rapidly. A wound which penetrates the cornea opens the anterior chamber, and aqueous humor escapes. An ulcer may also open the anterior chamber. Through a wound or a perforated ulcer the pupillary margin of the iris may prolapse. A trivial injury of the cornea is repaired by transparent tissue. A severe injury is repaired by fibrous tissue, and opacity results. A slight opacity resembling a cloud of gray smoke is called nebula; a more marked white opacity is called leucoma.

In abscess of the cornea pus gravitates between the layers to the lower part of the cornea and the purulent collection assumes a crescentic shape (onix). The areus senilis, seen in the aged, is a condition of haziness or opacity at the corneal margin due to fatty degeneration of the tissue of the cornea. It signifies interference with the blood-supply, because of senile degeneration of adjacent vessels. In cases of granular lids there is a peculiar affection of the cornea, called pusius, in which the anterior layers of the cornea become vascularized, and a rich network of blood-vessels may be seen on the cornea: and in interstitial keratitis new vessels extend into the cornea, giving it a pinkish hue, to which the term salmon patch is applied. The cornea is richly supplied with nerves, derived from the ciliary nerves, which

1 For the lymphatic channels of the eyeball see Deaver's Surgical Anatomy, vol. ii. p. 392.
enter the cornea through the forepart of the sclerotic and form plexuses in the stroma, terminating between the epithelial cells by free ends or in corpusescles. In cases of glaucoma the ciliary nerves may be pressed upon as they course between the choroid and sclerotic (Fig. 732), and in consequence of the pressure upon them, the cornea, to which they are distributed, becomes anesthetic. When a scar forms on the cornea and the iris becomes adherent, the scar and the iris, and sometimes even the lens, may bulge forward from intraocular tension. This condition is *staphyloma of the cornea.* In conditions of impaired nutrition the cornea may be bulged forward by intraocular pressure. The line of least resistance is a little below the centre of the cornea, and it is bulged forward and strongly curved. This condition is known as *conical cornea.* The sclerotic has very few blood-vessels and nerves. The blood-vessels are derived from the anterior ciliary, and form an open plexus in its substance. As they approach the corneal margin this arrangement is peculiar. Some branches pass through the sclerotic to the ciliary body; others become superficial and lie in the episcleral tissue, and form arches, by anastomosing with each other, some little distance behind the corneal margin. From these arches numerous straight vessels are given off, which run forward to the cornea, forming its marginal plexus. In *inflammation of the sclerotic and episcleral tissue* these vessels become conspicuous, and form a pinkish zone of straight vessels radiating from the corneal margin, commonly known as the zone of ciliary injection. In *inflammation of the iris and ciliary body* this zone is present, since the sclerotic speedily becomes involved when these structures are inflamed. But in *inflammation of the cornea* the sclerotic is seldom much affected, though the cornea and sclerotic are structurally continuous. This would appear to be due to the fact that the nutrition of the cornea is derived from a different source from that of the sclerotic. The *sclerotic* may be ruptured subcutaneously without any laceration of the conjunctiva, and the rupture usually occurs near the corneal margin, where the tunic is thinnest. It may be complicated with lesions of adjacent parts—laceration of the choroid, retina, iris, or suspensory ligament of the lens—and is then often attended with hemorrhage into the anterior chamber, which masks the nature of the injury. In some cases the lens has escaped through the rent in the sclerotic, and has been found under the conjunctiva. *Wounds of the sclerotic,* if they do not perforate, usually heal readily. If they extend through the sclerotic they cause diminished tension, are always dangerous, and are often followed by inflammation, suppuration, and by sympathetic ophthalmia. The sclerotic may be weakened by injury, inflammation, etc., and the weakened portion may bulge from intraocular pressure, and even a healthy sclera may bulge from excessive intraocular pressure. According to its situation the lesion is known as *ciliary staphyloma, equatorial staphyloma,* or *posterior staphyloma.*

One of the functions of the choroid is to provide nutrition for the retina and to convey vessels and nerves to the ciliary body and iris. *Inflammation of the choroid* is therefore followed by grave disturbance in the nutrition of the retina, and is attended with early interference with vision. *Purulent choroiditis* is not confined to the choroid; the retina, the vitreous, and the entire uveal tract become involved, and even other structures may suffer. In its diseases it bears a considerable analogy to those which affect the skin, and, like it, is one of the places from which *melanotic sarcoma* may grow. These tumors contain a large amount of pigment in their cells, and grow only from those parts where pigment is naturally present. The choroid may be ruptured without injury to the other tunics, as well as participating in general injuries of the eyeball. In cases of uncomplicated rupture the injury is usually at its posterior part, and is the result of a blow on the front of the eye. It is attended by considerable hemorrhage, which for a time may obscure vision, but in most cases this is restored as soon as the blood is absorbed.

The *iris* is the seat of a malformation, termed *coborama,* which consists in a deficiency or cleft, which in a great number of cases is clearly due to an arrest in development. In these cases it is found at the lower aspect, extending directly downward from the pupil, and the gap frequently extends through the choroid to the entrance of the optic nerve. In some rarer cases the gap is found in other parts of the iris, and is then not associated with any deficiency of the choroid. The iris is abundantly supplied with blood-vessels and nerves, and is therefore very prone to become inflamed. And when inflamed, in consequence of the fact that the iris and ciliary body are continuous, and that their vessels communicate, *iritis* is usually associated with *cyclitis,* the disease being called *irido-cyclitis.* And, in addition, inflammation of adjacent structures, the cornea and sclerotic, is apt to spread into the iris. The iris is covered with endothelium, and partakes of the character of a serous membrane, and, like these structures, is liable to pour out a plastic exudation when inflamed, and contract adhesions, either to the cornea in front (synecchia anterior), or to the capsule of the lens behind (synecchia posterior). In iritis the lens may become involved, and the condition known as *secondary cataract* may be set up. *Tumors* occasionally commence in the iris; of these, *cysts,* which are usually congenital and *sarcomatous tumors,* are the most common and require removal. *Gummata* are not unfrequently found in this situation. In some forms of injury of the eyeball, as the impact of a spent shot, the rebound of a twig, or a blow with a whip, the iris may be detached from the Ciliary muscle, the amount of detachment varying from the slightest degree to the separation of the whole iris from its ciliary connection.

The *Argyll-Robertson pupil* shows no reaction to light, but retains reaction to accommodation and vision remains good.
The retina, with the exception of its pigment-layer and its vessels, is perfectly transparent, and is invisible when examined by the ophthalmoscope, so that its diseased conditions are recognized by its loss of transparency. In retinitis, for instance, there is more or less dense and extensive opacity of its structure, and not unfrequently extravasations of blood into its substance. Hemorrhages may also take place into the retina from rupture of a blood-vessel without inflammation.

In optic neuritis, papillitis, or choked disk, the ophthalmoscope shows increase in vascularity, and swelling and opacity of the nerve, which extend beyond the disk margins. Optic atrophy is apt to follow. (Fig. 758 shows a normal optic disk.)

The retina may become displaced from effusion of serum between it and the choroid or by blows on the eyeball, or may occur without apparent cause in progressive myopia, and in this case the ophthalmoscope shows an opaque, tremulous cloud. Glioma, a form of sarcoma, and essentially a disease of early life, is occasionally met with in connection with the retina.

The lens has no blood-vessels, nerves, or connective tissue in its structure, and therefore is not subject to those morbid changes to which tissues containing these structures are liable. It does, however, present certain morbid or abnormal conditions of various kinds. Thus, variations in shape, absence of the whole or a part of the lens, and displacements are amongst its congenital defects. Opacities may occur from injury, senile changes, malnutrition, or errors in growth or development. An opacity of the capsule, of the lens, or of both, is known as a cataract. Senile changes may take place in the lens, impairing its elasticity and rendering it harder than in youth, so that its curvature can only be altered to a limited extent by the Ciliary muscle. And, finally, the lens may be dislocated or displaced by blows upon the eyeball, and its relations to surrounding structures altered by adhesions or the pressure of new growths.

There are two particular regions of the eye which require special notice: one of these is known as the "filtration area," and the other as the "dangerous area." The filtration area is the circumcorneal zone immediately in front of the iris. Here are situated the cavernous spaces of Fontana, which communicate with the canal of Schlemm, through which the chief transudation of fluid from the eye is now believed to take place. The dangerous area of the eye is the region in the neighborhood of the ciliary body, and wounds or injuries in this situation are peculiarly dangerous; for inflammation of the ciliary body is liable to spread to many of the other structures of the eye, especially to the iris and choroid, which are intimately connected by nervous and vascular supplies. Moreover, wounds which involve the ciliary region are especially liable to be followed by sympathetic ophthalmia, in which destructive inflammation of one eye is excited by some irritation in the other.

Emmetropia is normal vision. In normal vision the practically parallel light rays from distant objects focus on the retina without effort; divergent rays from near objects are focused on the retina by an effort of accommodation.

Hyperopia or hypermetropia is far-sightedness. In this condition the retina is in front of the principal focus when the eye is at rest. The patient endeavors to correct the failure by constant and tiresome efforts at accommodation. The condition is usually due to inordinate shortness of the axis of the eye, but may be due to loss of the lens, decreased convexity of the refractive surfaces, or lessened refractive power in the refractive media of the eye. It is corrected by the use of convex glasses.
**Myopia** is near-sightedness. In this condition the rays of light come to a focus in front of the retina, and the patient is subjected to continued eye-strain. It is usually due to too great length of the axis of the eye, but may result from increase in refractive power of refractive media. It is corrected by concave glasses. Sometimes, as a person with hyperopia begins to age, an increased refractive power of the lens causes myopia. The occurrence of myopia in a hyperopic eye is called *second sight*, and it enables the individual to cease wearing convex glasses.

Exenteration of the contents of the orbit means removal of all the contents except those at the orbital apex. Even the periosteum is taken away. It is performed for malignant disease.

Excision of the eyeball is performed by making a circular incision at the corneal margin and removing the internal and middle coats and the contents of the globe. The sclera is not removed. A glass ball is inserted into the scleral sheath, and the sclera is closed over the ball by vertical stitches, and the conjunctiva is closed over it by transverse stitches. The operation is performed for leucoma or staphyloma of the cornea. An artificial eye (a shell) is placed over the stump when healing is complete.

Excision, or excision of the eyeball, differs from exenteration of the orbital contents in the fact that only the eyeball is removed. A circular incision through the ocular conjunctiva is carried around and near to the corneal margin. The conjunctiva and capsule of Ténon are pushed back and the Rectus muscles are clamped and divided back of the clamp. Traction is made upon the globe in a forward and inward direction, and the optic nerve and adjacent structures are cut with scissors from the outer aspect of the globe. The eye is then pulled out of the orbit, and all structures which tend to retain it are divided. The stumps of the Recti muscles are sewed together.

**THE APPENDAGES OF THE EYE (TUTAMINA OCULI).**

The appendages of the eye include the *eyebrows*, the *eyelids*, the *conjunctiva*, and the *lachrymal apparatus*—viz., the *lachrymal gland*, the *lachrymal sac*, and the *nasal duct*.

**The Eyebrow (Supercilium).**

The eyebrows are two arched eminences of integument which surmount the upper circumference of the orbit on each side, and support numerous short, thick hairs, directed obliquely on the surface. The hairs may entangle foreign bodies and lessen somewhat the force of blows. In structure the eyebrows consist of thickened integument, connected beneath with the Orbicularis palpebrarum, Corrugator supercilli, and Occipito-frontalis muscles. These muscles serve, by their action on this part, to control to a certain extent the amount of light admitted into the eye.

**The Eyelid (Palpebra) (Figs. 760, 761).**

The eyelids are two thin, movable folds placed in front of the eye, and by closure protecting the eye from injury. The eyelids are composed of skin, superficial fascia, and areolar tissue, fibres of the Orbicularis palpebrarum muscle, palpebral and orbito-tarsal ligaments, tarsal cartilages, and conjunctiva. The upper lid also contains the Levator palpebrae superioris muscle. In the lids are blood-vessels, lymph-vessels, nerves, and Meibomian glands. There are two lids, the *upper* (*palpebra superior*) and the *lower* (*palpebra inferior*). The upper lid is the larger and the more movable of the two, and is furnished with a separate elevator muscle, the *Levator palpebrae superioris*. Each lid consists of two portions. The part near the orbital margin, "whose groundwork is formed merely by the *thin palpebral fascia (septum orbitale)"", is called the *orbital portion* (*pars orbitalis*). The part in which the tarsus lies is called the *tarsal portion* (*pars tarsalis*). Between the two portions in each lid is a sulcus, called, in the upper lid, the *superior orbito-palpebral sulcus* (*sulcus orbitopalpebralis superior*), and, in the lower lid, the *inferior orbito-palpebral sulcus* (*sulcus orbitopalpebralis inferior*). When the eyelids are

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open an elliptical space, the **interpalpebral slit** (*fissura palpebrarum*), is left between their margins, the angles of which correspond to the junction of the upper and lower lids, and are called **canthi**.

**The Canthi.**—The *outer canthus* (*angulus oculi lateralis*) is more acute than the inner, and the lids here lie in close contact with the globe; but the *inner canthus* (*angulus oculi medialis*) is prolonged for a short distance inward toward the nose. The two lids are separated at the inner canthus by a triangular space, the **lacus lacrimalis**. At the commencement of the lacus lacrimalis, on the margin of each eyelid, is a small conical elevation, the **lachrymal papilla**, the apex of which is pierced by a small orifice, the **punctum lacrimale** (Fig. 764), the commencement of the lachrymal canal (Fig. 763). When the lids are closed a space remains between them and the globe to permit of the flow of tears inward (*rivus lacrimalis*).

**The Eyelashes** (*cilia*) (Fig. 761).—The eyelashes are attached to the free edges of the eyelids; they are short, thick, curved hairs, arranged in a double or triple row at the margin of the lids; those of the upper lid, more numerous and longer than the lower, curve upward; those of the lower lid curve downward. Because of this arrangement the two sets do not interlace in closing the lids. Near the attachment of the eyelashes are the openings of **sebaceous glands** (*glandulae sebaceae*) (Fig. 761) and of a number of glands, **glands of Moll** (*glandulae ciliares [Moll]*) (Fig. 761), arranged in several rows close to the free margin of the lid. They are regarded as enlarged and modified sweat-glands. On the inner surface are the **Meibomian glands** (Fig. 763). Internal to the openings of the lachrymal canaliculi there are neither lashes nor Meibomian glands.

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**Structure of the Eyelids** (Fig. 761).—The eyelids are composed of the following structures, taken in their order from without inward:

Integument, areolar tissue, fibres of the Orbicularis muscle, tarsal plate, and its ligament, Meibomian glands, and conjunctiva. The upper lid has, in addition, the aponeurosis of the Levator palpebrae.

The **integument** is extremely thin, and continuous at the margin of the lids with the conjunctiva.

The **subcutaneous areolar tissue** is very lax and delicate, seldom contains any fat, and is extremely liable to serous infiltration.

The **fibres of the Orbicularis muscle**, where they cover the palpebrae (*m. ciliaris [Rioland]*) , are thin, pale in color, and possess an involuntary action.
The tarsal plates are two thin elongated plates of dense connective tissue about an inch in length. They are placed one in each lid, contributing to their form and support.

The superior tarsal plate, superior tarsus or superior tarsal body (tarsus superior) (Fig. 760), the larger, is of a semilunar form, about one-third of an inch in breadth at the centre, and becoming gradually narrowed at each extremity. To the anterior surface of this plate the aponeurosis of the Levator palpebrae is attached.

The inferior tarsal plate, inferior tarsus or inferior tarsal body (tarsus inferior) (Fig. 760), the smaller of the two, is thinner and of an elliptical form.

The free or ciliary margin of these plates is thick, and presents a perfectly straight edge. The attached or orbital margin is connected to the circumference of the orbit by the fibrous membrane of the lids, with which it is continuous. The outer angle of each plate is attached to the malar bone by the external tarsal or external lateral ligament, or the external palpebral ligament or raphé (ligamentum palpebrale lateralis) (Fig. 760). The inner angles of the two plates terminate at the commencement of the lacus lacrimalis; they are attached to the nasal process of the superior maxilla by the internal tarsal or internal lateral or internal palpebral ligament or the tendo oculi (ligamentum palpebrale mediale) (Fig. 760).

The fibrous membrane of the lids constitutes the orbito-tarsal ligaments or the palpebral fasciae. In reality these so-called ligaments are fascial expansions situated one in each lid, and are attached marginally to the edge of the orbit, where they are continuous with the periosteum. The superior ligament blends with the tendon of the Levator palpebrae, the inferior with the inferior tarsal plate. Externally the superior and inferior ligaments fuse to form the external tarsal ligament or raphé just referred to; internally they are much thinner, and, becoming separated from the internal tarsal ligament, are fixed to the lachrymal bone immediately behind the lachrymal sac. Together the ligaments form an incomplete septum, the orbital septum (septum orbitale), which is perforated by the vessels and nerves which pass from the orbital cavity to the face and scalp.

The Meibomian or Tarsal Glands (glandulae tarsales [Meibomi]) (Figs. 761 and 763) — The Meibomian or tarsal glands are situated upon the inner surface of the eyelids between the tarsal plates and conjunctiva, and may be distinctly seen through the mucous membrane on evertting the eyelids, presenting the appearance of parallel strings of pearls. They are about thirty in number in the upper eyelid, and somewhat fewer in the lower. They are embedded in grooves in the inner
surface of the tarsal plates, and correspond in length with the breadth of each plate; they are, consequently, longer in the upper than in the lower eyelid. Their ducts open on the free margin of the lids by minute foramina, which correspond in number to the follicles. The use of their secretion is to prevent adhesions of the lids.

Structure of the Meibomian Glands.—These glands are a variety of the cutaneous sebaceous glands, each consisting of a single straight tube or follicle, having a caecal termination, and with numerous small secondary follicles opening into it. The tubes consist of basement-membrane, lined at the mouths of the tubes by stratified epithelium; the deeper parts of the tubes and the secondary follicles are lined by a layer of polyhedral cells. They are thus identical in structure with the sebaceous glands.

The Conjunctiva (Figs. 727, 728, 740, 762).

The conjunctiva is the mucous membrane of the eye. It lines the inner surface of the eyelids, is reflected over the forepart of the sclerotic and cornea, and joins the lids to the eyeball. In each of these situations its structure presents some peculiarities.

The Palpebral Portion (tunica conjunctiva palpebrarum) (Fig. 763).—The palpebral portion of the conjunctiva lines the posterior surface of the lids. It is thick, opaque, highly vascular, and covered with numerous papillae, its deeper parts presenting a considerable amount of lymphoid tissue. At the margin of the lids it becomes continuous with the lining membrane of the ducts of the Meibomian glands, and, through the lachrymal canals, with the lining membrane of the lachrymal sac and nasal duct. At the outer angle of the upper lid the lachrymal ducts open on its free surface; and at the inner angle of the eye it forms a semi-lunar fold, the plica semilunaris (plica semilunaris conjunctiva) (Fig. 764). The folds formed by the reflection of the conjunctiva from the lids on to the eye are called the superior and inferior palpebral folds, the former being the deeper of the two. These folds form the superior and inferior conjunctival fornix (Fig. 762).

The Bulbar Portion (tunica conjunctiva bulbi).—Upon the sclerotic the conjunctiva is loosely connected to the globe; it becomes thinner, loses its papillary structure, is transparent, and only slightly vascular in health. Upon the cornea the conjunctiva consists only of epithelium, constituting the anterior layer of the cornea (conjunctival epithelium) already described (p. 1119). Lymphatics arise in the conjunctiva in a delicate zone around the cornea, from which the vessels run to the ocular conjunctiva.

Fornix of Conjunctiva. — At the point of reflection of each fold of the conjunctiva from the lid on to the globe of the eye a pocket or arch is formed. These arches are termed the fornix conjunctivae (Fig. 762).

Glands of Conjunctiva.—In the conjunctiva there are a number of mucous glands which are much convoluted. They are chiefly found in the upper lid. Other glands, analogous to lymphoid follicles, and called by Henle *trachoma glands*, are found in the conjunctiva, and, according to Stromeeyer, are chiefly situated near the inner canthus of the eye. They were first described by Brush, in his description of Peyer's patches of the small intestines, as "identical structures existing in the under eyelid of the ox."

The Nerves of the Conjunctiva. — The nerves in the conjunctiva are numerous and form rich plexuses. According to Krause, they terminate in a peculiar form of tactile corpuscle, which he terms the *terminal bulb*.

The Caruncula Lacrimalis.—The caruncula lacrimalis is a small, reddish, conical-shaped body, situated at the inner canthus of the eye, and filling up the small
triangular space in this situation, the lacus lacrimalis. It consists of an island of skin containing sebaceous and sweat-glands, and is the source of the whitish secretion which constantly collects at the inner angle of the eye. A few slender hairs are attached to its surface. On the outer side of the caruncula is a slight semilunar fold of conjunctiva, the concavity of which is directed toward the cornea; it is called the plica semilunaris (Fig. 764). Müller found smooth muscular fibres in this fold, and in some of the domesticated animals a thin plate of cartilage has been discovered. This structure is considered to be the rudiment of the third eyelid in birds, the membrana nictitans.

**The Lachrymal Apparatus (Apparatus Lacrimaïis)** (Figs. 763, 764).

The lachrymal apparatus consists of the lachrymal gland, which secretes the tears, and its excretory ducts, which convey the fluid to the surface of the eye. This fluid is carried away by the lachrymal canals into the lachrymal sac, and along the nasal duct into the cavity of the nose.

**The Lachrymal Glands** (glandula lacrimalis).—The lachrymal gland is lodged in a depression at the outer angle of the orbit, on the inner side of the external angular process of the frontal bone. It is of an oval form, about the size and shape of an almond. Its upper convex surface is in contact with the periosteum of the orbit, to which it is connected by a few fibrous bands. Its under concave surface rests upon the convexity of the eyeball and upon the Superior and External recti muscles. Its vessels and nerves enter its posterior border, whilst its anterior margin is closely adherent to the back part of the upper eyelid, where it is covered to a slight extent by the reflection of the conjunctiva. The forepart of the gland is separated from the rest by a fibrous septum; hence it is sometimes described as a separate lobe, called the inferior lachrymal gland, palpebral portion of the gland, or the accessory gland of Rosenmuller (glandula lacrimalis inferior), the back part of the gland then being called the superior lachrymal gland (glandula lacrimalis superior). The ducts of the lachrymal gland, from six to twelve in number, run obliquely beneath the mucous membrane for a short distance, and, separating from each other, open by a series of minute orifices on the upper and outer half of the conjunctiva near its reflection on to the globe. These orifices are arranged in a row, so as to disperse the secretion over the surface of the membrane.

**Structure of the Lachrymal Gland.**—In structure and general appearance the lachrymal resembles the serous salivary glands. In the recent state the cells are so
crowded with granules that their limits can hardly be defined. Each cell contains an oval nucleus, and the cell-protoplasm is finely fibrillated.

The Lachrymal Canaliculi or Canals (Fig. 764) commence at the minute orifices, puncta lacrimalia, on the summit of a small conical elevation, the lachrymal papilla or caruncle (carunculus lacrimalis), seen on the margin of the lids at the outer extremity of the lacus lacrimalis. The superior canal (ductus lacrimalis superior), the smaller and shorter of the two, at first ascends, and then bends at an acute angle, and passes inward and downward to the ampulla. The inferior canal (ductus lacrimalis inferior) at first descends, and then, abruptly changing its course, passes almost horizontally inward to the ampulla. These canals are dense and elastic in structure and somewhat dilated at their angle. The mucous membrane is covered with scaly epithelium. The two canals join in a dilatation, the ampulla (ampulla ductus lacrimalis), which empties into the lachrymal sac.

The Lachrymal Sac (saccus lacrimalis) (Fig. 764).—The lachrymal sac is the upper dilated extremity of the nasal duct, and is lodged in a deep groove formed by the lachrymal bone and the nasal process of the superior maxillary bone. It is oval in form, its upper extremity being closed in and rounded, whilst below it is continued into the nasal duct. It is covered by a fibrous expansion derived from the tendo oculi, and on its deep surface it is crossed by the Tensor tarsi muscle (Horner’s muscle, p. 373), which is attached to the ridge on the lachrymal bone.

Structure.—It consists of a fibrous elastic coat, lined internally by mucous membrane, the latter being continuous, through the ampulla and lachrymal canals, with the mucous lining of the conjunctiva, and, through the nasal duct, with the pituitary membrane of the nose.

The Nasal Duct (ductus nasolacrimalis) (Fig. 764).—The nasal duct is a membranous canal, about three-quarters of an inch in length, which extends from the lower part of the lachrymal sac to the inferior meatus of the nose, where it terminates by a somewhat expanded orifice, provided with an imperfect valve, the valve of Hasner (plica lacrimalis [Hasneri]), formed by the mucous membrane. It is contained in an osseous canal formed by the superior maxillary, the lachrymal, and the inferior turbinated bones, is narrower in the middle than at each extremity, and takes a direction downward, backward, and a little outward. It is lined by mucous membrane, which is continuous below with the pituitary lining of the nose. The membrane in the lachrymal sac and nasal duct is covered with columnar epithelium, as in the nose. This epithelium is in places ciliated.

Surface Form.—The palpebral fissure, or opening between the eyelids, is elliptical in shape, and differs in size in different individuals and in different races of mankind. In the Mongolian races, for instance, the opening is very small, merely a narrow fissure, and this makes the eyeball appear small in these races, whereas the size of the eye is relatively very constant. The normal direction of the fissure is slightly oblique, in a direction upward and outward, so that the outer angle is on a slightly higher level than the inner. This is especially noticeable in the Mongolian races, in whom, owing to the upward projection of the malar bone and the shortness of the external angular process of the frontal bone, the tarsal plate of the upper lid is raised at its outer part and gives an oblique direction to the palpebral fissure.
When the eyes are directed forward, as in ordinary vision, the upper part of the cornea is covered by the upper lid, and the lower margin of the cornea corresponds to the level of the lower lid, so that about the lower three-fourths of the cornea is exposed under ordinary circumstances. On the margins of the lids, about a quarter of an inch from the inner canthus, are two small openings, the puncta lachrymalis, the commencement of the lachrymal canals. They are best seen by exerting the eyelids. In the natural condition they are in contact with the conjunctiva of the eyeball, and are maintained in this position by the Tensor tarsi muscle, so that the tears running over the surface of the globe easily find their way into the lachrymal canals. The position of the lachrymal sac into which the canals open is indicated by a little tubercle, which is plainly to be felt on the lower margin of the orbit. The lachrymal sac lies immediately above and to the inner side of this tubercle, and a knife passed through the skin in this situation would open the cavity. The position of the lachrymal sac may also be indicated by the tendo oculi or internal tarsal ligament. If both lids be drawn outward, so as to tense the skin at the inner angle, a prominent cord will be seen beneath the thickened skin. This is the tendo oculi, which lies immediately over the lachrymal sac, bisecting it, and thus forming a useful guide to its situation. A knife entered immediately beneath the tense cord would open the lower part of the sac. A probe introduced through this opening can be readily passed downward through the duct into the inferior meatus of the nose. The direction of the duct is downward, outward, and backward, and this course should be borne in mind in passing the probe, otherwise the point may be driven through the thin bony walls of the canal. A convenient plan is to direct the probe in such a manner that if it were pushed onward it would strike the first molar tooth of the lower jaw on the same side of the body. In other words, the surgeon standing in front of his patient should carry in his mind the position of the first molar tooth, and should push his probe onward in such a way as if he desired to reach this structure.

Beneath the internal angular process of the frontal bone the pulley of the Superior oblique muscle of the eye can be plainly felt by pushing the finger backward between the upper and inner angle of the eye and the roof of the orbit; passing backward and outward from this pulley, the tendon can be felt for a short distance.

Surgical Anatomy.—The eyelids are composed of various tissues, and consequently are liable to a variety of diseases. The skin which covers them is exceedingly thin and delicate, and is supported on a quantity of loose and lax subeutaneous tissue which contains no fat. In consequence of this it is very freely movable, and is liable to be drawn down by the contraction of neighboring cicatrices. Such contractions may produce an elision of the lid known as ectropion. Inversion of the lids (entropion) from spasm of the Orbicularis palpbralorum or from chronic inflammation of the palpebral conjunctiva may also occur. In some individuals there is an extra row of eyelashes on the inner margin of the lid, directed toward the cornea (distichiasis). Trichiasis is a condition in which the lashes are directed toward the eye, but there is not inversion of the lid. The eyelids are richly supplied with blood, and are often the seat of vascular growths, such as navi. Rodent ulcer also frequently commences in this situation. The loose cellular tissue beneath the skin is liable to become extensively infiltrated either with blood or inflammatory products, producing very great swelling. Even from very slight injuries to this tissue the extravasation of blood may be so great as to produce considerable swelling of the lids and complete closure of the eye, and the same is the case when inflammatory products are poured out. The follicles are liable to become inflamed, constituting the disease known as marginal blepharitis, blepharitis ciliaris, or "blear-eye." Irregular or disorderly growth of the eyelashes not frequently occurs, some of them being turned toward the eyeball and producing inflammation and follicles of the eyelashes or the sebaceous glands associated with these follicles may be the seat of inflammation, constituting the ordinary hordeolum or "sty." The Meibomian glands are affected in the so-called "tarsal tumors," the tumor, according to some, being caused by the retained secretion of these glands; by others it is believed to be a neoplasm connected with the gland. The Orbicularis palpbralorum may be the seat of spasm (blepharospasm), either in the form of slight quivering of the lids or repeated twitchings, most commonly due to errors of refraction in children, or more continuous spasm, due to some irritation of the fifth or seventh cranial nerves. The Orbicularis may be paralyzed, generally associated with paralysis of the other facial muscles. Under these circumstances the patient is unable to close the lids, and if he attempts to do so, rolls the eyeball upward under the upper lid. The tears overflow from displacement of the lower lid, and the conjunctiva and cornea, being constantly exposed and the patient being unable to wink, become irritated from dust and foreign bodies. As a result there may be ulceration of the cornea, and possibly eventually complete destruction of the eye. In paralysis of the Levator palpbrae superioris there is drooping of the upper eyelid (ptosis) and other symptoms of implication of the third nerve. The eyelids may be the seat of bruises, wounds, or burns. After wounds or burns adhesions of the margins of the lids to each other or adhesion of the lids to the globe may take place. The eyelids are sometimes the seat of emphysema after fracture of some of the thin bones forming the inner wall of the orbit. If shortly after such an injury the patient blows his nose, air is forced from the nostrils through the lacerated structure into the
connective tissue of the eyelids, which suddenly swell up and present the peculiar crackling on pressure which is characteristic of this affection.

Foreign bodies frequently get into the conjunctival sac and cause great pain, especially if they come in contact with the corneal surface, during the movements of the lid and the eye on each other. The conjunctiva is frequently involved in severe injuries of the eyeball, but is seldom ruptured alone; the most common form of injury to the conjunctiva alone is from a burn, either from fire, strong acids, or lime. In these cases union is liable to take place between the eyelid and the eyeball. The conjunctiva is often the seat of inflammation arising from many different causes, and the arrangement of the conjunctival vessels should be remembered as affording a means of diagnosis between this condition and injection of the sclerotic, which is present in inflammation of the deeper structures of the globe. The inflamed conjunctiva is bright red; the vessels are large and tortuous, and greatest at the circumference, shading off toward the corneal margin; they anastomose freely and form a dense network, and they can be emptied by gentle pressure.

The lacrimal gland is occasionally, though rarely, the seat of inflammation (dacyroadenitis), either acute or chronic; it is also sometimes the seat of tumors, benign or malignant, and for these may require removal. This may be done by an incision through the skin just below the eyebrow; and the gland, being invested with a special capsule of its own, may be isolated and removed without opening the general cavity of the orbit. The canaliculi may be obstructed, either as a congenital defect or by some foreign body, as an eyelash or a dacryolith, causing the tears to run over the cheek. The canaliculi may also become occluded as the result of burns or injury; overflow of tears may in addition result from deviation of the puncta or from chronic inflammation of the lacrimal sac. When there is failure of the lacrimal tubes to drain off the tears and the fluid gathers beneath and flows over the lids, the condition is known as epiphora or stilićidium. This latter condition is set up by some obstruction to the nasal duct frequently occurring in tuberculous subjects. In consequence of this the tears and mucus accumulate in the lacrimal sac, distending it. Suppuration in the lacrimal sac (dacyrocytitis) is sometimes met with; this may be the sequel of a chronic inflammation; or may occur after some of the eruptive fevers in cases where the lacrimal passages were previously quite healthy. It may lead to lacrimal fistula.

THE EAR (ORGANON AUDITUS).

The organ of hearing is divisible into three parts—the external ear, the middle ear or tympanum, and the internal ear or labyrinth.

THE EXTERNAL EAR (AURIS EXTERNA).

The external ear consists of an expanded portion named pinna or auricle, and the auditory canal or meatus. The former serves to collect the vibrations of the air by which sound is produced; the latter conducts those vibrations to the tympanum.

The Pinna or Auricle (Auricula) (Fig. 765).

The pinna or auricle is attached to the side of the head midway between the forehead and occiput. "Its level is indicated by horizontal lines extending backward from the eyebrows above and from the tip of the nose below." (Hensman.) It is of an ovoid form, with its larger end directed upward. Its outer surface is irregularly concave, directed slightly forward. The angle which it bears to the head is called the cephalo-auricular angle. In some cases this angle is almost absent. In others it is nearly a right angle. The pinna of one side may vary in size, shape, and angle from the pinna of the other side. The pinna of a woman is apt to be smaller than that of a man, and is less often deformed. The outer surface of the pinna presents numerous eminences and depressions which result from the foldings of its fibro-cartilaginous element. To each of these, names have been assigned. Thus the external prominent rim of the auricle is called the helix. Another curved prominence, parallel with and in front of the helix, is called the antihelix; this bifurcates above and forms the crus (crura antihelicis), which encloses a triangular depression, the fossa of the antihelix (fossa triangularis [auriculae]). The narrow curved depression between the helix and antihelix is called the fossa of the helix or the scaphoid
fossa (scapha); the antihelix describes a curve around a deep, capacious cavity, the concha auriculae, which is partially divided into two parts by the crus of the helix (crus helicis), or the commencement of the helix; the upper part is termed the cymba-

conchae, the lower part the cavum conchae. In front of the concha, and projecting backward over the meatus, is a small pointed eminence, the tragus, so called from its being generally covered on its under surface with a tuft of hair resembling a goat's beard. Opposite the tragus, and separated from it by a deep notch (incisura intertragica), is a small tubercle, the antitragus. Below this is the lobule (lobulus auriculae), composed of tough areolar and adipose tissue, wanting the firmness and elasticity of the rest of the pinna. Sometimes the lobule does not hang freely, but is adherent. Where the helix turns downward a small tubercle, tubercle of Darwin (tuberculum auriculae [Darwini]), is frequently seen. This tubercle is very evident about the sixth month of foetal life; at this stage the human pinna has a close resemblance to that of some of the adult monkeys.
The cranial surface of the pinna presents elevations which correspond to the depressions on its outer surface and after which they are named, e.g., eminentia conchae, eminentia fossae triangularis, etc.

The eminentia conchae and the fossae triangularis are separated by a furrow (sulcus antihelicis transversus), which corresponds to the inferior crus of the antihelix, or groove (sulcus cruris helicis), and upon the eminence there is a vertical ridge, the ponticus, which indicates the point of insertion of the Retrahens auriculam muscle.

**Structure of the Pinna.**—The pinna is composed of a thin plate of yellow fibro-cartilage, covered with integument, and connected to the surrounding parts by the extrinsic ligaments and muscles, and to the commencement of the external auditory canal by fibrous tissue.

**The Integument.**—The integument is thin, closely adherent to the cartilage, and covered with hairs furnished with sebaceous glands, which are most numerous in the concha and scaphoid fossa. The hairs are most numerous and largest on the tragus and antitragus.

**The Cartilage of the Pinna** (cartilago auriculare) (Fig. 767).—The cartilage of the pinna consists of one single piece; it gives form to this part of the ear, and upon its surface are found all the eminences and depressions above described. It does not enter into the construction of all parts of the auricle; thus it does not form a constituent part of the lobule; it is deficient also between the lamina of the tragus and beginning of the crus helix, the notch between (incisura terminalis auris) them being filled up by dense fibrous tissue. At the front part of the pinna, where the helix bends upward, is a small projection of cartilage, called the spine of the helix (spina helicis), while the lower part of the helix is prolonged downward as a tail-like process, the cauda helicis; this is separated from the antihelix by a fissure, the fissura antitragohelicina. The fissures of Santorini are usually two in number: one in the substance of the tragus, which partially separates the different parts, and one in the cartilage of the meatus. The fissure of the helix is a short vertical slit, situated at the forepart of the pinna. Another fissure, the fissure of the tragus, is seen upon the anterior surface of the tragus. Anteriorly and inferiorly the cartilage of the pinna is continuous with the cartilage of the external auditory meatus by a cartilaginous isthmus (isthmus cartilaginis auris). Some authors regard the tragus as part of the cartilage of the meatus. The cartilage of the pinna is very pliable, elastic, of a yellowish color and belongs to that form of cartilage which is known under the name of yellow fibro-cartilage.

**The Ligaments of the Pinna** (ligamenti auriculare [Valsalvæ]).—The ligaments of the pinna consist of two sets: 1. The extrinsic set, or those connecting it to the side of the head. 2. The intrinsic set, or those connecting the various parts of its cartilage together.

The Extrinsic Ligaments, the most important, are three in number: superior, anterior, and posterior. The superior ligament (ligamentum auriculare superioris) extends from the suprameatal spine to the spine of the helix. The anterior ligament (ligamentum auriculare anterius) extends from the spina helicis and tragus to the
root of the zygoma. The posterior ligament (ligamentum auriculare posterius) passes from the posterior surface of the concha to the outer surface of the mastoid process of the temporal bone.

The chief Intrinsic Ligaments are: (1) a strong fibrous band, stretching across from the tragus to the commencement of the helix, completing the meatus in front, and partly encircling the boundary of the concha; and (2) a band which extends between the antihelix and the cauda helicis. Other less important bands are found on the cranial surface of the pinna.

The Muscles of the Pinna (Figs. 766 and 768).—The muscles of the pinna consist of two sets: 1. The extrinsic, which connect it with the side of the head, moving the pinna as a whole—viz., the Attollens, Attrahens, and Retrahens auriculam (p. 372). 2. The intrinsic, which extend from one part of the auricle to another, viz.:

- Helicis major
- Helicis minor
- Tragicus
- Antitragicus
- Transversus auriculae
- Obliquus auriculae

The Helicis Major (m. helicis major) is a narrow vertical band of muscular fibres, situated upon the anterior margin of the helix. It arises, below, from the spina helicis, and is inserted into the anterior border of the helix, just where it is about to curve backward. It is pretty constant in its existence.

The Helicis Minor (m. helicis minor) is an oblique fasciculur which covers the crus helicis.

The Tragicus (m. tragicus) is a short, flattened band of muscular fibres situated upon the outer surface of the tragus, the direction of its fibres being vertical.

The Antitragicus (m. antitragicus) arises from the outer part of the antitragus; its fibres are inserted into the cauda helicis and antihelix. This muscle is usually very distinct.

The Transversus Auriculæ (m. transversus auriculæ) is placed on the cranial surface of the pinna. It consists of scattered fibres, partly tendinous and partly muscular, extending from the convexity of the concha to the prominence corresponding with the groove of the helix.

The Obliquus Auriculæ (Tod) (m. obliquus auriculæ) consists of a few fibres extending from the upper and back part of the concha to the convexity immediately above it.

The Arteries of the Pinna.—The arteries of the pinna are the posterior auricular from the external carotid, the anterior auricular from the temporal and an auricular branch from the occipital artery.

The Veins of the Pinna.—The veins of the pinna accompany the corresponding arteries.

The Lymphatics of the Pinna.—The lymphatics enter into the pre-auricular glands and the glands upon the Sterno-mastoid muscle at its insertion.
The Nerves of the Pinna.—The nerves of the pinna are: the great auricular, from the cervical plexus; the auricular branch of the vagus; the auriculo-temporal branch of the inferior maxillary nerve; the small occipital from the cervical plexus, and the great occipital or internal branch of the dorsal division of the second cervical nerve. The muscles of the pinna are supplied by the facial nerve.

The External Auditory or External Acoustic Canal or External Auditory Meatus (Meatus Acusticus Externus or Meatus Auditorius Externus).

The external auditory or acoustic canal or meatus extends from the bottom of the concha to the membrana tympani (Figs. 765, 769, and 770). It is about an inch and a half in length if measured from the tragus; from the bottom of the concha its length is about an inch. It forms a sort of S-shaped curve, and is directed at first inward, forward, and slightly upward (pars externa); it then passes inward and backward (pars media), and lastly is carried inward, forward, and slightly downward (pars interna). It forms an oval cylindrical canal, the greatest diameter being in the vertical direction at the external orifice, but in the transverse direction at the tympanic end. It presents two constrictions, one near the inner end of the cartilaginous portion, and another, the isthmus, in the osseous portion, about three-quarters of an inch from the bottom of the concha. The membrana tympani (Figs. 769 and 770), which occupies the termination of the meatus, is directed obliquely, in consequence of which the floor of the canal is longer than the roof, and the anterior wall longer than the posterior. The auditory canal is formed partly by cartilage and membrane, partly by bone, and is lined by perichondrium and periosteum, which is covered with skin.

The Cartilaginous Portion (meatus acusticus externus cartilagineus).—The cartilaginous portion is about one-third of an inch (8 mm.) in length; it is formed by the cartilage of the pinna, prolonged inward, and firmly attached to a greater portion of the circumference of the auditory process of the temporal bone. The cartilage is deficient at its upper and back part, its place being supplied by fibrous membrane. This part of the canal is rendered extremely movable by two or three deep fissures, the fissures of Santorini (incisurae cartilaginis meatus acustici externi [Santorini]), which extend through the cartilage in a vertical direction. It is firmly attached at its lower and front part to the middle root of the zygoma and to the lateral edge of the tympanic portion of the temporal bone.
The Osseous Portion (meatus acusticus externus osseus).—The osseous portion is about two-thirds of an inch (16 mm.) in length, and narrower than the cartilaginous portion. It is directed inward and a little forward, forming a slight curve in its course, the convexity of which is upward and backward. Its inner end, which communicates, in the dry bone, with the cavity of the tympanum, is smaller than the outer and sloped, the anterior wall projecting beyond the posterior about two lines; it is marked, except at its upper part, by a narrow groove, the tympanic sulcus (sulcus tympanicus), for the insertion of the membrana tympani. Its outer edge is dilated and rough in the greater part of its circumference, for the attachment of the cartilage of the pinna. Its vertical transverse section is oval, the greatest diameter being from above downward. The front and lower parts of this canal are formed by a curved plate of bone, which, in the foetus, exists as a separate ring (annulus tympanicus), incomplete at its upper part. (See Section on Osteology.)

The Skin of the Meatus.—The skin lining the meatus is a prolongation of the external skin; it is thin, adheres closely to the cartilaginous and osseous portions of the tube, and covers the surface of the membrana tympani, forming a very thin outer layer. After maceration the thin pouch of epidermis, when withdrawn, preserves the form of the meatus. In the thick subcutaneous tissue of the cartilaginous part of the meatus are numerous ceruminous glands (glandulae ceruminosae) which secrete the ear-wax. They resemble in structure sweat-glands, and their ducts open on the surface of the skin.

Relations of the Meatus.—In front of the osseous part is the glenoid fossa, which receives the condyle of the mandible (Fig. 762), which, however, is separated from the cartilaginous part by the retromandibular part of the parotid gland. The movements of the jaw influence to some extent the lumen of the cartilaginous portion. Behind the osseous part are the mastoid air-cells (cellulae mastoideae), separated from it by a thin layer of bone (Fig. 46).

The Arteries of the External Meatus.—The arteries supplying the external meatus are branches from the posterior auricular, internal maxillary, and superficial temporal.
The Veins of the External Meatus.—Veins accompany the corresponding arteries and pass to the internal maxillary, temporal, and posterior auricular veins.

The Lymphatics of the External Meatus.—The lymphatics accompany the veins and enter the parotid and posterior auricular lymph-glands.

The Nerves of the External Meatus.—The nerves are derived from the auriculotemporal branch of the inferior maxillary nerve, the auriculotemporalis magnus, and the auricular branch of the vagus.

Surface Form.—The point of junction of the osseous and cartilaginous portions of the tube is an obtuse angle, which projects into the canal at its antero-inferior wall. This produces a sort of constriction in this situation, and renders it the narrowest portion of the canal—an important point to be borne in mind in connection with the presence of foreign bodies in the ear. The cartilaginous is connected to the bony part by fibrous tissue, which renders the outer part of the tube very movable, and therefore by drawing the pinna upward and backward the canal is rendered almost straight. At the external orifice are a few short, crisp hairs which serve to prevent the entrance of small particles of dust, flies or other insects. In the external auditory meatus the secretion of the ceruminous glands serves to catch any small particles which may find their way into the canal, and prevent their reaching the membrana tympani, where their presence might excite irritation. In young children the meatus is short, the osseous part being very deficient, and consisting merely of a bony ring (annulus tympanicus), which supports the membrana tympani. In the fetus the osseous part is entirely absent. The shortness of the canal in children should be borne in mind in introducing the aural speculum, so that it shall not be pushed in too far, at the risk of injuring the membrana tympani; indeed, even in the adult the speculum should never be introduced beyond the constriction which marks the junction of the osseous and cartilaginous portions. In using this instrument it is advisable that the pinna should be drawn upward, backward, and a little outward, so as to render the canal as straight as possible, and thus assist the operator in obtaining, by the aid of reflected light, a good view of the membrana tympani. Just in front of the membrane is a well-marked depression, situated on the floor of the canal and bounded by a somewhat prominent ridge; in this foreign bodies may become lodged. By aid of the speculum, combined with traction of the auricle upward and backward, the whole of the membrana tympani is rendered visible. It is a pearly-gray membrane, slightly glistening in the adult, placed obliquely, so as to form with the floor of the meatus a very acute angle (about 55 degrees), while with the roof it forms an obtuse angle. At birth it is more horizontal—being situated in almost the same plane as the base of the skull. About midway between the anterior and posterior margins of the membrane, and extending from the centre obliquely upward, is a reddish-yellow streak; this is the handle of the malleus, which is inserted into the membrane (Fig. 773). At the upper part of this streak, close to the roof of the meatus, a little white rounded prominence is plainly to be seen; this is the processus brevis of the malleus, projecting against the membrane. The membrana tympani does not present a plane surface; on the contrary, its centre is drawn inward, on account of its connection with the handle of the malleus, and thus the external surface is rendered concave.

**THE MIDDLE EAR, DRUM OR TYMPANUM (AURIS MEDIA)**

(Figs. 769, 770, 771, 775).

The middle ear or tympanum is an irregular cavity, compressed from without inward, and is situated within the petrous portion of the temporal bone. It is placed above the jugular fossa; the carotid canal lying in front, the mastoid cells behind, the external auditory meatus externally, and the labyrinth internally. It is lined with mucous membrane, is filled with air, and communicates with the mastoid cells, and with the naso-pharynx by the Eustachian tube. The tympanum is traversed by a chain of movable bones, which connect the membrana tympani with the labyrinth, and serve to convey the vibrations communicated to the membrana tympani across the cavity of the tympanum to the internal ear. In shape it is roughly biconcave, the concave surfaces being placed vertically and forming the external and internal walls. The cavity forms an angle of 45 degrees with the median plane (Spalteholz).

The Tympanic Cavity (cavum tympani) (Figs. 775 and 776).—The tympanic cavity consists of two parts: the atrium or tympanic cavity proper (Fig. 776), opposite the tympanic membrane, and the attic or epitympanic recess or aditus ad antrum (recessus epitympanicus) (Figs. 774 and 775), above the level of the
upper part of the membrane; the latter contains the upper half of the malleus and the greater part of the incus. The diameter of the tympanic cavity, including the attic, measures about \( \frac{3}{8} \) inch (15 mm.) vertically and transversely. From without inward it measures about \( \frac{1}{4} \) inch (6 mm.) above and \( \frac{1}{4} \) inch (4 mm.) below; opposite the centre of the tympanic membrane it is only about \( \frac{1}{10} \) inch (2 mm.). It is bounded externally by the membrana tympani and neatus; internally, by the outer surface of the internal ear; and communicates behind with the mastoid antrum and through it with the mastoid cells; and in front with the Eustachian tube and canal for the Tensor tympani. Its roof and floor are formed by thin osseous laminae, the one forming the roof being a thin plate situated on the anterior surface of the petrous portion of the temporal bone, close to its angle of junction with the squamous portion of the same bone.

The Roof of the Tympanum (paries tegmental).—The roof of the tympanum is broad, flattened, and formed of a thin plate of bone (tegmen tympani) (Fig. 775), which separates the cranial and tympanic cavities. It is prolonged backward so as to roof in the mastoid antrum; it is also carried forward to cover in the canal for the Tensor tympani muscle.

The Floor (paries jugularis) (Fig. 775).—The floor is narrow, and is separated by a thin plate of bone (fondus tympani) from the jugular fossa. It frequently presents numerous small notches in the bone (cellulae tympanicae). There is one small aperture in the floor. It is near the inner wall and is the opening of the canaliculus tympanicus, for the transmission of Jacobson’s nerve (n. tympanicus). On the floor near the posterior wall there is often to be found a slight bony projection (prominentia styloidea).

The Outer Wall (Fig. 770).—The outer wall is formed mainly by the membrana tympani, partly by the ring of bone into which this membrane is inserted. This part formed by the membrana tympanum is called the paries membranaceus. This ring of bone is incomplete at its upper part, forming a notch, the notch of Rivinus (incisura tympanica [Rivini]) (Fig. 773). The anterior edge of the notch is known as the spina tympanica major, the posterior edge as the spina tympanica minor. The groove for the reception of the membrana tympani is the sulcus tympanicus. Close to the notch are three small apertures: the iter chordae posterior, the Glaserian fissure, and the iter chordae anterius.

The iter chordae posterior or the tympanic aperture (canaliculus chordae tympani) (Fig. 774) is in the angle of junction between the posterior and external walls of the tympanum, immediately behind the membrana tympani and on a level with the upper end of the handle of the malleus; it leads into a minute canal, which descends
in front of the aquaeductus Fallopii, and terminates in the aqueduct near the stylomastoid foramen. Through it the chorda tympani nerve enters the tympanum.

The Glaserian or petro-tympanic fissure (fissura petrotympanica [Glaseri]) (Fig. 774) opens just above and in front of the ring of bone into which the membrana tympani is inserted; in this situation it is a mere slit about a line in length. It lodges the long process and anterior ligament of the malleus, and gives passage to the tympanic branch of the internal maxillary artery.

The iter chordae anterius (Fig. 774) is seen at the inner end of the preceding fissure; it leads into a canal, the canal of Huguer, which runs parallel with the Glaserian fissure. Through it the chorda tympani nerve leaves the tympanum.

The outer wall bounds the epitympanic recess externally.

The Internal Wall of the Tympanum (paries labyrinthica) (Figs. 771 and 775).—The internal wall of the tympanum is adjacent to the labyrinth, is vertical in direction, and looks directly outward. It presents for examination the following parts:

Fenestra ovalis. Promontory.
Fenestra rotunda. Ridge of the aquaeductus Fallopii.
Prominence of the external semicircular canal.

The Fenestra Ovalis, the Oval or the Vestibular Window (fenestra vestibuli) (Fig. 771) is a reniform opening leading from the tympanum into the vestibule. It is situated in the depths of a fossa (fossula fenestrae vestibuli). Its long diameter is directed horizontally, and its convex border is upward. The opening in the recent state is occupied by the base of the stapes (Figs. 770 and 776), which is connected to the margin of the foramen by an annular ligament.

The Fenestra Rotunda, the Round or Cochlear Window (fenestra cochleae) (Fig. 771), is an aperture placed at the bottom of a funnel-shaped depression (fossula fenestrae cochleae) leading into the cochlea. It is situated below and rather behind the fenestra ovalis, from which it is separated by a rounded elevation, the promontory; at its border is a narrow ridge of bone (crista fenestrae cochleae), which is closed in the recent state by a membrane, the membrane of Scarpa or the secondary ear-drum membrane (membrana tympani secundaria). This membrane is concave toward the tympanum, convex toward the cochlea. It consists of three layers: the external or mucous, derived from the mucous lining of the tympanum; the internal, from the lining membrane of the cochlea; and an intermediate or fibrous layer.

The Promontory (promontorium) (Fig. 775) is a rounded hollow prominence, formed by the projection outward of the first turn of the cochlea; it is placed between the fenestrae, and is furrowed on its surface (sulcus promontorii) for the lodgement of the tympanic plexus. A minute spicule of bone frequently connects the promontory to the pyramid.

The Rounded Eminence of the Aquaeductus Fallopii (prominentia canalis facialis) (Fig. 775), the prominence of the bony canal in which the facial nerve is contained, traverses the inner wall of the tympanum above the fenestra ovalis, and behind that opening curves nearly vertically downward along the posterior wall.

Just above the eminence of the aquaeductus Fallopii the wall is bulged by the external semicircular canal (prominentia canalis semicircularis lateralis).

The Posterior Wall of the Tympanum (paries mastoidea) (Fig. 775).—The posterior wall of the tympanum is wider above than below, and the lower portion of the posterior wall contains many tympanic cells. The posterior wall presents for examination the—

Opening of the antrum. Prominentia styloideae.
Fossa incudis. Pyramid.
Apertura tympanica canaliculi chordae.
The Opening of the Antrum is a large irregular aperture, which extends backward from the epitympanic recess and leads into a considerable air space, the mastoid antrum (antrum tympanicum), which is the entrance to the mastoid cells (p. 87). The antrum communicates with large irregular cavities contained in the interior of the mastoid process, the mastoid air-cells. These cavities vary considerably in number, size, and form; they are lined by mucous membrane continuous with that lining the cavity of the tympanum.

The Fossa Incudis (Fig 775) is placed in the posterior and inferior part of the epitympanic recess. It lodges the short process of the incus.

The Prominentia Styloideae is sometimes seen below the aperture tympanica canaliculi chordae. It is a prominence produced by a prolongation of the styloid process.

The Pyramid (eminentia pyramidalis) (Fig. 771) is a conical eminence situated immediately behind the fenestra ovalis, and in front of the vertical portion of the eminence above described; it is hollow in the interior, and contains the Stapedius muscle; its summit projects forward toward the fenestra ovalis, and presents a small aperture which transmits the tendon of the muscle. The cavity in the pyramid is prolonged into a minute canal, which communicates with the aquaeductus Fallopii and transmits the nerve which supplies the Stapedius.

The Apertura Tympanica Canaliculi Chordae is just back of the posterior edge of the tympanic membrane, nearly level with the superior end of the manubrium mallei.

The Anterior Wall of the Tympanum (partes carotica).—The anterior wall of the tympanum is bony on its lower portion. Its upper part is the tympanic opening of the Eustachian tube. The long anterior wall contains tympanic cells. The anterior wall is wider above than below; it corresponds with the carotid canal, from which it is separated by a thin plate of bone (Fig. 775), perforated by the canaliculi caroticotympanici, which transmit the tympanic branch of the internal carotid artery and the carotico-tympanic nerves. It presents for examination the—

Canal for the Tensor tympani. Orifice of the Eustachian tube.

The processus cochleariformis.

The orifice of the canal for the Tensor tympani and the orifice of the Eustachian tube are situated at the upper part of the anterior wall, being incompletely separated from each other by a thin, delicate, horizontal plate of bone, the processus cochleariformis (septum canalis musculotubarius) (Figs. 49 and 771). The canalis musculotubarius is divided by this long process into the canal for the Tensor tympani and the canal for the Eustachian tube. These canals run from the tympanum forward, inward, and a little downward, to the retiring angle between the squamous and petrous portions of the temporal bone.

The Canal for the Tensor Tympani (semicanalis m. tensoris tympani) (Figs. 49, 771, and 775) is the superior and the smaller of the two; it is rounded and lies beneath the forward prolongation of the tegmen tympani. It extends on to the inner wall of the tympanum and ends immediately above the fenestra ovalis. The processus cochleariformis passes backward below this part of the canal, forming its outer wall and floor; it expands above the anterior extremity of the fenestra ovalis and terminates by curving outward so as to form a pulley over which the tendon passes. The bony wall of this canal is incomplete, and the osseous vacancy is filled by tough connective tissue.

The Eustachian Tube or Ear Trumpet (tuba auditiva [Eustachii]) (Figs. 49, 771, and 772) is the channel through which the tympanum communicates with the pharynx. Its length is an inch and a half (36 mm.), and its direction downward, inward, and forward, forming an angle of about 45 degrees with the sagittal plane and one of from 30 to 40 degrees with the horizontal plane.
The canal for the Eustachian tube (semicanalis tubae auditivae) (Fig. 772) is formed partly of bone, partly of cartilage and fibrous tissue.

The Osseous Portion (pars ossea tubae auditivae or semicanalis tubae auditivae) is about half an inch in length. It is the outer portion of the tube. It commences in the anterior wall of the tympanum, below the processus cochleariformis (ostium tympanicum tubae auditivae), and, gradually narrowing, terminates at the angle of junction of the petrous and squamous portions of the temporal bone, its extremity presenting a jagged margin which serves for the attachment of the cartilaginous portion. The roof of the osseous portion is the tegmen tympani. The inner wall is formed in part by the inner wall of the tympanum and in part by the canal for the Tensor tympani muscle. The outer wall is the tympanic portion of the temporal bone. The floor is a groove which near the tympanum contains the openings of air-cells (cellulae pneumatici tubarii).

The Cartilaginous Portion (pars cartilaginea tubae auditivae), about an inch in length, is formed of a triangular plate of elastic fibro-cartilage (cartilago tubae auditivae), the apex of which is attached to the margin of the inner extremity of the osseous canal, while its base lies directly under the mucous membrane of the naso-pharynx, where it forms an elevation or cushion above and behind the pharyngeal orifice of the tube. The upper edge of the cartilage is curled upon itself, being bent outward so as to present on transverse section the appearance of a hook (lamina lateralis); a groove or furrow is thus produced, which opens below and externally, and this part of the canal is completed by fibrous membrane. On transverse section the cartilage exhibits the laminae which above are continuous with each other: the hard, thick lamina medialis and the thin and hooked lamina lateralis. The cartilage of the Eustachian tube, with a hood plate of cartilage, forms the posterior portion of the inner wall (the lamina medialis). The cartilage is fixed to the base of the skull, and lies in a groove (sulcus tubae auditivae) between the petrous-temporal and the greater wing of the sphenoid; this groove ends opposite the middle of the internal pterygoid plate, in a projection, the
processus tubarius. At the pharyngeal orifice the entire wall of the tube is cartilaginous, but the breadth of the cartilage progressively lessens as the isthmus is approached. Here and there the cartilage is deficient or pieces lie separate from the rest, the spaces between the islands being occupied by fibrous tissue. The Tensor palati muscle is placed to the outer side of the tube. The fibres of the muscle which take origin from the lamina lateralis are known as the dilator tubae muscle of Rudinger. The Tensor palati muscle and the mucous membrane of the pharynx lie to the inner side of the tube. The under and outer portion of the canal is completed by the membranous part (lamina membranacea), which is a strong fibrous membrane, passing between the two margins of the cartilage. It is thin above, but thick below, and the thick portion is called the fascia salpingopharyngea of Tröltzsch, and from it arise some fibres of the Tensor palati (m. salpingopharyngeus). The cartilaginous and bony portions of the tube are not in the same plane, the former inclining downward a little more than the latter. They join each other at a large obtuse angle, open below. The diameter of the canal is not uniform throughout, being greatest at the pharyngeal orifice and least at the junction of the bony and cartilaginous portions, where it is named the isthmus (isthmus tubae auditivae); it again expands somewhat as it approaches the tympanic cavity. The position and relations of the pharyngeal orifice (ostium pharyngeum tubae auditivae) are described with the anatomy of the naso-pharynx. Through this canal the mucous membrane of the pharynx is continuous with that which lines the tympanum. The mucous membrane is covered with ciliated epithelium and is thin in the osseous portion, while in the cartilaginous portion it contains many mucous glands and near the pharyngeal orifice a considerable amount of adenoid tissue, which has been named by Gerlach the tube-tonsil. The tube is opened during deglutition by the Salpingo-pharyngeus and Dilator tubae muscles.

The Drumhead or Membrana Tympani (Figs. 770, 772, 773, and 774).—The membrana tympani or drumhead separates the cavity of the tympanum from

![Diagram](image-url)
the bottom of the external meatus. It is a thin, semi-transparent membrane, nearly oval in form, somewhat broader above than below, and directed very obliquely downward and inward, so as to form an angle of about 55 degrees with the floor of the meatus (Fig. 770). The antero-inferior portion is, therefore, placed at the greatest distance from the external orifice of the meatus. It is asserted that in musicians the membrana tympani is placed more nearly perpendicular, and that in deaf-mutes and cretins it is placed more obliquely than the usual 55 degrees. In a newborn child the membrana tympani is almost horizontal. The greatest diameter of the membrana tympani is from 9 to 10 mm.;

its least diameter is from 8 to 9 mm. (Cunningham). The greater part of its circumference (limbus membranae tympanae) is thickened to form an annular ring (annulus fibrocartilagineus), which is fixed in a groove, the sulcus tympanicus, at the inner extremity of the external meatus. This sulcus is deficient superiorly at the incisure or notch of Rivinus (incisura tympanica [Rivini]) (Fig. 773). From the extremities of the notch (spinae tympanicae) two folds pass and converge to the short process of the malleus (Fig. 773). One is known as the anterior tympano-malleolar fold or ligament (plica membranae tympani anterior). The other is known as the posterior tympano-malleolar fold or ligament (plica membranae tympani posterior). These are not to be confused with the anterior and posterior malleolar folds (p. 1172). The small, somewhat triangular part of the membrane situated above these folds is lax and thin, and is named the flaccid portion or the membrana flaccida of Shrapnell (Figs. 773 and 774). In it a small orifice is sometimes seen, which is of artificial and pathological formation. The larger lower portion of the drum membrane is stretched tightly, and is called the tense portion or pars tensa (Figs. 773 and 774).
The handle of the malleus is firmly attached to the inner aspect of the membrane tympani as far as its centre (Fig. 774). It draws the central part of the membrane inward and makes its outer aspect concave. The most depressed part of the concavity is called the umbo or navel (umbo membranae tympanae) (Fig. 773). The walls of the umbo are concave outward.

On the outer surface of the drum membrane a light stripe (stria malleolaris) is seen. It runs from in front and above downward and backward, and is produced by the handle of the malleus, showing through the membrane (Fig. 773).

Structure.—This membrane is composed of three layers: an external (cuticular), a middle (fibrous), and an internal (mucous). The cuticular lining (stratum cutaneum) is derived from the integument lining the meatus. The fibrous or middle layer (membrana propria) consists of two strata: an external, of radiating fibres (stratum radiatum), which diverge from the handle of the malleus, and an internal, of circular fibres (stratum circulare), which are plentiful around the circumference, but sparse and scattered near the centre of the membrane. Branched or dendritic fibres, as pointed out by Grüber, are also present, especially in the posterior half of the membrane. Both muscular layers are connected to the annulus fibrocartilagineus, and both are absent in the pars flaccida. The inner or epithelial layer is mucous membrane (stratum mucosum), which is a portion of the mucous membrane of the drum cavity.

The Arteries are derived from the deep auricular branch of the internal maxillary, which ramifies beneath the cuticular layer and from the stylo-mastoid branch of the posterior auricular and tympanic branch of the internal maxillary, which are distributed on the mucous surface. The arteries of the cutaneous set anastomose with the arteries of the mucous set by minute branches which penetrate the drum membrane near its margin. The superficial veins open into the external jugular; those on the mucous surface drain themselves partly into the lateral sinus and veins of the dura and partly into a plexus on the Eustachian tube.
The outer surface of the drum membrane receives its nerve supply from the auriculo-temporal branch of the inferior maxillary and the auricular branch of the vagus. The inner surface is supplied by the tympanic branch of the glosso-pharyngeal.

There are two sets of lymphatics, the cutaneous and mucous, which freely communicate. The spaces between the dendritic fibres of Grüber are lymph-spaces (Kessel).

The Ossicles of the Tympanum (Ossicula Auditus) (Fig. 776).

The tympanum contains in its upper part a chain of movable bones, three in number, the malleus, incus, and stapes. The first is attached to the membrana tympani, the last to the fenestra ovalis. The incus is placed between the two, and is connected to both by delicate articulations.

The Malleus or Hammer (Fig. 777).—The malleus or hammer, so named from its fancied resemblance to a hammer, is placed farthest in front and outward. It consists of a head, neck, and three processes—the handle or manubrium, the processus gracilis, and the processus brevis.

The Head (capitulum mallei).—The head is the large upper extremity of the bone, and is situated in the epitympanic recess (Fig. 774). It is oval in shape, and articulates posteriorly with the incus, being free in the rest of its extent. The facet for articulation with the incus is covered with cartilage, is constricted near the middle, and is divided by a ridge into an upper, larger, and a lower, lesser part, which form nearly a right angle with each other. Opposite the constriction the lower margin of the facet projects in the form of a process, the cog-tooth or spur of the malleus. On the back of the head below the spur is a crest (crista mallei), to which the posterior ligament of the malleus is attached.

The Neck (collum mallei).—The neck is the narrow contracted part just beneath the head; and below this is a prominence, to which the various processes are attached. The outer surface of the neck faces the membrana flaccida. The chorda tympani nerve crosses the inner surface (Fig. 774).

The Handle or Manubrium (manubrium mallei).—The manubrium is a vertical process of bone, which is connected by its outer margin with the fibrous layer of the membrana tympani, its entire length being fastened to the fibrous layer of the drum membrane by its own periosteum and by a layer of cartilage (Grüber) (Figs. 774 and 776). It is directed downward, inward, and backward; it decreases in size toward its extremity, where it is curved slightly forward, and is flattened from within outward. The handle forms a variable angle with the head of the hammer. It averages about 130 degrees, but is always greater in the right ear than in the left. It forms an angle with the horizontal, averaging on the right side 50 degrees and on the left side 45 degrees (Spalteholz). Internally the handle is covered by the mucous membrane of the tympanum. On the inner side, near its upper end, is a slight projection, into which the tendon of the Tensor tympani is inserted (Fig. 774).

The Processus Gracilis or Long Process (processus anterior [Folii]).—The processus gracilis is a long and very delicate process, which passes from the front of
THE OSSICLES OF THE TYMPANUM

the neck forward and outward to the Glaserian fissure, to which it is connected by ligamentous fibres, constituting the broad ligament of Meckel. In the foetus this is the longest process of the malleus, and is in direct continuity with the cartilage of Meckel.

The Processus Brevis (processus lateralis).—The processus brevis is a slight conical projection, which springs from the root of the manubrium; it is directed outward, and is attached to the upper part of the tympanic membrane by cartilage and to the margins of the notch of Rivinus by the two malleolar folds.

The Incus or Anvil (Fig. 778).—The incus or anvil has received its name from its supposed resemblance to an anvil, but it is more like a bicuspid tooth with two roots, which differ in length, and are widely separated from each other. It consists of a body and two processes. The body and the short process are placed in the epitympanic recess (Fig. 776).

The Body (corpus incudis).—The body is somewhat quadrilateral, but compressed laterally. On its anterior surface is a deeply concavo-convex facet, which articulates with the head of the malleus, and the lower part is hollowed for the spur of the malleus. In the fresh state the articular surface is covered with cartilage and the joint is lined with synovial membrane.

Processes.—The two processes diverge from one another at an angle of from 90 to 100 degrees.

The Short Process (crus breve), somewhat conical in shape, projects nearly horizontally backward, and articulates with a depression, the incus fossa (fossa incudis), in the lower and back part of the epitympanic recess.

The Long Process (crus longum), longer and more slender than the preceding, descends nearly vertically behind and parallel to the handle of the malleus, and,
bending inward, terminates in a rounded globular projection, the os orbiculare or lenticular process (processus lenticularis), which is tipped with cartilage, and articulates with the head of the stapes. In the fetus the os orbiculare exists as a separate bone.

The Stapes or Stirrup (Fig. 779).—The stapes or stirrup, so called from its close resemblance to a stirrup, consists of a head, neck, two crura, and a base.

The Head (capitulum stapedis).—The head presents a depression, tipped with cartilage, which articulates with the os orbiculare.

The Neck.—The neck, the constricted part of the bone succeeding the head, receives the insertion of the Stapedius muscle.

The Crura.—The two crura (crus anterius and crus posterius) diverge from the neck and are connected at their extremities by a flattened, oval-shaped plate, the foot-plate or base (basis stapedis), which forms the foot-plate of the stirrup and is fixed to the margin of the fenestra ovalis by ligamentous fibres. The foot-plate almost fills the oval window (Fig. 770). Of the two crura, the anterior is shorter and less curved than the posterior. In a recent specimen a membrane will be observed filling the space between the crura and the foot-plate. This membrane is connective tissue and is called the membrana obturatoria stapedis. The stirrup lies practically horizontal.

Articulations of the Ossicles of the Tympanum (articulationes ossiculorum auditus) (Fig. 776).—These small bones are connected with each other and with the walls of the tympanum by ligaments, and are moved by small muscles. There is an articulation between the head of the hammer and the body of the anvil; one between the os orbiculare of the anvil and the head of the stirrup; and there is a syndesmosis between the margins of the oval window and the base of the stirrup. The bones are fastened in the tympanum, the handle of the hammer being fastened in the drum membrane and the base of the stirrup to the oval window. The articular surfaces of the malleus and incus and the orbicular process of the incus and head of the stapes are covered with cartilage, connected together by delicate capsular ligaments and lined by synovial membrane.

Ligaments Connecting the Ossicula with the Walls of the Tympanum (ligamenta ossiculorum auditus).—The malleus is fastened to the wall of the tympanum by three ligaments: the anterior, superior, and external ligaments.

The Anterior Ligament of the Malleus (ligamentum mallei anterius) consists of two parts, the band of Meckel and the anterior ligament of Helmholtz.

The band of Meckel is attached to the base of the processus gracilis and passes through the Glaserian fissure to reach the spine of the sphenoid. It was formerly described by Sömmering as a muscle, and it was called the laxator tympani muscle. It is now, however, believed by most observers to consist of ligamentous fibres only.

The anterior ligament of Helmholtz extends from the anterior margin of the notch of Rivinus to the anterior portion of the malleus, just above the processus gracilis.

The Superior Ligament of the Malleus (ligamentum mallei superius) is a delicate round bundle of fibres which descends perpendicularly from the root of the epi-tympanic recess to the head of the malleus. It is sometimes called the suspensory ligament.

The External Ligament of the Malleus (ligamentum mallei laterale) is a triangular plane of fibres passing from the posterior part of the notch in the tympanic ring...
to the crest of the malleus. The posterior portion of the external ligament is sometimes called the posterior ligament of Helmholtz (ligamentum mallei posterius [Helmholtzi]). The malleus rotates around an axis composed of the external and anterior ligaments, hence these two ligaments constitute what Helmholtz called the axis ligament of the malleus.

The incus is fastened to the wall of the tympanum by two ligaments, the posterior and the superior.

The Posterior Ligament of the Incus (ligamentum incudis posterius) is a short, thick, ligamentous band which connects the extremity of the short process of the incus to the posterior and lower part of the epitympanic recess, near the margin of the opening of the mastoid cells.

A Superior Ligament of the Incus (ligamentum incudis superius) has been described by Arnold, but it is little more than a fold of mucous membrane.

The inner surface and the circumference of the base of the stapes are covered with hyaline cartilage, and the annular ligament of the stapes (ligamentum annulare baseos stapedis) connects the circumference of the base to the margin of the fenestra ovalis.

The Muscles of the Tympanum (m. ossiculorum auditus).—The muscles of the tympanum are two:

Tensor tympani. Stapedius.

The Tensor Tympani (m. tensor tympani) (Fig. 775), the larger, is contained in the bony canal above the osseous portion of the Eustachian tube, from which it is separated by the processus cochleariformis. It arises from the under surface of the petrous bone, from the cartilaginous portion of the Eustachian tube, and from the osseous canal in which it is contained. Passing backward through the canal, it terminates in a slender tendon which enters the tympanum and makes a sharp bend outward around the extremity of the processus cochleariformis, and is inserted into the handle of the malleus near its root. Its nerve-supply is from the motor root of the trigeminal nerve by way of the otic ganglion.

The Stapedius (m. stapedius) (Fig. 775) arises from the side of a conical cavity hollowed out of the interior of the pyramid; its tendon emerges from the orifice at the apex of the pyramid, and, passing forward, is inserted into the neck of the stapes. Its surface is aponeurotic, its interior fleshy, and its tendon occasionally contains a slender bony spine, which is constant in some mammalia. It is supplied by the tympanic branch of the facial nerve.

Actions.—The Tensor tympani draws the handle of the malleus inward and thus heightens the tension of the drum membrane. It also causes slight rotation of the bone around its long axis. When the Stapedius contracts it draws the head of the stirrup backward, and in consequence the anterior end of the footplate passes outward toward the tympanum, and the posterior end inward toward the vestibule, and the annular ligament is made tense.

Movements of the Ossicles of the Tympanum.—The chain of bones is a lever-like arrangement, by means of which the vibrations of the membrana tympani are transferred to the membrane covering the oval window, and from this to the perilymph in the labyrinth. When the drum membrane moves inward, the handle of the malleus moves with it. The movement of the malleus moves the incus, and the movement of the incus drives the foot of the stapes toward the labyrinth. When the handle of the malleus moves inward, the spur on the head becomes locked with the body of the incus. During outward movement it is unlocked. The ordinary outward movement of the drum membrane causes the above-described movements to be reversed. When there is overforcible outward movement the incus does not go outward quite as far as the malleus, but slides at the joint between the malleus and incus. This reluctance of the incus saves the foot of the stapes from being pulled away from the oval window.
The Mucous Membrane of the Tympanum (tunica mucosa tympanica).—The mucous membrane of the tympanum is continuous with the mucous membrane of the naso-pharynx through the Eustachian tube, and is firmly united to the periosteum. It invests the ossicula, and the muscles and nerves contained in the tympanic cavity; forms the internal layer of the membrana tympani, and the outer layer of the membrana tympani secundaria, and is reflected into the mastoid antrum and air-cells, which it lines throughout. It forms several vascular folds (plicae), which extend from the walls of the tympanum to the ossicles. In these folds the ossicles are enveloped.

The anterior malleolar fold (plica malleolaris anterior) comes off from the membrane tympani between the anterior edge of the notch of Rivinus and the handle of the malleus, envelops the processus gracilis of the malleus, the anterior ligament of the malleus, and the anterior portion of the chorda tympani nerve, and terminates in a free concave edge (Spalteholz). The posterior malleolar fold (plica malleolaris posterior) is the larger of the two. It comes off from the margin of the notch of Rivinis, envelops the external ligament of the malleus, the posterior part of the chorda tympani nerve, is attached to the handle of the malleus, and ends in a free concave margin (Spalteholz). The fold of the incus (plica incudis) takes origin from the roof of the epitympanic recess and passes to the body and short process of the incus; and a similar fold passes from the head of the malleus to the anterior wall of the epitympanic recess. The entire stapes, with its obturator membrane, is enwrapped by the fold of the stapes (plica stapidis). This fold also ensheaths the tendon of the stapedius muscle and often reaches to the posterior wall of the cavity of the tympanum. The mucous membrane over the round window forms the membrana tympani secundaria. These folds separate off pouch-like cavities, and give the interior of the tympanum a somewhat honey-comb appearance. One of these pouches is well marked—viz., the pouch of Prussak, which lies between the neck of the malleus and the membrana flaccida.

The inferior external pouch of the tympanum or the pouch of Prussak (recessus membranae tympani superior) is between the flaccid portion of the membrana tympani, the external ligament of the malleus, and the neck of the malleus. The anterior and posterior malleolar folds with the tympanic membrane form two pouches. These are the anterior and posterior pouches or recesses of Tröltsch (recessus membranae tympani, anterior and posterior). The anterior pouch is blind above and has a slit-like opening below. The posterior pouch is continued into the blind superior pouch of the drum membrane. In the tympanum this membrane is pale, thin, slightly vascular, and covered for the most part with columnar ciliated epithelium, but that covering the pyramid, ossicula, and membrana tympani possesses a flattened, non-ciliated epithelium. In the antrum and mastoid cells its epithelium is also non-ciliated. In the osseous portion of the Eustachian tube the membrane is thin; but in the cartilaginous portion it is very thick, highly vascular, covered with ciliated epithelium, and provided with numerous mucous glands.

The Arteries of the Tympanum.—The arteries supplying the tympanum are six in number. Two of them are larger than the rest—viz., the tympanic branch of the internal maxillary, which enters by way of the Glaserian fissure and supplies the membrana tympani; and the stylo-mastoid branch of the posterior auricular, which passes through the stylo-mastoid foramen and the aqueduct of Fallopian, and supplies the inner wall and floor of the tympanum, the mastoid cells, and antrum and the Stapedius muscle. This vessel anastomoses around the drum membrane with the tympanic. The medidural sends a small branch to the Tensor tympani muscle near its origin. The petrosal branch of the medidural enters the tympanum by way of the hiatus Fallopii. Minute branches from the posterior branch of the medidural pass through the petro-squamous fissure and are dis-
tributed to the antrum and epitympanic recess (Cunningham). Two tympanic branches come off from the internal carotid artery in its course through the carotid canal. A branch from the ascending pharyngeal and another from the Vidian accompany the Eustachian tube. The two tympanic branches from the internal carotid are given off in the carotid canal and perforate the thin anterior wall of the tympanum.

The Veins of the Tympanum.—The veins of the tympanum terminate in the pterygoid plexus, the medidural vein, and the superpetrosal sinus.

The Nerves of the Tympanum.—The nerves of the tympanum constitute the tympanic plexus (plexus tympanicus [Jacobsoni]), which ramifies upon the surface of the promontory (Fig. 775). The plexus is formed by (1) the tympanic branch of the glosso-pharyngeal; (2) the small deep petrosal nerve; (3) the small superficial petrosal nerve; and (4) a branch which joins the great superficial petrosal.

The Tympanic Branch of the Glosso-pharyngeal or Jacobson's Nerve (n. tympanicus) enters the tympanum by an aperture in its floor close to the inner wall and divides into branches, which ramify on the promontory and enter into the formation of the plexus. The small deep petrosal nerve (n. petrosus profundus), from the carotid plexus of the sympathetic, passes through the wall of the carotid canal, and joins the branches of Jacobson's nerve. The branch to the great superficial petrosal passes through an opening on the inner wall of the tympanum in front of the fenestra ovalis. The small superficial petrosal nerve (n. petrosus superficialis minor), derived from the otic ganglion, passes through a foramen in the middle fossa of the base of the skull (sometimes through the foramen ovale), passes backward and enters the petrous bone through a small aperture, situated external to the hiatus Fallopii on the anterior surface of this bone; it then courses downward through the bone, and, passing by the gangliform enlargement of the facial nerve, receives a connecting filament from it (Fig. 779) and enters the tympanic cavity, where it communicates with Jacobson's nerve, and assists in forming the tympanic plexus.

The branches of distribution of the tympanic plexus are distributed to the mucous membrane of the tympanum; one special branch passing to the fenestra ovalis, another to the fenestra rotunda, and a third to the Eustachian tube. The small superficial petrosal may be looked upon as a branch from the plexus to the otic ganglion.

In addition to the tympanic plexus there are the nerves supplying the muscles. The Tensor tympani is supplied by a branch from the third division of the trigeminal through the otic ganglion, and the Stapedius by the tympanic branch of the facial.

The chorda tympani (Figs. 771 and 774) crosses the tympanic cavity. It is given off from the facial as it passes vertically downward at the back of the tympanum, about a quarter of an inch before its exit from the stylo-mastoid foramen. It passes from below upward and forward in a distinct canal, and enters the cavity of the tympanum through an aperture, iter chordae posterius, already described (p. 1161), and becomes invested with mucous membrane. It passes forward, through the cavity of the tympanum, crossing internal to the membrana tympani and over the handle of the malleus to the anterior inferior angle of the tympanum, and emerges from that cavity through the iter chordae anterius or canal of Huguier (p. 1162). It is invested by the fold of mucous membrane already mentioned, and therefore lies between the mucous and fibrous layers of the membrana tympani.

THE INTERNAL EAR OR LABYRINTH (AURIS INTERNA).

The internal ear is the essential part of the organ of hearing, receiving the ultimate distribution of the auditory nerve. It is called the labyrinth, from the
complexity of its shape, and consists of two parts: the **osseous labyrinth**, a series of cavities channelled out of the substance of the petrous bone, and the **membranous labyrinth**, the latter being contained within the former.

**The Osseous Labyrinth (Labyrinthus Osseus)** (Fig. 780).

The osseous labyrinth consists of three parts: the **vestibule**, **semicircular canals**, and **cochlea**. These are cavities hollowed out of the substance of the bone, and lined by periosteum. A clear fluid is contained in the space between the osseous labyrinth and the membranous labyrinth. The space is called the **perilymph space**, and the fluid is called **perilymph** or **liquor Cotunnii**.

**The Vestibule** (**vestibulum**) (Figs. 776 and 780).—The vestibule is the common central cavity of communication between the parts of the internal ear. It is situated on the inner side of the tympanum, behind the cochlea, and in front of the semicircular canals. It is somewhat ovoidal in shape from before backward, flattened from within outward, and measures about one-fifth of an inch from before back-

![Diagram of the internal ear](https://via.placeholder.com/150)

Opening of aqueductus vestibuli.

Bristle passed through foramen rotundum.

Opening of aqueductus cochleae.

**Fig. 780.**—The osseous labyrinth laid open (enlarged).

ward, as well as from above downward, and about one-eighth of an inch from without inward. On its **outer** or tympanic wall is the **fenestra ovalis** (**fenestra vestibuli**), closed, in the recent state, by the base of the stapes, and its annular ligament. On its **inner wall**, at the forepart, is a small circular depression, **fovea hemisphaerica** or **spherical recess** (**recessus sphaericus**), in which the saccule is placed. This recess is perforated, at its anterior and inferior part, by about a dozen minute holes (**macula cribrosa media**), for the passage of filaments of the auditory nerve to the saccule. Above and behind this depression is an oblique ridge, the **crista vestibuli**. The anterior extremity of the crista vestibuli is the shape of a triangle, and is called the **pyramid** (**pyramis vestibuli**). This ridge bifurcates posteriorly to enclose a small depression, the **recessus cochlearis of Reichert**, which is perforated by eight small holes for the passage of filaments of the auditory nerve which supply the posterior end of the ductus cochlearis. An oval depression is placed in the roof and inner wall of the vestibule above and behind the crista vestibuli. It is called the **fovea hemielliptica**, **elliptical recess** or **spherical recess** (**recessus ellipticus**), and receives the utricle. The pyramid and the adjacent elliptical recess are perforated by numerous minute foramina (**macula cribrosa superior**),
The openings in the pyramid transmit filaments from the vestibular nerve to the utricle; the openings in the elliptical recess transmit filaments from the vestibular nerve to the ampullae of the superior and external semicircular canals. Below and behind the elliptical recess is a groove which deepens into a canal and is called the *aquaeductus vestibuli*. This canal passes to the posterior surface of the petrous portion of the temporal bone and opens as a mere crack between the internal auditory meatus and the groove for the lateral sinus. It transmits a small vein, and contains a tubular prolongation of the lining membrane of the vestibule, the *ductus endolymphaticus*, which ends in a cul-de-sac between the layers of the dura within the cranial cavity. *Behind*, the semicircular canals open into the vestibule by five orifices. *In front* is an elliptical opening, which communicates with the scala vestibuli of the cochlea by an orifice, *apertura scalae vestibuli cochleae*. This opening is bounded below by a thin plate of bone (*lamina spiralis ossea*), which takes origin from the vestibular floor external to the spherical recess and in the cochlea forms the bony portion of the partition between the scala tympani and the scala vestibuli. In the anterior portion of the vestibular floor is a fissure (*fissura vestibuli*), which passes into the bony part of the canal of the cochlea. The external boundary of this fissure is a small, thin plate of bone (*lamina spiralis secundaria*).

**The Semicircular Canals** (*canales semicirculares ossei*) (Fig. 780).—The semicircular canals are three bony canals situated above and behind the vestibule. They are of unequal length, compressed from side to side, and each describes the greater part of a circle. They measure about one-twentieth of an inch in diameter, and each presents a dilatation at one end, called the *ampulla ossea*, which measures more than twice the diameter of the tube. These canals open into the vestibule by five orifices, one of the apertures being common to two of the canals.

**The Superior Semicircular Canal** (*canalis semicircularis superior*).—The superior semicircular canal is vertical in direction, and is placed transversely to the long axis of the petrous portion of the temporal bone, on the anterior surface of which its arch forms a round projection. It describes about two-thirds of a circle. Its outer extremity, which is ampullated, communicates by a distinct orifice with the upper part of the vestibule; the opposite end of the canal, which is not dilated, joins with the corresponding part of the posterior canal to form the *crus commune*, which opens into the upper and inner part of the vestibule.

**The Posterior Semicircular Canal** (*canalis semicircularis posterior*).—The posterior semicircular canal, also vertical in direction, is directed backward, nearly parallel to the posterior surface of the petrous bone; it is the longest of the three; its ampullated end commences at the lower and back part of the vestibule, its opposite end joining to form the common canal already mentioned. In the wall of the ampulla of the posterior canal are a number of small openings (*macula cribrosa inferior*) for the entrance of nerves to the ampulla.

**The External or Horizontal Canal** (*canalis semicircularis lateralis*).—The external or horizontal canal is the shortest of the three, its arch being directed outward and backward; thus each semicircular canal stands at right angles to the other two. Its ampullated end corresponds to the upper and outer angle of the vestibule, just above the fenestra ovalis, where it opens close to the ampullary end of the superior canal; its opposite end opens by a distinct orifice at the upper and back part of the vestibule.

**The Cochlea** (Figs. 780, 781, 782, and 783).—The cochlea bears some resemblance to a common snail-shell; it forms the anterior part of the labyrinth, is conical in form, and placed almost horizontally in front of the vestibule; its apex is directed forward and outward, with a slight inclination downward, toward the upper and front part of the inner wall of the tympanum; its base corresponds with the anterior depression at the bottom of the internal auditory meatus, and is perforated by numerous
apertures for the passage of the cochlear divisions of the auditory nerve. It measures nearly a quarter of an inch (5 mm.) from base to apex, and its breadth across

the base is somewhat greater (about 9 mm.). It consists of a conical-shaped central axis, the modiolus or columnella; of a canal, the bony canal of the cochlea, the inner wall of which is formed by the central axis, wound spirally around it for two

turns and three-quarters, from the base to the apex, and of a delicate lamina, the lamina spiralis ossea, which projects from the modiolus, and, following the windings
of the canal, partially subdivides it into two. In the recent state certain membranous layers are attached to the free border of this lamina, which project into the canal and completely separate it into two passages, which, however, communicate with each other at the apex of the modiolus by a small opening, named the helicotrema.

The Modiolus (Figs. 782 and 783).—The modiolus or columella is the central axis or pillar of the cochlea. It is conical in form, and extends from the base to the apex of the cochlea. Its base (basis modioli) is broad, and appears at the bottom of the internal auditory meatus, where it corresponds with the area cochleae. It is perforated by numerous orifices, which transmit filaments of the cochlear division of the auditory nerve, the nerves for the first turn and a half being transmitted through the foramina of the tractus spiralis foraminosus; the fibres for the apical turn passing up through the foramen centrale. The foramina of the tractus spiralis foraminosus pass up through the modiolus and successively bend outward to reach the attached margin of the lamina spiralis ossea. Here they become enlarged, and by their apposition form a spiral canal (canalis spiralis modioli), which follows the course of the attached margin of the lamina spiralis ossea and lodges the ganglion of Corti (ganglion spirale cochleae). The foramen centrale is continued as a canal up the middle of the modiolus to its apex, and from this canal numerous minute foramina pass outward to the unattached edge of the lamina spiralis. In the foramina are vessels and nerves. The axis diminishes rapidly in size in the second and succeeding coil.

![Image](783.-The cochlea laid open (enlarged).

The Bony Canal or the Spiral Canal of the Cochlea (canalis spiralis cochleae) (Fig. 783).—The bony canal of the cochlea takes two turns and three-quarters round the modiolus. The first turn of the canal is called the basal coil, the second is called the central coil, the third turn is called the apical coil. The promontory on the inner wall of the tympanic cavity is caused by the basal coil. The bony canal of the cochlea is a little over an inch in length (about 30 mm.), and diminishes gradually in size from the base to the summit, where it terminates in a cul-de-sac, the cupula (cupula), which forms the apex of the cochlea. The commencement of this canal is about the tenth of an inch in diameter; it diverges from the modiolus toward the tympanum and vestibule, and presents three openings. One, the fenestra rotunda, communicates with the tympanum; in the recent state this aperture is closed by a membrane, the membrana tympani secundaria. Another aperture, of an elliptical form, enters the vestibule. The third is the aperture of the aquaeductus cochleae, leading to a minute funnel-shaped canal, which opens on the basilar surface of the petrous bone internal to the jugular fossa, and transmits a small vein, and also forms a communication between the subarachnoidian space of the skull and the perilymph contained in the scala tympani.

The Lamina Spiralis Ossea.—The lamina spiralis ossea is a bony shelf or ledge which projects outward from the modiolus into the interior of the spiral canal,
and, like the canal, takes two and three-quarter turns around the modiolus. It reaches about half-way toward the outer wall of the spiral tube, and partially divides its cavity into two passages or scalae, of which the upper is named the scala vestibuli, while the lower is termed the scala tympani. Near the summit of the cochlea the lamina terminates in a hook-shaped process, the hamulus (hamulus laminae spiralis), which assists in forming the boundary of a small opening, the helicotrema, by which the two scalae communicate with each other. From the canalis spiralis modioli numerous foramina pass outward through the osseous spiral lamina as far as its outer or free edge. In the lower part of the first turn a second bony lamina (lamina spiralis secundaria) projects inward from the outer wall of the bony tube; it does not, however, reach the primary osseous spiral lamina, so that if viewed from the vestibule a narrow fissure, the fissura vestibuli, is seen between them.

The membrana basilaris (Fig. 781) is stretched from the unattached edge of the lamina spiralis ossea to the outer wall of the cochlea. The lamina spiralis makes an incomplete septum between the scala tympani and scala vestibuli; the membrana basilaris completes the septum. Even with the perfected septum the two scalae communicate at the apex of the cochlea by means of the helicotrema.

The Fundus of the Internal Auditory Meatus (fundus meatus acustici interni).—This structure is the inner wall of the vestibule and the base of the modiolus. A transverse ridge (cista transversa) maps it off into two parts, the fossula superior and the fossula inferior. The facial area (area n. facialis) is in the anterior portion of the fossula superior. The opening seen here is the beginning of the aqueduct of Fallopius (canalis facialis) for the transmission of the facial nerve. The superior area of the vestibule (area vestibularis superior) is the posterior portion of the fossula superior. Here the nerves perforate which supply the utricle and the ampullae of the superior and external semicircular canals (Cunningham). The area cochleae is the anterior portion of the fossula inferior. In it is the canalis centralis for the nerve-fibres to the apical turn of the cochlea; and the tractus spiralis foraminosa for the transmission of nerves to the first turn and a half of the cochlea. The

![Diagram of the inner ear](image_url)
in inferior area of the vestibule (area vestibularis inferior) is back of the area cochleae and a ridge separates the two. It transmits nerves to the saccule. At the posterior part of the fossula inferior is a solitary foramen, the foramen singulare, which transmits nerves to the ampulla of the posterior semicircular canal.

The Membranous Labyrinth (Labyrinthus Membranaceus) (Figs. 784, 785).

The membranous labyrinth is contained within the bony cavities just described, having the same general form as the cavities in which it is contained, though considerably smaller, being separated from the bony walls by a quantity of fluid, the perilymph or liquor Cotunnii (perilymph). It does not, however, float loosely in this fluid, but in places is fixed to the walls of the cavity. The membranous sac contains fluid, the endolymph (endolympha), and on the sac the ramifications of the auditory nerve are distributed.

Within the osseous vestibule the membranous labyrinth does not quite preserve the form of the bony cavity, but presents two membranous sacs, the utricle and the saccule.

The Utricle (utriculus).—The utricle is the larger of the two, of an oblong form, compressed laterally, and occupies the upper and back part of the vestibule, lying in contact with the fovea semi-elliptica and the part below it. The highest portion of the utricle is called the recess (recessus utriculi); it is placed in the elliptical recess, and opening into it are the ampulla of the superior and external semicircular canals. The central portion of the recess of the utricle receives upon the side the external semicircular canal. This opening has not an ampulla. The superior sinus is a prolongation upward and backward from the central portion of the utricle and in the superior sinus the crus commune and the superior and posterior semicircular canals open. The lower and inner portion of the utricle is the inferior sinus, and into it the ampulla of the posterior semicircular canal opens. The floor and anterior wall of the recess of the utricle are much thicker than elsewhere, and form the macula acustica utriculi, which receives the utricular filaments of the auditory nerve and has attached to its internal surface a layer of calcareous particles which are called otothls. The cavity of the utricle communicates behind with the membranous semicircular canals by five orifices. From its anterior wall is given off a small canal (ductus utriculosaccularis), which joins with a canal from the saccule, the ducus endolymphaticus. The utricle is joined to the bony wall by numerous fibrous bands.

![Diagram of the memranous labyrinth](image)
The Saccule (sacculus).—The saccule is the smaller of the two vesicular sacs; it is globular in form, lies in the elliptical recess near the opening of the scala vestibuli of the cochlea. Its anterior part exhibits an oval thickening, the macula acustica sacculi, to which are distributed the saccular filaments of the auditory nerve. Its cavity does not directly communicate with that of the utricle. From the posterior wall is given off a canal, the ductus endolymphaticus. This duct passes along the aquaeductus vestibuli and ends in a blind pouch on the posterior surface of the petrous portion of the temporal bone, where it is in contact with the dura. The upper extremity of the saccule looks upward and backward and forms the sinus utricularis sacculi. This lies in contact with but is not a part of the wall of the utricle. The vestibule contains the closed end of the ductus cochlearis. This is known as the caecum vestibulare. The ductus cochlearis lies below the saccule in what Reichert described as the recessus cochlearis, and it enters the spiral canal. From the lower part of the saccule a short tube, the canalis reunies of Hensen (ductus reunies [Hensen]), passes downward and outward to open into the ductus cochlearis. The saccule is held in position by numerous fibrous bands which pass between the saccule and the bony wall.

The Membranous Semicircular Canals (ductus semicirculares).—The membranous semicircular canals are about one-third the diameter of the osseous canals, but in number, shape, and general form they are precisely similar, and present at one end within the osseous ampulla a membranous ampulla. These ampullae are called ampullae membranaceae. The canals open by five orifices into the utricle, one opening being common to two canals. In the ampullae the wall is thickened, and projects into the cavity as a fiddle-shaped, transversely placed elevation, the septum transversum, in which the nerves end.

The membranous canals are attached here and there to the bone by numerous fibrous bands, the so-called ligaments (ligamenta labyrinthi canaliculorum).

Structure.—The walls of the utricle, saccule, and membranous semicircular canals consist of three layers. The outer layer is a loose and flocculent structure, apparently composed of ordinary fibrous tissue, containing blood-vessels and pigment-cells analogous to those in the pigment coat of the retina. The middle layer, thicker and more transparent, bears some resemblance to the hyaloid membrane, but it presents on its internal surface, especially in the semicircular canals, numerous papilliform projections, and, on the addition of acetic acid, presents an appearance of longitudinal fibrillation and elongated nuclei. The inner layer is formed of polygonal nucleated epithelial cells. The raphé of each semicircular canal is a line upon the concave side of the canal. Along the raphé the height of the epithelial cells is distinctly increased. In the ampullae adjacent to the crista acusticae the cells are cylindrical and constitute the plana semilunata. In the maculae of the utricle and saccule, and in the transverse septa of the ampullae of the canals, the middle coat is thickened and the epithelium is columnar, is increased in height, and passes into the neuro-epithelium. The neuro-epithelium consists of supporting cells and hair-cells.

1. The supporting cells are long, wider at the ends than in the centre, contain an oval nucleus, and the lower end of the cell is fissured.

2. The hair-cells are columnar, with bulged lower ends and free upper ends. The bulged lower ends, each of which contains a spherical nucleus, do not reach higher than the middle of the epithelial layer. Each free upper end is surmounted by a long, tapering filament. These filaments constitute auditory hair, and they project into the cavity. The filaments of the auditory nerve enter these parts, and, having pierced the outer and thickened middle layer, they lose their medullary sheath, and their axis-cylinders divide into three or four branches at the larger and deeper ends of the hair-cells. These branches form a horizontal plexus
"These surround the hair-cells like the calyx of a flower, and give off ascending branches, which, however, do not reach the surface. In this way one branch usually comes in contact with many hair-cells."

Numerous small prismatic bodies termed **statoliths**, **otokonien crystals** or **otoliths**, and consisting of a mass of minute crystalline grains of carbonate of lime, held together in a mesh of delicate fibrous tissue, are contained in the walls of the utricle and saccule opposite the distribution of the nerves. The membrane is

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Histology and Microscopic Anatomy. By Dr. Ladislaus Szymonowicz. Translated and edited by John Bruce MacCallum, M.D.
called the otolith membrane. A calcareous material is also, according to Bowman, sparingly scattered in the cells lining the ampullae of the semicircular canals. The conical thickening in the ampulla corresponds to the otolith membrane and is called the cupola.

The Membranous Cochlea, Ductus Cochlearis or Scala Media consists of a spirally arranged tube enclosed in the bony canal of the cochlea and lying along its outer wall. It begins as a blind end in the recessus cochlearis of the vestibule. This beginning is the caecum vestibulare. It ascends inside the bony cochlea and terminates at the apex of the cochlea by a blind end, the lagenæ (caecum cupulare). The manner in which it is formed will now be described.

The osseous spiral lamina, as above stated, extends only part of the distance between the modiolus and the outer bony wall of the cochlea. A membrane, the basilar membrane (membrana basilaris) (Fig. 786), stretches from its free edge to the outer wall of the cochlea, and completes the roof of the scala tympani. A second and more delicate membrane, the membrane of Reissner (membrana vestibularis [Reissneri]) (Fig. 786), extends from the thickened periosteum covering the lamina spiralis ossea to the outer wall of the cochlea, to which it is attached at some little distance above the membrana basilaris. A canal is thus shut off between the scala tympani below and the scala vestibuli above; this is the membranous canal of the cochlea (ductus cochlearis or scala media) (Fig. 787). It is triangular on transverse section, its roof being formed by the membrane of Reissner, its outer wall by the periosteum which lines the bony canal, and its floor by the membrana basilaris, and the outer part of the lamina spiralis ossea, on the former of which is placed the organ of Corti. Reissner's membrane is thin and homogeneous, and is covered on its upper and under surfaces by a layer of epithelium. The periosteum, which forms the outer wall of the ductus cochlearis, is greatly thickened and altered in character, forming what is called the spiral ligament of the cochlea (ligamentum spirale cochleae) (Fig. 786). It projects inward below as a triangular prominence, the crista basilaris, which gives attachment to the outer edge of the membrana basilaris, and immediately above which is a concavity, the sulcus spiralis externus (Fig. 786). The upper portion of the ligamentum spirale contains numerous capillary loops and small blood-vessels, and forms what is termed the stria vascularis. The stria is limited below by a prominence (prominencia spiralis), in which a blood-vessel (vas prominens) is distinctly visible.

The lamina spiralis ossea (Fig. 787) consists of two plates of bone extending outward; between these are the canals for the transmission of the filaments of the auditory nerve. On the upper plate of that part of the osseous spiral lamina which is outside Reissner's membrane the periosteum is thickened to form the limbus laminae spiralis, and this terminates externally in a concavity, the sulcus spiralis internus, which presents, on section, the form of the letter C; the upper part of the letter, formed by the overhanging extremity of the limbus, is named the labium vestibulare; the lower part, prolonged and tapering, is called the labium tympanicum, and is perforated by 4000 foramina (foramina nervosa) for the passage of the cochlear nerves. Externally, the labium tympanicum is continuous with the membrana basilaris. The upper surface of the labium vestibulare is intersected at right angles by a number of furrows, between which are numerous elevations; these present the appearance of teeth along the free margin of the

![Fig. 788.—Part of the cochlear nerve, highly magnified. (Hindle.)](image)
labium, and have been named by Huschke the auditory teeth. There are 7000 auditory teeth. The basilar membrane may be divided into two areas, inner and outer. The inner is thin, and is named the zona arcuata or zona tecta (Fig. 786); it supports the organ of Corti. The outer is thicker and striated, and is termed the zona pectinata. The under surface of the membrane is covered by a layer of vascular connective tissue. One of these vessels is somewhat larger than the rest, and is named the vas spirale (Fig. 789); it lies below Corti's tunnel.

Organ of Corti\(^1\) (organon spirale [Cortii]) (Figs. 786, 787, 789, and 790).—The inner part of the membrana basilaris—that is, the part directed toward the canal of the ductus cochlearis—is covered with epithelium, which is largely neuro-epithe-

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\(^1\) Corti's original paper is in the Zeitschrift f. Wissen. Zool., iii., 109.
pianoforte. The organ of Corti consists of an inner part and an outer part. Each part contains auditory cells and supporting cells. Of these cells, the two central ones are rod-like bodies and are called the inner and outer rods of Corti. They are placed on the basilar membrane, at some little distance from each other, but are inclined toward each other, so as to meet at their opposite extremities, and form a series of arches roofing over a minute tunnel, the canal or tunnel of Corti, between them and the basilar membrane, which ascends spirally through the whole length of the cochlea.

The inner rods (Fig. 789), some 6000 in number, are more numerous than the outer ones, and rest on the basilar membrane, close to the labium tympanicum; they project obliquely upward and outward, and terminate above in expanded extremities which resemble in shape the upper end of the ulna, with its sigmoid cavity, coronoid and olecranon processes. On the outer side of the rod, in the angle formed between it and the basilar membrane, is a nucleated mass of protoplasm; while on the inner side is a row of epithelial cells, inner hair-cells (Fig. 789), surmounted by a brush of fine, stiff, hair-like processes. On the inner side of these cells are two or three rows of columnar supporting cells, which are continuous with the cubical cells lining the sulcus spiralis internus.

The outer rods (Fig. 789), numbering about 4000, also rest by a broad foot on the basilar membrane; they incline upward and inward, and their upper extremity resembles the head and bill of a swan; the back of the head fitting into the concavity—the analogue of the sigmoid cavity—of one or more of the internal rods, and the bill projecting outward as a phalangeal process of the membrana reticularis, presently to be described.

In the head of these outer rods is an oval portion, where the fibres of which the rod appears to be composed are deficient, and which stains more deeply with carmine than the rest of the rod. At the base of the rod, on its internal side—that is to say, in the angle formed by the rod with the basilar membrane—is a similar protoplasmic mass to that found on the outer side of the base of the inner rod; these masses of protoplasm are probably the undifferentiated portions of the cells from which the rods are developed. External to the outer rod are three or four successive rows of epithelial cells, more elongated than those found on the
internal side of the inner rod, but, like them, furnished with minute hairs or cilia. These are termed the outer hair-cells, in contradistinction to the inner hair-cells above referred to. There are about 12,000 outer hair-cells, and about 3500 inner hair-cells.

The hair-cells are somewhat oval in shape; their free extremities are on a level with the heads of Corti’s rods, and from each some twenty fine hairlets project and are arranged in the form of a crescent, the concavity of which opens inward. The deep ends of the cells are rounded and contain large nuclei; they reach only as far as the middle of Corti’s rods, and are in contact with the ramifications of the nervous filaments. Between the rows of the outer hair-cells are rows of supporting cells, called the cells of Deiters; their expanded bases are planted on the basilar membrane, while their opposite ends present a clubbed extremity or phalangeal process. Immediately to the outer side of Deiters’ cells are some five or six rows of columnar cells, the supporting cells of Hensen. Their bases are narrow, while their upper parts are expanded and form a rounded elevation on the floor of the ductus cochlearis. The columnar cells lying outside Hensen’s cells are termed the cells of Claudius. A space is seen between the outer rows of Corti and the adjacent hair-cells; this is called the space of Nuel.

The lamina reticularis or membrane of Kölliker is a delicate framework perforated by rounded holes. It extends from the inner rods of Corti to the external row of the outer hair-cells, and is formed by several rows of “minute fiddle-shaped cuticular structures” called phalanges, between which are circular apertures containing the free ends of the hair-cells. The innermost row of phalanges consists of the phalangeal processes of the outer rods of Corti; the outer rows are formed by the modified free ends of Deiters’ cells.

Covering over these structures, but not touching them, is the membrana tectoria or membrane of Corti (Figs. 786 and 789), which is attached to the vestibular surface of the lamina spiralis close to the attachment of the membrane of Reissner. It is thin near its inner margin, and overlies the auditory teeth of Huschke. Its outer half is thick, and along its lower edge, opposite the inner hair-cells, is a clear band, named Hensen’s stripe. Externally, the membrane becomes much thinner, and is attached to the outer row of Deiters’ cells (Retzius).

The fibres from the cochlear nerve enter the organ of Corti as axis-cylinders, which pass directly to the deepest portions of the inner and outer hair-cells by way of the canal of Corti or by the space of Nuel. The terminations arborize about the lower portions of the hair-cells and end on the surfaces of the hair-cells.

The inner surface of the osseous labyrinth is lined by an exceedingly thin fibroserous membrane, analogous to a periosteum, from its close adhesion to the inner surfaces of these cavities, and performing the office of a serous membrane by its free surface. It lines the vestibule, and from this cavity is continued into the semicircular canals and the scala vestibuli of the cochlea, and through the helicotrema into the scala tympani. A delicate tubular process is prolonged along the aqueduct of the vestibule to the inner surface of the dura. This membrane is continued across the fenestra ovalis and fenestra rotunda, and consequently has no communication with the lining membrane of the tympanum. Its attached surface is rough and fibrous, and closely adherent to the bone; its free surface is smooth and pale, covered with a layer of epithelium, and secretes a thin, limpid fluid, the aqua labyrinthi, liquor Cistumii or perilymph (Blainville).

The scala media is closed above and below. The upper blind extremity is termed the lagena, and is attached to the cupula at the upper part of the helicotrema; the lower end is lodged in the recessus cochlearis of the vestibule. Near this blind extremity, the scala media receives the canalis reuniens of Hensen (Fig. 785), a very delicate canal, by which the ductus cochlearis is brought into continuity with the saccule.
The Arteries of the Labyrinth.—The arteries of the labyrinth are the internal auditory, from the basilar, and the stylo-mastoid, from the posterior auricular. The internal auditory divides at the bottom of the internal auditory meatus into two branches, cochlear and vestibular.

The cochlear artery divides into numerous minute branches, which enter foramina in the tractus spiralis foraminosa and course in the lamina spiralis ossea to reach the membranous structures. The largest of the cochlear branches is in the canalis centralis.

The vestibular branches accompany the nerves, and supply the membranous structures in the vestibule and semicircular canals. Two arteries go to each canal. The two vessels enter opposite extremities of the canal, and anastomose at the summit of the canal. The vestibular vessels form a minute capillary network in the substance of each membranous labyrinth.

The Veins of the Labyrinth.—The veins of the vestibule and semicircular canals, the auditory veins, accompany the arteries, and receive those of the cochlea at the base of the modiolus, to form the internal auditory vein (vv. auditivae internae), which opens into the posterior part of the inferior petrosal sinus or into the lateral sinus.

The Nerves of the Labyrinth.—The auditory nerve (n. acusticus), the special nerve of the sense of hearing, divides, at the bottom of the internal auditory meatus, into two branches, the cochlear and vestibular.

The Vestibular Nerve (n. vestibularis), the posterior of the two, presents, as it lies in the internal auditory meatus, a ganglion, the vestibular ganglion or the ganglion of Scarpa (ganglion vestibulare); the nerve divides into three branches which pass through minute openings at the upper and back part of the bottom of the meatus (area vestibularis posterior), and, entering the vestibule, are distributed to the utricle and to the ampulla of the external and superior semicircular canals.

The nerve filaments enter the ampullary enlargements opposite the septum transversum, and arborize around the hair-cells. In the utricle and saccule the nerve-fibres pierce the membrana propria of the maculae, and end in arborizations around the hair-cells.

The Cochlear Nerve (n. cochlearis) gives off the branch to the saccule, the filaments of which are transmitted from the internal auditory meatus through the foramina of the area vestibularis inferior, which lies at the lower and back part of the floor of the meatus. It also gives off the branch for the ampulla of the posterior semicircular canal, which leaves the meatus through the foramen singulare.

The rest of the cochlear nerve divides into numerous filaments at the base of the modiolus; those for the basal and middle coils pass through the foramina in the tractus foraminosus, those for the apical coil through the canalis centralis, and the nerves bend outward to pass between the lamellae of the osseous spiral lamina. Occupying the spiral canal of the modiolus is the spiral ganglion or ganglion of Corti (ganglion spirale), consisting of bipolar nerve-cells, which really constitute the true cells of origin of this nerve, one pole being prolonged centripetally to the brain and the other peripherally to the hair-cells of Corti's organ. Reaching the outer edge of the osseous spiral lamina, the nerve fibres pass through the foramina in the labium tympanicum, where they lose their axis-cylinders. They enter the organ of Corti and pass directly to the deep portions of the inner and outer hair-cells by way of the canal of Corti and the space of Nuel. The terminations arborize about the lower portions of the hair-cells and end in the surfaces of the cells.

Surgical Anatomy.—Malformations, such as imperfect development of the external parts, absence of the meatus, or supernumerary auricles, are occasionally met with. Or the pinna may present a congenital fistula, which is due to defective closure of the first visceral cleft, or rather of that portion of it which is not concerned in the formation of the Eustachian tube, tympanum, and meatus. In some cases the cephalo-auricular angle is almost absent; in others it is nearly
THE MEMBRANOUS LABYRINTH

a right angle. Projecting ears and long ears are said by some observers to be more common among degenerates, criminals, and the insane than among the normal, the non-criminal, and the same. The skin of the auricle is thin and richly supplied with blood, but in spite of this it is frequently the seat of frost-bite, due to the fact that it is much exposed to cold, and lacks the usual underlying subcutaneous fat found in most other parts of the body. A collection of blood is sometimes found between the cartilage and perichondrium (haematoma auris), usually the result of traumaism, but not necessarily due to this cause. It is said to occur most frequently in the ears of the insane. Keloid sometimes grows in the auricle around the puncture made for ear-rings, and epithelioma occasionally affects this part. Deposits of urate of soda are often met with in the pinna in gouty subjects.

The external auditory meatus can be most satisfactorily examined by light reflected down a funnel-shaped speculum; by gently moving the latter in different directions the whole of the canal and membrana tympani can be brought into view. The points to be noted are: the presence of wax or foreign bodies, the size of the canal, and the condition of the membrana tympani. The accumulation of wax is often the cause of deafness, and may give rise to very serious consequences, causing ulceration of the membrane and even absorption of the bony wall of the canal. Foreign bodies are not infrequently introduced into the ear by children, and, when situated in the first portion of the canal, may be removed with tolerable facility by means of a minute hook or loop of fine wire, the parts being illuminated with reflected light; but when they have slipped beyond the narrow middle part of the meatus, their removal is in nowise easy, and attempts to effect it, in inexperienced hands, may be followed by destruction of the membrana tympani and possibly injury of the contents of the tympanum. The calibre of the external auditory canal may be narrowed by inflammation of its lining membrane, running on to suppuration; by periostitis; by polyypi, sebaceous tumors, and exostoses. The membrana tympani, when seen in a healthy ear, “reflects light strongly, and, owing to its peculiar curvature, presents a bright spot of triangular shape at its lower and anterior portion.”

From the apex of this, proceeding upward and slightly forward, is a white streak formed by the handle of the malleus, while near the upper part of the membrane may be seen a slight projection, caused by the short process of the malleus. In disease alterations in color, lustre, curvature or inclination, and perforation must be noted. Such perforations may be caused by a blow, a loud report, a wound, or as the result of suppuration in the middle ear.

The upper wall of the meatus is separated from the cranial cavity by a thin plate of bone; the anterior wall is separated from the temporo-mandibular joint and parotid gland by the bone forming the genoid fossa; and the posterior wall is in relation with the mastoid cells; hence inflammation of the external auditory meatus may readily extend to the membranes of the brain, to the temporo-mandibular joint, or to the mastoid cells; and, in addition to this, blows on the chin may cause fracture of the wall of the meatus.

The nerves supplying the meatus are the auricular branch of the vagus, the auriculo-temporal, and the auricularis magnus. The connections of these nerves explain the fact of the occurrence, in cases of any irritation of the meatus, of constant coughing and sneezing from implication of the vagus, or of yawning from implication of the auriculo-temporal. No doubt also the association of carache with toothache in cancer of the tongue is due to implication of the same nerve, a branch of the trigeminal, which supplies also the teeth and the tongue. The vessels of the meatus and membrana tympani are derived from the posterior auricular, temporal, and internal maxillary arteries. The upper half of the membrana tympani is much more richly supplied with blood than the lower half. For this reason, and also to avoid the chorda tympani nerve and ossicles, incisions through the membrane should be made at the lower and posterior part.

The principal point in connection with the surgical anatomy of the tympanum is its relations to other parts. Its roof is formed by a thin plate of bone, which, with the dura, is all that separates it from the temporal lobe of the brain. Its floor is immediately above the jugular fossa and the carotid canal, the fossa being behind and the canal in front. Its posterior wall presents the openings of the mastoid cells. On its anterior wall is the opening of the Eustachian tube. Thus it follows that in disease of the middle ear we may get subdural abscess, septic meningitis, or abscess of the cerebrum or cerebellum from extension of the inflammation through the bony roof; thrombosis of the lateral sinus, with or without pyemia, by extension through the floor; or mastoid abscess by extension backward. In addition to this, we may get fatal hemorrhage from the internal carotid in destructive changes of the middle ear; and in throat disease we may get the inflammation extending up the Eustachian tube to the middle ear. The Eustachian tube is accessible from the nose. If the nose and mouth be closed and an attempt made to expire air, a sense of pressure with dulness of hearing is produced in both ears, from the air finding its way up the Eustachian tube and bulging out the membrana tympani. During the act of swallowing, the pharyngeal orifice of the tube, which is normally closed, is opened, probably by the action of the Dilator tubea muscle. This fact was employed by Politzer in devising an easy method of inflating the tube. The nozzle of an india-rubber syringe is inserted into the nostril; the patient takes a mouthful of water and holds it in his mouth, both nostrils are closed with the finger and thumb to prevent the escape of air, and the patient is then requested to swallow; as he does so the
surgeon squeezes the bulb and the air is forced out of the syringe into his nose, and is driven into the Eustachian tube, which is now open. The impact of the air against the membrana tympani can be heard by the surgeon, if the membrane is intact, sound being conveyed by means of a piece of india-rubber tubing, one end of which is inserted into the meatus of the patient’s ear, the other into that of the surgeon. The direct examination of the Eustachian tube is made by the Eustachian catheter. This is passed along the floor of the nostril, close to the septum, with the point touching the floor, to the posterior wall of the pharynx. When this is felt, the catheter is to be withdrawn about half an inch, and the point rotated outward through a quarter of a circle, and pushed again slightly backward, when it will enter the orifice of the tube, and will be found to be caught, and air forced into the catheter will be heard impinging on the tympanic membrane if the ears of the patient and surgeon are connected by an india-rubber tube.

THE SKIN (INTEGUMENTUM COMMUNE).

The skin covers the body surface and is continuous with the mucous membrane at the origin and termination of the alimentary canal and at the openings of other canals. The skin is a protective coat, a regulator of body-temperature, contains multitudes of the terminations of sensor nerves, and is the seat of the organ of touch (organon tactus). These nerve-terminations are connected with nerve-fibres of temperature, pressure, and pain. Connected with the skin are sweat-glands which have important excretory functions and sebaceous glands. From its superficial part come appendages, the hairs, and nails. The skin is elastic and varies in thickness from 0.5 mm. to 4 mm. It is thinnest in the eyelids and prepuce, and thickest over the back of the neck, back of the shoulders, palms of the hands, and soles of the feet. Its color depends in part on the blood within it, and in part upon pigment. The deepest hue is about the anus, in the genital region, in the axillae, over the mammary glands, and in the parts exposed to air, light, and varied temperatures. The color varies with age, being pinkish in extreme youth and becoming yellow in old age. It varies with exposure and with climate, being deepest in those who brave all weathers and temperatures and in those who dwell beneath a tropical sun. It also varies with race, and this is so well recognized that races are classified by the color of the skin into the Black, White, Yellow, and Brown races. The color of the skin is also affected in certain diseases; being extremely pale in anaemia, brown in Addison’s disease, yellow in jaundice, etc.

In most situations the skin is movable, but in some it is attached closely to underlying structures, and is consequently immovable on the scalp, the palms of the hands, the soles of the feet, and the outer portion of the pinna of the ear. The skin is fairly smooth, but close examination discloses multitudes of openings, creases, furrows, depressions, folds, and hairs. Hair-follicles open upon the surface, and the ducts of sebaceous glands and of sweat-glands perforate the skin.

About the joints are folds of skin (retinacula cutis), and temporary folds or wrinkles are created by the contraction of superficial muscles. The facial wrinkles of advancing years are due to habitual expression and loss of skin elasticity. A dimple is a permanent pit or depression due to adhesion of the surface to parts beneath. The ridges and furrows on the palms, soles, and flexor aspects of the
digits are permanent, and over the palmar surface of the digits they are arranged in definite forms which endure through life and are so distinctive that they have been utilized by police officials in determining the identity of individuals. These folds are due to the papillae of the skin being arranged in rows; some of the papillae proliferate, and linear depressions occur in the horny layer (Philipppson).

**Fig. 793.**—Anterior surface.
The general course of the connective-tissue bundles of the corium, determined by the direction assumed by the linear clefts made in the skin when it is punctured by a round awl. (Langer.)

**Fig. 794.**—Posterior surface.

Fig. 792 shows skin ridges (*cristae cutis*), skin furrows (*sulci cutis*), furrows opposite joints due to acts of flexion, and called flexure furrows, and longitudinal furrows.

When the skin is punctured by a round awl it tends to split in a definite direction, which direction varies with the region stabbed. These clefts are known
as the lines of cleavage of Langer (Figs. 793 and 794), and depend upon the arrangement of the connective-tissue bundles of the corium. These connective-tissue bundles certainly influence the formation of folds and furrows. In many portions of the body the cutaneous surface is divided by linear furrows into irregularly shaped areas (Fig. 795). The skin consists of two layers: a superficial layer, the epidermis, and a deep layer, the corium or dermis.

The Corium, Cutis Vera, Dermis or True Skin (Figs. 796, 797, and 799) is a connective-tissue structure which arises from the mesoderm. It consists especially of connective tissue and elastic fibres; it contributes elasticity to the skin, and is the seat of the sensitive layer. The corium is composed of two layers, the reticular and the papillary.

The Deep or Reticular Layer or Tunica Propria (stratum reticulare) rests upon the subcutaneous tissue. It passes superficially into the papillary layer, and at most places into the subcutaneous tissue without a sharp line of differentiation. At some places, for instance in the nipple, the deep layer of the corium rests upon a layer of muscular fibre. In the face this muscle-fibre is striated and sends prolongations to the papillary layer; in the nipple and scrotum it is non-striated. The reticular layer is composed of bundles of white fibrous tissue, arranged in a network. In the meshes of the network are fat, blood-vessels, lymphatics, sebaceous glands, sweat-glands, and hair-follicles.

The Subcutaneous Areolar Tissue or Tela Subcutanea (panniculus adiposus) connects, the skin to the parts beneath; it is composed of bundles of connective tissue

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**Fig. 796.**—Vertical section through the skin of the finger-tip. The layers of the epidermis and of the corium. The subcutaneous areolar tissue. The sudoriferous or sweat-gland. (Toldt.)

**Fig. 795.**—The furrows of the skin and the areas which these furrows delimit, reproduced from an impression of the dorsal surface of the wrist. (Toldt.)
which cross repeatedly and form spaces. In almost all regions the spaces contain fat, but in the scrotum and external ear they do not contain fat. When the connective tissue fibres of the panniculus adiposus are long and nearly parallel to the skin surface the skin becomes wrinkled; when they are short and nearly at right angles to the surface, the skin cannot wrinkle.

The Superficial or Papillary Layer or Corpus Papillare of the Corium (stratum papillare) lies just beneath the epidermis, contains the papillae, and is composed of a network of fine bundles of fibrous tissue. The papillae are composed of fine strands of connective tissue and elastic tissue. They project from the corium beneath the epidermis and enter into depressions of the epidermis. They vary greatly in size, averaging \( \frac{1}{20} \) of an inch in height and \( \frac{1}{50} \) of an inch in width at the base. In the face, especially in the eyelids, they are insignificant. On the glans penis, the palms of the hands, and the soles of the feet, and in the nipples, they are large. In the palmar surfaces of the hands and fingers and the plantar surfaces of the feet and toes they produce permanent ridges (Fig. 798). A ridge is composed of two or more rows of papillae, and the ducts of sweat-glands emerge between rows of papillae, and open on the curved surface ridges (Fig. 798). Most of the papillae contain loops of capillaries, and are called vascular papillae. Some contain nerve-terminations and are called nervous papillae. Between the papillary layer of the corium and the epidermis is a very thin and structureless membrane called the basal membrane.

![Diagram of the skin layers](image)

**The Cuticle, Scarf Skin or Epidermis** (Figs. 796, 797, 799, and 800).—The cuticle, scarf skin or epidermis is composed of layers of epithelium and is derived from the ectoderm. The epithelium is stratified, and there are no blood-vessels. Two layers can be readily made out, the superficial or horny layer and the deeper or Malpighian layer.

**The Horny Layer** (stratum corneum).—The horny layer is formed by several layers of non-nucleated scaly cells. The cells consist of keratin. The surface cells of the horny layers are being constantly rubbed off, and are being replaced by cells from the Malpighian layer, which are converted into keratin as they near the surface.
The Malpighian Layer.—The Malpighian layer of the epidermis is divided into four layers, named, from without inward, the stratum lucidum, the stratum granulosum, the stratum mucosum, and the stratum germinativum.

The Stratum Lucidum is not classified by all writers as part of the Malpighian layer. Some anatomists classify it as a separate layer. It is here regarded as the most superficial part of the Malpighian layer. It consists of several layers of flat cells, the nuclei of which are beginning to disappear. The cells contain eleidin granules. In regions where the epidermis is thin the stratum lucidum is absent.

The Stratum Granulosum consists of several layers of nucleated flat cells, containing keratohyaline granules. These granules are probably formed from the disintegrating nucleus, and in the stratum lucidum are converted into eleidin.

The Mucous Layer, the Stratum Spinosum or the Stratum Mucosum consists of numerous layers of nucleated, polygonal, spine-shaped cells known as prickle cells or finger cells. Between the cells of the stratum mucosum are spaces containing pigment granules and leukocytes. Processes from the prickle-cells join adjacent cells. This layer contains numerous connective-tissue fibres arranged in a network, and known as epidermic fibrils.

The Stratum Cylindricum or Stratum Germinativum is composed of cylindrical or prickle-cells, the points of which are directed downward. Fine fibrils pass up from the corium between the cells, and there is cement-substance as well between them.

Pigmentation of the Skin.—As previously stated, in certain regions the skin of the white race is brown because of pigmentation (areolae, nipples, around the anus, axillae, scrotum, labia majora). This is due to pigment within the epithelial and
connective-tissue cells of the papillary layer of the corium, and in the basal cells of the epidermis. There are few or none of these pigmented cells in the stratum corneum of one of the Caucasian race.

In negroes and other colored races the deep pigmentation is due to a similar distribution of the pigment granules in the entire epidermis; but even here the pigmentation decreases toward the surface, although the uppermost cells of the stratum corneum always contain some pigment. The nuclei of the cells are always free from coloring matter. The question as to the origin of the pigment is as yet unsolved."

The Arteries and Veins of the Skin (Fig. 802).—The arteries supplying the skin vary in number, and vary much in size, being largest in regions exposed to pressure, as the skin of the palms, soles, and buttocks. The arteries enter the skin from a network in the subcutaneous tissue, and by an anastomosis in the deepest part of the corium form a network (rete arteriosum cutaneum). The vessels send branches to the fat and to the sweat-glands. Branches from the network just described ascend and form a second network in the corium beneath the papillae. This is called the subpapillary network (rete arteriosum subpapillare). From this network fine capillary vessels pass into the papillae, forming, in the smaller papillae, a single capillary loop, but in the larger a more or less convoluted vessel. From this network branches go to the hair-follicles and sebaceous glands. The blood from the papillae passes into a plexus (rete venosum) beneath the papillae. This communicates with another plexus in the skin of the sole of the foot. (Spalteholz.)

In some regions one or more retia are interposed between these two. The veins from the sweat-glands, sebaceous glands, superficial fat, and hair-follicles are received by the retia venosa. From the deepest rete veins pass to the subcutaneous tissue, and these veins enter the large subcutaneous veins.

The Lymphatics of the Skin.—There are numerous lymphatics supplied to the skin which form two networks, superficial and deep, communicating with each other and with the lymphatics of the subcutaneous tissue by oblique branches. They originate in the cell-spaces of the tissue.

The Nerves of the Skin.—The nerves of the skin terminate partly in the epidermis (Figs. 796 and 800) and partly in the cutis vera (Fig. 796). The former are prolonged into the epidermis from a dense plexus in the superficial layer of the corium and terminate between the cells in bulbous extremities; or, according to some observers, in the deep epithelial cells themselves. The latter terminate in end-bulbs, touch-corpuscles, or Pacinian bodies (Figs. 524 and 796), in the manner already described; and, in addition to these, a considerable number of fibrils are distributed to the hair-follicles, which are said to entwine about the follicle in a circular
manner. Other nerve-fibres are supplied to the plain muscular fibres of the hair-follicles (arrectores pili) and to the muscular coat of the blood-vessels. These are probably amyelinic fibres.

The Appendages of the Skin.

The appendages of the skin are the nails, the hairs, the sudoriferous and sebaceous glands, and their ducts.

The nails and hairs are peculiar modifications of the epidermis, consisting essentially of the same cellular structure as that tissue.

The Nails (ungues) (Figs. 803, 804, 805, 806, 807, and 808).—The nails are flattened, elastic structures of a horny texture, placed upon the dorsal surface of the terminal phalanges of the fingers and toes. Each nail is convex on its outer surface, concave within. Its chief mass, called the body (corpus unguis), lies upon the nail-bed. The free edge is called the margo liber. Each lateral margin (margo lateralis), like the proximal short edge of the nail (margo occultus), lies in a groove of the cutis, the ungual fold (sulcus matrixis unguis). The ungual wall (vallum unguis) overlies the lateral and posterior edges. The nail is implanted by means of a portion, called the root (radix unguis), into a groove in the skin. The root is beneath the ungual wall and is composed of cells which have not yet become horny. It is white in color. The nail has a very firm adhesion to the cutis vera, being accurately moulded upon the surface of the true skin, as the epidermis is in other parts. The part of the cutis beneath the body and root of the nail is called the matrix (matrix unguis), because it is the part from which the nail is produced. Corresponding to the body of the nail, the matrix is thick, and raised into a series of longitudinal ridges (cristae matrixis unguis), which are very vascular, and the color is seen through the transparent tissue. Behind this, near the root of the nail, the papillae are small, less vascular, and have no regular arrangement, and here the tissue of the nail is somewhat more opaque; hence this portion is of a whiter color, and is called the lunula on account of its crescentic shape.
The cuticle, as it passes forward on the dorsal surface of the finger or toe, is attached to the surface of the nail, a little in advance of the nail root; at the extremity of the finger it is connected with the under surface of the nail a little behind its free edge. The cuticle and the horny substance of the nail (both epidermic structures) are thus directly continuous with each other. The nails consist of a greatly thickened stratum lucidum, the stratum corneum forming merely the thin cuticular fold (eponychium) which overlaps the lunula. The cells have a laminated arrangement, and are essentially similar to those composing the epidermis. The deepest layer of cells, which lie in contact with the papillae of the matrix, are columnar in form and arranged perpendicularly to the surface; those which succeed them are of a rounded or polygonal form, the more superficial ones becoming broad, thin, and flattened, and so closely compacted as to make the limits of each cell very indistinct. It is by the successive growth of new cells at the root and under surface of the body of the nail that it advances forward and maintains a due thickness, while, at the same time, the growth of the nail in the proper direction is secured. As these cells in their turn become displaced by the growth of new ones, they assume a flattened form, and finally become closely compacted together into a firm, dense, horny texture. In chemical composition the
The Hairs (pili) (Figs. 797, 799, 801, 809, 810, and 811).—The hairs are peculiar modifications of the epidermis, and consist essentially of the same structure as that membrane. They are found on nearly every part of the surface of the body, excepting the palms of the hands, soles of the feet, the vermillion borders of the lips, the dorsal surfaces of the phalanges, the nipples, the inner surface of the prepuce, and the glans penis. Hairs include hairs of the head (capilla); of the eyebrows (supercilia); of the beard (barba); of the ears (tragi); of the nostrils (vibrisseae); the eyelashes (cilia); hairs of the axilla (hirci); pubes (pubes); and the small hairs of the skin or woolly hairs (lanugo). They vary much in length, thickness, and color in different parts of the body and in different races of mankind. In some parts, as in the skin of the eyelids, they are so short as not to project beyond the follicles containing them; in others, as upon the scalp, they are of considerable length; again, in other parts, as the eyelashes, the hairs of the pubic region, and the whiskers and beard, they are remarkable for their thickness. Straight hairs are stronger than curly hairs, and present on transverse section a cylindrical or oval outline; curly hairs, on the other hand, are flattened. The hairs are usually oblique to the surface from which they arise (Fig. 797). Their direction depends upon the region from which they spring, being fairly regular in certain regions. Thus are formed hair-streams (flu-mina pilorum) and hair-whirlpools (vortices pilorum).

A hair consists of the root, the part implanted in the skin; the shaft or stem, the portion projecting from its surface; and the point.

The Root of the Hair (radix pili) presents at its extremity a bulbous enlargement, the hair-bulb (bulbus pili) (Figs. 799 and 809), which is whiter in color and softer in texture than the shaft, and is lodged in a follicular involution of the epidermis called the hair-follicle (folliculus pili) (Figs. 797 and 801). When the hair is of considerable length the follicle extends into the subcutaneous cellular tissue (Fig. 799). The hair-follicle commences on the surface of the skin with a funnel-shaped opening, and passes inward in an oblique or curved direction—the latter in curly hair—to become dilated at its deep extremity or fundus (fundus folliculi pili), where it corresponds with the bulbous condition of the hair which it contains. It has opening into it, near its free extremity, the orifices of the ducts of one or more sebaceous glands (Figs. 799, 801, 809, and 810). At the bottom of each hair-follicle is a small conical, vascular eminence or papilla, the hair-papilla (papilla pili) (Figs. 809 and 810),

nails resemble the upper layers of the epidermis, containing, however, a somewhat larger proportion of carbon and sulphur (Mulder).
similar in every respect to the papillae found upon the surface of the skin; it is continuous with the dermic layer of the follicle, is highly vascular, and is probably supplied with nerve fibrils. In structure the hair-follicle consists of two coats—an outer or dermic, and an inner or epidermic (Figs. 809 and 811).

The Outer or Dermic Coat is formed mainly of fibrous tissue; it is continuous with the corium, is highly vascular, and is supplied by numerous minute nerve filaments. It consists of three layers. The most internal, the cuticular lining of the follicle, consists of a hyaline basement-membrane, the hyaline layer, having a glassy, transparent appearance, which is well marked in the larger hair-follicles, but is not very distinct in the follicles of minute hairs. It is continuous with the basement-membrane of the surface of the corium. External to this is the inner fibrous layer, a compact layer of fibres and spindle-shaped cells arranged circularly around the follicle. This layer extends from the bottom of the follicle as high as the entrance of the ducts of the sebaceous glands. Externally is the outer fibrous layer, a thick layer of connective tissue, arranged in longitudinal bundles, forming a more open texture and corresponding to the reticular part of the corium. In this are contained the blood-vessels and nerves.

Fig. 810.—Vertical section through the skin of the head. The hairs of the head in longitudinal section. (Toldt.)

The Inner or Epidermic Layer is closely adherent to the root of the hair, so that when the hair is plucked from its follicle this layer most commonly adheres to it and forms what is called the root-sheath. It consists of two strata, named respectively the outer and inner root-sheaths; the former of these corresponds with the Malpighian layer of the epidermis, and resembles it in the rounded form and soft character of its cells; at the bottom of the hair-follicle these cells become continuous with those of the root of the hair. The inner root-sheath consists of a delicate cuticle next the hair, composed of a thin layer of imbricated scales having a downward direction, so that they fit accurately over the upwardly directed imbricated scales of the hair itself; then of one or two layers of horny, flattened nucleated cells, known as Huxley’s layer; and finally of a single layer of horny oblong cells without visible nuclei, called Henle’s layer.

The hair-follicle contains the root of the hair, which terminates in a bulbous extremity, and is excavated so as to exactly fit the papilla from which it grows. The bulb is composed of polyhedral epithelial cells, which as they pass upward into the root of the hair become elongated and spindle-shaped, except some in the centre which remain polyhedral. Some of these latter cells contain pigment-
granes, which give rise to the color of the hair. It occasionally happens that these pigment-granules completely fill the cells of the medullary substance in the centre of the bulb, which gives rise to the dark tract of pigment often found, of greater or less length, in the axis of the hair.

The Stem or Shaft of the Hair (scapus pili) (Fig. 809), consists of a central pith or medulla, the fibrous part of the hair, and the true cuticle externally. The medulla (substantia medullaris pili) occupies the centre of the shaft and ceases toward the point of the hair. It is usually wanting in the fine hairs covering the surface of the body, and commonly in those of the head. It is found in the shafts of all thick hairs and in the deeper parts of the root of most hairs. It is more opaque and deeper colored when viewed by transmitted light than the fibrous part; but when viewed by reflected light it is white. It is composed of rows of polyhedral cells, which contain granules of eleidin and frequently air-bubbles. The fibrous portion or cortical substance of the hair (substantia corticalis pili) constitutes the chief part of the shaft; its cells are elongated and unite to form flattened fusiform fibres. Between the fibres are found minute spaces which contain either pigment-granules in dark hair or minute air-bubbles in white hair. In addition to this there is also a

diffused pigment contained in the fibres. The cells which form the outer hair membrane or true cuticle (cuticula pili) consist of a single layer which surrounds those of the fibrous part; they are converted into thin, flat scales, having an imbricated arrangement.

Connected with the hair-follicles are minute bundles of involuntary muscular fibres, termed arrectores pili (mm. arrectores pilorum) (Figs. 797 and 809). They arise from the superficial layer of the corium, and are inserted into the outer surface of the hair-follicle, below the entrance of the duct of the sebaceous gland. They are placed on the side toward which the hair slopes, and by their action elevate the hair. When the hair is elevated a depression forms over the seat of origin of the muscle, and the parts about the hair are elevated. This condition is known as goose-skin. It is probable that the contraction of these muscles aids in emptying sebaceous glands.

Blood-vessels and Nerves (Fig. 799).—A hair-follicle possesses a rich network of capillaries about the hyaline membrane, and capillary loops pass to the papilla.

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1 Arthur Thomson suggests that the contraction of these muscles on follicles which contain weak, flat hairs will tend to produce a permanent curve in the follicle, and this curve will be impressed on the hair which is moulded within it, so that the hair, on emerging through the skin, will be curled. Curved hair-follicles are characteristic of the scalp of the Bushman.—Ed. of 15th English edition.
We have little knowledge as to nerve-terminations of the human hair. "In other mammals the nerves end below the sebaceous glands. Myelinic fibres lose their medullary sheaths, divide, and penetrate to the hyaline membrane. Here some of the branches encircle the hair, while others end freely on the hyaline membrane as naked axis-cylinders. These branch regularly and run parallel to the long axis of the hair."

The Sudoriferous or Sweat-glands (glandulae sudoriferae) (Figs. 796, 797, 799, 801, and 810).—The sudoriferous or sweat-glands are the organs by which a large portion of the aqueous and gaseous substances is excreted by the skin. They are found in almost every part of this structure, being absent on the red border of the lips, the glans penis, and inner surface of the prepuce. On the eyelids they are somewhat modified, and are called ciliary glands (glandulae ciliares [Molli]); about the anus they are extremely large, and are called circumanal glands (glandulae circumanales). The sweat-glands are situated in small pits below the under surface of the corium, or, more frequently, in the subcutaneous areolar tissue, surrounded by a quantity of adipose tissue. They are small, lobular, reddish bodies, consisting of a single convoluted tube, from which the efferent duct (ductus sudoriferus) proceeds upward through the corium and cuticle. The duct in the corium has true walls; in the epidermis it has not individual walls, but is simply an epidermic tube. It becomes somewhat dilated at its extremity, and opens on the surface of the cuticle by an oblique valve-like aperture (porus sudoriferus). The duct, as it passes through the epidermis, presents a spiral arrangement, being twisted like a corkscrew, in those parts where the epidermis is thick; where, however, the epidermis is thin, the spiral arrangement does not exist. In the superficial layers of the corium the duct is straight, but in the deeper layers it is convoluted or even twisted. The spiral course of these ducts is especially distinct in the thick cuticle of the palm of the hand and sole of the foot. The size of the glands varies. They are especially large in those regions where the flow of perspiration is copious, as in the axillae, where they form a thin, mamillated layer of a reddish color, which corresponds exactly to the situation of the hair in this region; they are large also in the groin. Their number varies. They are most numerous on the palm of the hand, presenting, according to Krause, 2800 orifices on a square inch of the integument, and are rather less numerous on the sole of the foot. In both of these situations the orifices of the ducts are exceedingly regular, and open on the curved surface ridges. In other situations they are more irregularly scattered, but the number in a given extent of surface presents a fairly uniform average. In the neck and back they are least numerous, their number amounting to 417 on the square inch (Krause). Their total number is estimated by the same writer at 2,381,248, and, supposing the aperture of each gland to represent a surface of \( \frac{1}{37} \) of a line in diameter, he calculates that the whole of these glands would present an evaporating surface of about eight square inches. Each gland consists of a single tube intricately convoluted, terminating at one end by a blind extremity, and opening at the other end upon the surface of the skin.

The wall of the tubercle of the secreting coil is lined with cubical epithelial cells, external to these is a layer of smooth muscle-cells, and more externally a layer of connective tissue, the membrana propria. The duct in the corium, in contrast to the secreting coil, has no layer of muscle-cells, but instead a second layer of epithelial cells covered by connective tissue. As previously stated, the duct becomes spiral in the epidermis, its own wall disappears, and the channel is bounded by epidermic cells.

Blood-vessels and Nerves.—The blood-vessels are branches from the subcutaneous vessels and the arterial plexus of the deep part of the corium. Numerous

1 Histology and Microscopic Anatomy. By Dr. Ladislaus Szymonowicz. Translated and edited by John Bruce MacCallum, M.D.
anyeline nerve-fibres lie upon the membrana propria of a sweat-gland. From them fibrils pass inward and terminate by end-bulbs upon the cells of the gland.

The Sebaceous Glands (glandulae sebaceae).—The sebaceous glands are small, sacculated, glandular organs, lodged in the substance of the corium. They are found in most parts of the skin, and are usually connected with hair-follicles. This connection is so common that they are sometimes called hair-follicle glands. They are found in some regions which are devoid of hairs—the vermillion borders of the lips, the labia minora, the glans penis, and prepuce. These glands are especially abundant in the scalp and face; they are also very numerous around the apertures of the anus, nose, mouth, and external ear; but are wanting in the palms of the hands and soles of the feet. Each gland consists of a single duct, more or less capacious, which terminates in a cluster of small secreting pouches or saccules. The sacculi connected with each duct vary, in number, as a rule, from two to five, but in some instances may be as many as twenty. They are composed of a transparent, colorless membrane, enclosing a number of epithelial cells. Those of the outer or marginal layer are small and polyhedral, and are continuous with the lining cells of the duct. The remainder of the sac is filled with larger cells, containing fat, except in the centre, where the cells have become broken up, leaving a cavity containing their debris and a mass of fatty matter, which constitutes the sebaceous secretion. The orifices of the ducts open most frequently into the hair-follicles, but occasionally upon the general surface, as in the labia minora and the free margins of the lips. On the nose and face the glands are of large size, distinctly lobulated, and often become much enlarged from the accumulation of pent-up secretion. The largest sebaceous glands are those found in the eyelids—the Meibomian glands.
THE ORGANS OF DIGESTION.

THE Apparatus for the Digestion of the Food (apparatus digestorius) consists of the alimentary canal and of certain accessory organs.

THE ALIMENTARY CANAL.

The alimentary canal is a musculo-membranous tube, about thirty feet in length, extending from the mouth to the anus, and lined throughout its entire extent by mucous membrane. It has received different names in the various parts of its course; at its commencement, the mouth, we find provision made for the mechanical division of the food (mastication), and for its admixture with a fluid secreted by the salivary glands (insalivation); beyond this are the pharynx and the oesophagus, the organs which convey the food (deglutition) into that part of the alimentary canal, the stomach, in which the principal chemical changes occur, and in which the reduction and solution of the food take place; in the small intestines the nutritive principles of the food, the chyle, are separated, by its admixture with the bile, pancreatic and intestinal fluids, from that portion which passes into the large intestine, most of which is expelled from the system.

Alimentary Canal.

Mouth. Small intestine { Duodenum.
Pharynx. Jejunum.
Oesophagus. Ileum.
Stomach. Caecum.
Large intestine { Colon.
Rectum.

Accessory Organs.

Teeth. { Parotid.
Salivary glands { Submaxillary.
{ Sublingual. Liver.
Pancreas.
Spleen.

THE MOUTH, ORAL OR BUCCAL CAVITY (CAVUM ORIS).

The mouth is placed at the commencement of the alimentary canal; it is a nearly oval-shaped cavity, in which the mastication and insalivation of the food take place (Figs. 812, 831, and 837).

The aperture of the mouth (rima oris) is bounded by the lips. The angle of the mouth (angulus oris) is formed on each side by the meeting of the upper and lower lips (commissura labiorum). When at rest with the lips in contact, the rima is a slightly curved line. Every movement which the lips make alters the shape of the rima. When the mouth is closed the floor and roof are usually in contact and its sides are approximated to the dental arches. The mouth consists of two
parts: an outer, smaller portion, the vestibule, and an inner, larger part, the cavity proper of the mouth.

The Vestibule (vestibulum oris).—The vestibule is a slit-like space, bounded in front and laterally by the lips and cheeks; behind and internally by the gums and teeth. Above and below it is limited by the reflection of the mucous membrane from the lips and cheeks to the gum covering the upper and lower alveolar arch respectively. It receives the secretion from the parotid glands, and communicates, when the jaws are closed, with the cavum oris by an aperture on each side behind the wisdom teeth.

The Cavity of the Mouth Proper (cavum oris proprium).—The cavity of the mouth proper is bounded laterally and in front by the alveolar arches with their contained teeth; behind it communicates with the pharynx by a constricted aperture termed the isthmus faucium. It is roofed in by the hard and soft palate. The greater part of the floor is formed by the tongue, the remainder being completed by the reflection of the mucous membrane from the sides and under surface of the tongue to the gum lining the inner aspect of the mandible. It receives the secretion from the submaxillary and sublingual glands.

The Mucous Membrane.—The mucous membrane lining the mouth is continuous with the integument at the free margin of the lips and with the mucous lining of the pharynx behind; it is of a rose-pink tinge during life, and very thick where it covers the hard parts bounding the cavity. It is covered by stratified epithelium.

The Lips (Labia Oris).

The lips are two fleshy folds which surround the orifice of the mouth, formed externally by integument and internally by mucous membrane, between which are found the Orbicularis oris muscle (Fig. 263), the coronary vessels (Fig. 397), some nerves (Fig. 397), areolar tissue, and fat, and numerous small labial glands. The upper lip is called the labium superius; the lower lip is called the labium inferius. The inner surface of each lip is connected in the middle line to the gum of the corresponding jaw by a fold of mucous membrane, the frenulum (frenulum labii superius and frenulum labii inferioris). The frenulum labii superioris is the larger of the two. On each side, external to the angle of the mouth, the lips become continuous.

The Labial Glands (glandulae labiales) (Fig. 397):—The labial glands are situated between the mucous membrane and the Orbicularis oris muscle around the orifice of the mouth. They are rounded in form, about the size of small peas, and their ducts open by minute orifices upon the mucous membrane. In structure they resemble the salivary glands.
The Cheeks (Buccae).

The cheeks form the sides of the face and are continuous in front with the lips. They are composed externally of integument, internally of mucous membrane, and between the two of a muscular stratum, besides a large quantity of fat, areolar tissue, vessels, nerves, and buccal glands.

The Mucous Membrane.—The mucous membrane lining the cheek is reflected above and below upon the gums, where its color becomes lighter; it is continuous behind with the lining membrane of the soft palate. Opposite the second molar tooth of the upper jaw is a papilla, the summit of which presents the aperture of the duct of the parotid gland (ductus parotideus [Stenonis]) (Fig. 837). The principal muscle of the cheek is the Buccinator, but numerous other muscles enter into its formation—viz., the Zygomatici, Risorius Santorini, and Platysma myoides.

The Buccal Glands (glandulae buccales).—The buccal glands are placed in the submucous tissue between the mucous membrane and Buccinator muscle; they are similar in structure to the labial glands, but smaller. Four or five glands of larger size than the previously mentioned glands are placed beneath the mucous membrane in the neighborhood of the last molar tooth. They are called the molar glands (glandulae molares). Their ducts open into the mouth opposite the last molar tooth.

The Gums (Gingiva).

The gums are composed of a dense fibrous tissue closely connected to the periosteum of the alveolar processes and surrounding the necks of the teeth. They are covered by smooth and vascular mucous membrane, which is remarkable for its limited sensibility. Around the necks of the teeth this membrane presents numerous fine papillae; and from this point it is reflected into the alveolus, where it is continuous with the periosteal membrane lining that cavity.

The Teeth (Dentes).

The human subject is provided with two sets of teeth, which make their appearance at different periods of life. The first set appear in childhood, and are called the temporary, deciduous or milk teeth. The second set are named permanent.

The temporary teeth are twenty in number—four incisors, two canine, and four molars in each jaw (Figs. 813 and 830).

The permanent teeth are thirty-two in number—four incisors (two central and two lateral), two canines, four bicuspids, and six molars in each jaw (Figs. 815 and 819).

General Characters (Fig. 820).—Each tooth consists of three portions; the crown or body (corona dentis), projecting above the gum; the root or fang (radix dentis), entirely concealed within the alveolus; and the neck (collum dentis), the constricted portion, between the root and crown.

Surfaces.—The surfaces of a tooth are named thus: that which comes in contact with the teeth of the opposite jaw is the grinding or masticating surface (facies masticatoria); that which touches the next tooth in the same row is the contact surface (facies contactus). That surface which is toward its predecessor is called the proximal surface (in incisors and canines, facies medialis; in molars and premolars, facies anterior). That surface which is toward its successor is called the distal surface (in incisors and canines, facies lateralis; in molars and premolars, facies posterior). That which looks toward the lips and cheek is the labial or buccal surface (facies labialis). That toward the tongue is the lingual surface (facies lingualis). In part this method of designation applies to the roots as well as to the crowns of teeth.
The Roots of the Teeth.—The roots of the teeth are firmly implanted within the sockets or alveoli of the jaws (alveoli dentales) (see pp. 109 and 124). These depressions are lined with periosteum, called the pericementum, which is reflected on to the tooth at the point of the root and covers it as far as the neck. This is the root membrane (periostea alveolare). At the margin of the alveolus the periosteum becomes continuous with the fibrous structure of the gums.

Temporary, Deciduous or Milk Teeth (dentes decidui) (Figs. 813, 814, and 830).—The temporary or milk teeth are smaller, but resemble in form those of the permanent set. The neck is more marked, owing to the greater degree of convexity of the labial and lingual surfaces of the crown. The hinder of the two temporary molars is the largest of all the deciduous teeth, and is succeeded by the second bicuspid. The first upper molar has only three cusps—two labial, one lingual; the second upper molar has four cusps. The first lower molar has four cusps; the second lower molar has five. The roots of the temporary molar teeth are smaller and more diverging than those of the permanent set, but in other respects bear a strong resemblance to them.

Permanent Teeth (dentes permanentes) (Figs. 815, 816, 817, and 819). The Incisors (dentes incisivi).—The incisors or cutting teeth are so named from their presenting a sharp cutting edge, adapted for incising the food. They are eight in number, and comprise the four front teeth in each jaw.

The crown is directed almost vertically and is spade-like in form; it has the form of a truncated cone whose top has been compressed into a sharp horizontal cutting
edge. Before being subjected to attrition this edge presents three small elevations. The labial surface is convex, and marked by free longitudinal ridges extending from the edge tubercles toward the neck of the tooth. The lingual surface is concave, and is marked by two marginal ridges extending from an encircling ridge at the neck to the angles of the cutting edge of the tooth. The ridge at the neck is termed the cingulum or basal ridge. The mesal and distal surfaces are triangular, the apex of the triangle being at the cutting edge. The neck of the tooth is constricted. The root is long, single, and has the form of a transversely flattened cone, thicker before than behind. The root may be curved.

The Incisors of the Upper Jaw are altogether larger and stronger than those of the lower jaw, the central incisors being larger and flatter than the lateral incisors. They are directed obliquely downward and forward.

The Incisors of the Lower Jaw are smaller and flatter than the upper, and the elevations upon their lingual faces are not marked. The two central are smaller than the two lateral incisors, being the smallest of all the teeth. The roots of these teeth are flattened laterally.

The Canine Teeth or Cuspidati (dentes canini).—The canine teeth are four in number, two in the upper, two in the lower jaw—one being placed distal to each lateral incisor. They are larger and stronger than the incisors, especially in the roots, which are deeply implanted and each causes a well-marked prominence of the process at the place of insertion.

The crown is large, of spear-head form, and its very convex labial surface is marked by three longitudinal ridges. The concave lingual surface is also marked by three ridges which unite at a basal ridge. The point or cusp is longer than in the other teeth, and is the point of division between a short mesal and a long distal cutting edge. These two edges form an obtuse angle with each other.

The root is single, oval, or elliptical on transverse section, and is longer and more prominent than the roots of the incisors.

The Upper Canines or cuspids, vulgarly called the eye teeth, are larger and longer than the two lower, and in occlusion are distal to them to the extent of half the width of the crown.

The Lower Canines, vulgarly called the stomach teeth, have the general form of the upper cuspids, but their lingual surfaces are much more flattened, owing to
the absence of the elevations marking the upper. Their roots are more flattened and may be bifid at their apices.

The Bicuspid Teeth or the Premolars (*dentes premolares*).—The bicuspid teeth are eight in number, four in each jaw; they are placed distal to the cuspid teeth, two upon each side of the jaw. They are double cuspids in form. The crown is surmounted by two cusps, one buccal and one lingual, separated by a groove, the buccal being more prominent and larger than the lingual. The lower bicuspids are not truly bicuspid, the first having but a primitive lingual cusp, the second having the lingual cusp divided into two sections—*i. e.*, it is usually tricuspid. The necks of the teeth are oval; the roots are single and laterally compressed, that of the first upper bicuspid being frequently bifid. The first upper bicuspid is usually the largest of the series. The roots of the lower bicuspid are less compressed and more rounded.

The Molar Teeth, the Multicuspidati or Grinders (*dentes molares*).—The molar teeth are the largest and strongest teeth of the denture. They are adapted by their forms for the crushing and grinding of the food. They are twelve in number, six in each jaw, three being placed posterior to each second bicuspid.

The crowns are cuboidal in form, are convex buccally and lingually; they are flattened mesially and distally. They are formed by the fusion of three primitive cusps in the upper and four in the lower. To these are added in the first and second upper molars a *disto-lingual tubercle*, and in the first and third molars of the lower jaw a *disto-buccal tubercle*. The unions of the primitive forms are marked by sulci. The necks of these teeth are large and rhomboidal in form. The roots of the upper molars are three in number—one large *lingual* or *palatal root*, and two smaller *buccal roots*. In the lower molars, two roots are found, a mesial and a distal, each of which is much flattened from before backward.

The First Molar Teeth are the largest of the dental series; they have four cusps on the upper and five in the lower—three buccal and two lingual.

The Second Molars are smaller; the crowns of the upper are compressed until the disto-lingual cusp is reduced. The crowns of the lower are almost rectangular, with a cusp at each angle.

The Third Molars are called the wisdom teeth or *dentes sapientae* (*dentes serotini*), from their late eruption; they have three cusps upon the upper and five upon the lower. The three roots of the upper are frequently fused together, forming a grooved cone, which is usually curved backward. The roots of the lower, two in number, are compressed together, and curve backward.

**Arrangement of the Teeth.**—The human teeth are arranged in two parabolic arches, the upper row or arch (*arcus dentalis superior*) being larger, its teeth overlapping the lower row or arch (*arcus dentalis inferior*). The average distance between the centres of the condyles of the inferior maxillary bones is about four inches, which is also the distance from either of these points to the line of junction between the lower incisor teeth. Whether the jaw be large or small, the equilateral triangle indicated is included in it; the range of size is between three and one-half and four and one-half inches.

Owing to the smaller sizes of the lower incisors, the teeth of the lower jaw are each one-half a tooth in advance of its upper fellow, so that each tooth of the dental series has two antagonists, with the exception of the lower central incisors and upper third molars (Figs. 818 and 819).

The grinding faces of the upper bicuspid and molars curve progressively upward and point outward, the first molar being at the lowest point of the curve, the third molar at the highest. The curve of the lower dental arch is the reverse, the first molar at its deepest part, the third molar at its extremity. The greater the depth
to which the upper incisors overlap the lower, the more marked this curve and the more pointed are the cusps of the grinding teeth.

The movement of the human mandible is forward and downward, the resultant of these directions being an oblique line, upon an average of 35 degrees from the horizontal plane.¹ When the lower jaw is advanced until the cutting edges of

¹ W. E. Walker, Dental Cosmos, 1896.
the incisors are in contact, the jaws are separated, but at the highest point of the lower arch its third molar advances, and meets and rests upon a high point, the second molar of the upper arch, and thus undue strain upon the incisors is obviated.

In the lateral movements of the mandible but one side is in effective action at one time; the oblique positions of the cusps of the opposite teeth are such that when either side is in action the other is balanced at two or more points.

There is an anatomical correspondence between the forms and arrangement of the teeth, the form of the condyle of the mandible, and the muscular arrangement. Individuals who have teeth with long cusps have the head of the bone much rounded from before backward, and have a preponderance of the direct over the oblique muscles of mastication, and vice versa; teeth with short or no cusps are associated with a flattened condyle and strong oblique muscles.

Very great aberrations in the dental arrangement are frequently followed by accommodative changes in the heads of the mandible.

Structure of the Teeth. The Dental Pulp (pulpa dentis).—A longitudinal section of a tooth will show the presence of a central chamber having the general form of the crown of the tooth. Processes of the chamber pass from its body, one for each root and down each root, and open at the apex by a minute orifice. This cavity is known as the pulp-chamber or pulp-cavity (carum dentis) (Figs. 820 and 821). The minute canal in each root is called the pulp-canal or root-canal (canalis radicis dentis). The foramen at the apex of the root is the apical foramen (foramen apicis dentis). The cavity contains a soft, vascular, and sensitive organ called the dental pulp (pulpa dentis). It is made up of fibrous cellular connective tissue, the fibres of which are extremely fine, and contains numerous blood-vessels and nerves, which enter by way of the apical foramina. It has not been proved that there are lymphatics in the dental pulp, although some authors assert that they exist (Wangemann and others). It seems to have been proved that the spaces between the fibres of the pulp communicate with the lymphatic system. The periphery of the pulp is bounded by a layer of cells arranged like columnar epithelium, each cell sending one or more branched processes through the basic substance

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**Fig. 820.—Vertical section of a molar tooth.**

**Fig. 821.—Vertical section of a tooth in situ (15 diameters). 1 is placed in the pulp-cavity, opposite the cervix or neck of the tooth; the part above is the crown, that below is the root (fang). 1. Enamel with radial and concentric markings. 2. Dentine with tubules and incremental lines. 3. Cement or crista petrosa, with bone corpuscles. 4. Dental periosteum. 5. Bone of lower jaw.**
of the dentine. These processes constitute the dentine fibres. Other processes come off from the cells which pass in the direction of the pulp and surround it. The cells at the periphery of the pulp are the dentine-forming cells, the odontoblasts of Waldeyer. The blood-vessels break up into innumerable capillary loops which lie beneath the layer of odontoblasts. The nerve-fibrils break up into numberless amyleinic filaments, which spread out beneath the odontoblasts, and probably send terminal filaments to the extreme periphery of the pulp outside the odontoblasts.

The matrix cells and their processes are irregularly arranged in the body of the pulp, but in the canal portion the fibrillae are in the direction of the axis of the root.

**The Solid Portion of the Tooth.**—The section will exhibit three hard tissues in a tooth: one, the proper dental substance, forming the greater mass of the tooth; hence its name dentine or ivory. The dentine upon the exposed crown is sheathed by a layer called the enamel; the dentine of the root is enclosed in a distinct tissue, the cementum or crista petrosa; both cementum and enamel are thinnest at the neck and thickest upon their distal portions.

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*Fig. 822.*—From a ground-section through the parts of a dentine, near the pulp, of a human canine tooth which has been impregnated with pigment. The dental canaliculi are cut across and are joined together by side branches. × 400.

*Fig. 823.*—Longitudinal ground-section through the apex of a canine tooth from a three-and-a-half-year-old boy. The entrance of the dental canaliculi between the enamel prisms and the course taken by the latter are shown. × 135. (Szymonowicz.)
The Ivory or Dentine (substantiae eburnea) (Figs. 821, 822, 823, and 824) forms the principal mass of a tooth; in its central part is the cavity enclosing the pulp. It is a modification of osseous tissue, from which it differs, however, in the fact that it does not contain cells placed in cavities, but the cells lie in the periphery of the pulp, against but not in the dentine. The dentine contains the processes of the cells, which are known as dental or dentinal fibres. On microscopic examination it is seen to consist of a number of minute wavy and branching tubes having distinct parietes. They are called the dentinal tubuli or dental canals, and are embedded in a dense homogeneous substance, the intertubular tissue.

The dentinal tubuli (canaliculi dentales) (Fig. 824) are placed parallel with one another, and open at their inner ends into the pulp-cavity. In their course to the periphery they present two or three curves, and are twisted on themselves in a spiral direction. The direction of these tubes varies; they are vertical in the upper portion of the crown, oblique in the neck and upper part of the root, and toward the lower part of the root they are inclined downward. The tubuli, at their commencement, are about \( \frac{1}{40} \) of an inch in diameter; in their course they divide and subdivide dichotomously, so as to give to the cut surface of the dentine a striated appearance. From the sides of the tubes, especially in the root, ramifications of extreme minuteness are given off, which join together in loops in the intertubular substance, or terminate in small dilatations, from which branches are given off. Near the pulp the lateral branches are few and are almost at right angles to the canals. Nearer the periphery the lateral branches are more numerous, and they come off at acute angles. The terminations of the chief canals at the periphery vary. In the crown they break up into branches like fingers just beneath the enamel. Some of these finger-like branches leave the dentine and enter the cement substance between enamel prisms. The majority of the chief canals end in blind extremities at the margin of the enamel and do not enter this structure. In the lower portion of the tooth the chief canals do not emerge from the dentine, but end at the margin of the cement in blind extremities. They may reach the spaces of the granular sheath. Near the periphery of the dentine of the crown the finer ramifications of the tubuli pass through a layer of irregular branched spaces which communicate with each other. These are called the interglobular spaces of Czermak (spatia interglobularia) (Fig. 824, J). These spaces are gaps in the dentine due to failure of calcification and are filled with uncalcified dentine. The outer part of the dentine in the lower portion of the tooth contains a layer of interglobular spaces known as the granular layer or granular sheath of Tomes. The dentinal tubuli have comparatively thick walls, and contain slender cylindrical prolongations from the processes of the cells of
the pulp-tissue already mentioned, and first described by Mr. Tomes and named Tomes's fibres or dentinal fibres. These dentinal fibres are analogous to the soft contents of the canaliculi of bone. Between Tomes's fibres and the ivory around the canals there is a tissue which is markedly resistant to the action of acids—the dentinal sheath of Neumann.

The intertubular substance or tissue is translucent and contains the chief part of the earthy matter of the dentine. After the earthy matter has been removed by steeping a tooth in weak acid the animal basis remaining may be torn into laminae which run parallel with the pulp-cavity across the direction of the tubules. These laminae show the method of growth to be by deposition of successive strata of dentine. Fibrils have been found in the matrix of the intertubular substance, and are probably continuous with the dentinal fibres of Tomes. In a dry tooth a section of dentine often displays a series of lines—the incremental lines of Salter—which are parallel with the laminae above mentioned. These lines are caused by two facts: (1) The imperfect calcification of the dentinal laminae immediately adjacent to the line. (2) The drying process, which reveals these defects in the calcification. These lines are wide or narrow according to the number of laminae involved, and along their course, in consequence of the imperfection in the calcifying process, little irregular cavities are left, which are the interglobular spaces already referred to. They have received their name from the fact that they are surrounded by minute nodules or globules of dentine. Other curved lines may be seen parallel to the surface. These are the concentric lines of Schreger, and are due to the optical effect of simultaneous curvature of the dentinal tubules.

![Diagram](https://via.placeholder.com/150)

**Fig. 825.**—Enamel prisms (350 diameters). A, fragments and single fibres of the enamel isolated by the action of hydrochloric acid. B, surface of a small fragment of enamel, showing the hexagonal ends of the fibres.

**Chemical Composition.**—According to Berzelius and Bibra, dentine consists of twenty-eight parts of animal and seventy-two of earthy matter. The animal matter is resolvable by boiling into gelatin. The earthy matter consists of phosphate and carbonate of calcium, with a trace of fluoride of calcium, phosphate of magnesia, and other salts.

The Enamel (substantia adamantina) (Figs. 821, 823, and 825) is the hardest and most compact part of a tooth, and forms a thin crust over the exposed part of the crown as far as the commencement of the root. It is thickest on the grinding surface of the crown until worn away by attrition, and becomes thinner toward the neck. It consists of a congeries of minute hexagonal rods, columns, or prisms known as enamel fibres or enamel prisms (prismata adamantina) (Fig. 825). In general, they lie parallel with one another, resting by one extremity upon the dentine, which presents a number of minute depressions for their reception, and
forming the free surface of the crown by the other extremity. There are occasional collections of prisms which run diagonally. The prisms are directed vertically on the summit of the crown, horizontally at the sides; they are about the \( \frac{1}{3000} \) of an inch in diameter, and pursue a more or less wavy course. By reflected light radial striations are visible. These are Schreger's lines, and are due to the fact that the prisms take an undulatory course and those of two layers may have opposite directions. Another series of lines, having a brown appearance from pigmentation, and denominated the parallel striae or brown striae of Retzius or the colored lines, are seen on a section of the enamel. These lines are concentric and cross the enamel rods. They are caused by the mode of enamel deposition. Inasmuch as the enamel columns, when near the dentine, cross each other and only become parallel farther away, a series of radial markings, light and dark alternately, is obtained (Fig. 821). The enamel prisms are themselves calcified and are fixed to each other by a very small amount of cement substance. Numerous minute interstices intervene between the enamel-fibres near their dentinal surface. It is noted that some of the dentinal canals at the crown penetrate a certain distance between the rods of the enamel (Fig. 823). No nutritive canals exist in the enamel, except the very few dentinal canals which at the crown penetrate a short distance, and these are found only in a small area.

Chemical Composition.—According to Bibra, enamel consists of 96.5 per cent. of earthy matter and 3.5 per cent. of animal matter. The earthy matter consists of the phosphate and the carbonate of calcium, with traces of fluoride of calcium, phosphate of magnesia, and other salts.

The enamel of a recently erupted tooth is covered by a membrane, the thickness of which is \( \frac{1}{3000} \) of an inch. It is known as enamel cuticle or Nasmyth's membrane (cuticula dentis). It is probably the most recent, and hence an uncalcified, or partly calcified enamel layer. Some believe it to be a product of the outer layer of the cells of the enamel organ.

The Cortical Substance, Cementum or Crusta Petrosa (substantia ossea) (Figs. 808 and 811) is disposed as a thin layer on the roots and neck of a tooth, from the termination of the enamel as far as the apex of the root, where it is usually very thick. At the neck it overlies a slight margin of enamel. In structure and chemical composition it is true bone. It contains, sparingly, the lacunae and canaliculi which characterize true bone; the lacunae placed near the surface have the canaliculi radiating from the side of the lacunae toward the periodontal membrane or dental periosteum, and those more deeply placed join with adjacent dentinal tubuli. The teeth of the young usually contain Haversian systems in the thicker portions of the cementum. The neck of the tooth does not contain lacunae. The cementum is occasionally laminated. Sharpey's fibres (p. 37) are very numerous. Some of the lacunae of the cementum receive dentinal tubes from the dentine.

As age advances the cement increases in thickness, and gives rise to those bony growths, or exostoses, so common in the teeth of the aged; the pulp-cavity becomes also partially filled up by a hard substance intermediate in structure between dentine and bone (the osteo-dentine of Owen; the secondary dentine of Tomes). It is formed by the odontoblasts, the dental pulp lessening in volume.

Development of the Teeth (Figs. 826, 827, 828, and 829).—The teeth are an evolution from the dermoid system, and not of the bony skeleton; they are developed from two of the blastodermic layers, the epiblast and mesoblast. From the former the enamel is developed; from the latter the dentinal pulp, dentine, cementum, and pericementum. It is customary to view the development of the permanent and temporary teeth as separate studies.

The earliest evidence of tooth-formation in the human embryo is observed about the seventh week. The mucous membrane covering the embryonic jaws is seen to rise as a longitudinal ridge along the summit of each jaw. This ridge is
the maxillary rampart of Kölliker and Waldeyer. A transverse section through the jaw will show the elevation to be due to a linear and outlined activity of the germinal epithelial layer; a corresponding epithelial growth is seen to sink as a band into the mesoblastic tissue beneath. This band is called the dental lamina or dental band. The local cell-activity continues, and in its descent the band appears to meet with a resistance which causes a flattening of its extremity into a continuous lamina. From the inner (toward the tongue) edge of the lamina epithelial cords are given off, ten in number, one for each temporary tooth.

![Diagram of method of development of the teeth.](image)

The growth of each cord continues, and each expands into a flask-like form, the walls covered by a layer of germinal cells, its interior by swollen mature cells. The ingrowing bulb is now seen to flatten upon its lower surface, as though it had met with an outlined resistance from the mesoblastic tissue beneath. The epithelial ingrowth assumes the general form of the several teeth; it is the enamel-organ of the tooth (Fig. 826). The cellular tissue of the jaw beneath the cap of the enamel-organ grows and projects into the cap. This projection is the dentine papilla (papilla dentis). At this period the mesoblastic tissue around each enamel-organ is seen to become differentiated into fibrous tissue surrounding the enamel-organs,

![Vertical section of the inferior maxilla of an early human foetus.](image)

but at some distance from them. Islets of bone are also seen to be forming the beginning of the bony maxillae.

The indentation of the base of the enamel-organ continues until it assumes the form of the future teeth. The cells bounding the organ assumes a cylindrical form; the cells of the interior become much expanded, and irregular in size and form.

The mesoblastic tissue underlying the enamel-organ is much condensed; evidences of cellular differentiation and a vascular system appear. Bone continues to
develop until all of the tooth-follicles are embraced in a gutter of bone. From the lingual side of the cords of the temporary teeth epithelial buds are given off, which sink into the mesoblastic tissue and form the enamel-organs of the permanent teeth. The condensation of fibrous tissue continues until each embryonic tooth is enveloped in a sac, the dental sac (Fig. 827); this, together with all of its contents, is called the dental follicle.

The tooth which is undergoing development with its enamel-organ and dentine papilla is known as the tooth germ. This tooth germ is encompassed and shut off from surrounding structures by the bag of membranous structure known as the dental sac.

The cells of the enamel-organ now undergo a series of differentiations: the inner layer, arranged as columnar epithelium, are the enamel cells, or ameloblasts. The layer is called the ameloblastic or enamel-forming layer (Figs. 827 and 828). The cells of the outer wall remain cuboidal; the cells which lie between become much distended, and on account of their appearance when seen in section this portion of the organ is called the enamel jelly or the stellate reticulum. The layer of cells immediately contiguous to the ameloblasts form a layer called the stratum intermedium (Fig. 828 A, D).

![Fig. 828](image_url)

The enclosed mesoblastic papilla (the future dental pulp) has its peripheral cells, which are called odontoblasts, differentiated into columnar bodies disposed as a layer, each cell having a large nucleus. The vascular supply of the pulp is now well marked. A section of a follicle at this period will exhibit the follicular wall springing from the base of the dental papilla and having a well-marked blood-supply. The bony alveolar walls are well outlined, and evidences of a periosteum appear (Figs. 827 and 828).

**Development of Enamel** (Fig. 828 B).—In point of time, the deposition of dentine actually begins before that of enamel, so that the first-formed layer of enamel is deposited against a layer of immature dentine. The enamel is built up of two distinct substances—globules of uniform size which are formed by the ameloblasts, and a cementing substance, probably an albuminate of calcium (calcoglobulin), the basis of all the calcified tissues. At the ends of the ameloblasts,
next to the dentine, the secretion of calco-globulin is deposited, and into the plastic mass the enamel-globules are extruded, each globule remaining connected with the ameloblasts by plasmic strings, which also join the globules laterally.

The first deposit of enamel begins in the tips of the cusps, and is quickly followed by a disappearance of the stellate reticulum at that point; the stellate reticulum appears to atrophy, so that the vascular follicular wall is brought into direct apposition with the stratum intermedium, which becomes differentiated into a glandular (secreting) tissue which elaborates the calcic albuminous basis of the enamel. The secretion passes from the cells of the stratum intermedium through a membrane into the ameloblasts, where it is in part combined with the cellular globules, and irregular masses of it are extruded as cementing substance. The deposition continues until the enamel-cap has its typical form. The deposition of the layers of globules is indicated by parallel lines transverse to the axes of the enamel-rods. At the completion of amelification the ameloblasts are partially calcified and form the enamel cuticle or Nasmyth's membrane (cuticula dentis).

Formation of Dentine.—The layer of columnar cells bounding the periphery of the pulp, the odontoblasts, are in apposition with a plexus of capillary vessels (Fig. 829). Each cell is a secreting body which selects the material for dentine-building. Against the layer of ameloblasts covering the dental papilla the odontoblasts deposit globules, of the calcium albuminate, and receding as the deposits are made, leave one or more protoplasmic processes in the calcic deposit. These are known as Tomes's fibres. The process continues until the normal dentine thickness is formed. The deposit is laid down in a scaffolding of finely fibrillated tissue. The layer of formative cells remains constant. The remains of the dentine papilla constitute the pulp and lie in the pulp-cavity (p. 1210).

Formation of Cementum.—Hertwig asserts that the epithelial edge of the enamel organ formed by the inner and outer epithelial layers of the organ grows downward, or rather the developing tooth grows upward until the future root-form of the tooth is outlined by a double layer of epithelial cells, constituting the root-sheath of Hertwig. The growth of the alveolar process is synchronous.

Upon the pulp side of the sheath a layer of odontoblasts is developed; upon the outer side the fibrous encasement becomes closely attached to the sheath and a layer of osteogenetic cells is differentiated. These cells are called cementoblasts. The growth of the dentine of the root is exactly similar to the growth of that of the crown. The epithelial sheath undergoes atrophic changes, leaving the epithelial whors which remain in the pericementum. The cementum is developed as subperiosteal bone. The cementum over the apex of the root is not formed until after the eruption of the tooth.

Formation of Alveoli.—By the time the crowns of the teeth have formed, each is enclosed in a loculus of bone which has developed around it and at some distance from it; the loculus is open at the top toward the gums, where it is closed by fibrous tissue; the developing permanent tooth is contained in the same loculus, but is later separated from the temporary tooth by a growth of bone. The alveolar

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1 J. L. Williams, Dental Cosmos, 1896.
process is not completed until after the eruption of the teeth. During eruption that portion of the process overlying the crown undergoes absorption, and as soon as the immature tooth has erupted the alveolar process is developed about the root, whose formation is also completed after eruption.

Development of the Permanent Teeth.—The permanent teeth as regards their development may be divided into two sets: (1) those which replace the temporary teeth, and which, like them, are ten in number; these are the \textit{successional permanent teeth}; and (2) those which have no temporary predecessors, but are superadded at the back of the dental series. These are three in number on either side in each jaw, and are termed the \textit{superadded permanent teeth}. They are the three molars of the permanent set, the molars of the temporary set being replaced by the premolars or bicuspids of the permanent set.

The \textit{Development of the Successional Permanent Teeth}—the ten anterior ones in either jaw—will be first considered. As already stated, the germ of each milk tooth is a special thickening of the “free” edge of the common dental germ or dental lamina. In like manner is formed the special dental germ of each of the successional permanent teeth. But these thickenings are not at the “free” edge of the dental lamina, but occur behind and lateral to each of the milk-tooth germs (Fig. 826). There are ten of these, and they appear in order, about the sixteenth week, on each side, the central incisor germs being the first.

These special dental germs now go through the same transformations as were described in connection with those of the milk teeth, and the changes also eventuate in the germs becoming enamel organs; that is, they recede into the substance of the gum behind the germs of the temporary teeth. As they recede they become flask-shaped, form an expansion of their distal extremity, and finally meet a papilla, which has been formed in the mesoblast, just in the same manner as was the case in the temporary teeth. The apex of the papilla indents the dental germ, which encloses it, and forming a cap for it, undergoes analogous changes to those described in the development of the milk teeth, and becomes converted into the enamel, whilst the papilla forms the dentine of the permanent tooth. In its development it becomes enclosed in a dentinal sac which adheres to the back of the sac of the temporary tooth. The sac of each permanent tooth is also connected with the fibrous tissue of the gum by a slender band of the \textit{gubernaculum}, which passes to the margin of the jaw behind the corresponding milk tooth (see above).

The \textit{Superadded Permanent Teeth}—three on each side in each jaw—arise from successive extensions backward—\textit{i.e.}, along the line of the jaw—of the common dental germ from the back of the special dental germ of the immediately preceding tooth. During the fourth month or seventeenth week, in that portion of the common dental germ which lies behind—\textit{i.e.}, lateral to the special dental germ of the last temporary molar tooth, and which has hitherto remained unaltered—there is developed the special dental germ of the first permanent molar into which a papilla projects. In a similar manner, about the fourth month after birth the second molar is formed, and about the third year the third molar.

Eruption.—When the calcification of the different tissues of the \textit{milk} tooth is sufficiently advanced to enable it to bear the pressure to which it will be afterward subjected, its eruption takes place, the tooth making its way through the gum. The gum is absorbed by the pressure of the crown of the tooth against it, which is itself pressed up by the increasing size of the fang. At the same time the septa between the dentinal sacs, at first fibrous in structure, ossify and thus form the \textit{loculi} or \textit{alveoli}; these firmly embrace the necks of the teeth and afford them a solid basis.

Previous to the permanent teeth penetrating the gum, the bony partitions which separate their sacs from the deciduous teeth are absorbed, the roots of
the temporary teeth disappear by absorption through the agency of particular multinucleated cells, called **odontoclasts**, which are developed at the time in the neighborhood of the root, and the permanent teeth become placed under the loose crown of the deciduous teeth; the latter finally become detached, and the permanent teeth take their place in the mouth (Fig. 830).

**Calcification** of the permanent teeth proceeds in the following order: First molar, soon after birth; the central incisor, lateral incisor, and cuspids, about six months after birth; the bicuspid, at the second year or later; second molar, end of second year; third molar, about the twelfth year.

The **Eruption of the Temporary Teeth** commences at the seventh month, and is complete about the end of the second year.

The periods for the eruption of the temporary set are (C. S. Tomes)—

<table>
<thead>
<tr>
<th>Teeth</th>
<th>Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower central incisors</td>
<td>6 to 9 months.</td>
</tr>
<tr>
<td>Upper incisors</td>
<td>8 to 10 &quot;</td>
</tr>
<tr>
<td>Lower lateral incisors and first molars</td>
<td>15 to 21 &quot;</td>
</tr>
<tr>
<td>Canines</td>
<td>16 to 20 &quot;</td>
</tr>
<tr>
<td>Second molars</td>
<td>20 to 24 &quot;</td>
</tr>
</tbody>
</table>

The **Eruption of the Permanent Teeth** takes place at the following periods, the teeth of the lower jaw preceding those of the upper by a short interval:

- 6½ years, first molars.
- 7th year, two middle incisors.
- 8th year, two lateral incisors.
- 9th year, first bicuspid.
- 10th year, second bicuspid.
- 11th to 12th year, canine.
- 12th to 13th year, second molars.
- 17th to 21st year, third molars.
The Palate (Palatum).

The palate forms the roof of the mouth; it consists of two portions, the **hard palate** in front, the **soft palate** behind.

**The Hard Palate** (*palatum durum*) (Figs. 831 and 832).—The hard palate is bounded in front and at the sides by the upper alveolar arches and gums. In front and to the sides it is continuous with the gums; behind, it is continuous with the soft palate. It is formed by the palate processes of the superior maxillary bones and the palate processes of the palate bones (Fig. 72). It is covered by a dense structure formed by the periosteum and mucous membrane of the mouth, which are intimately adherent, particularly to the front and sides, by means of a layer of fibrous tissue. Along the middle line is a **linear ridge** or **raphe** (*raphe palati*), which terminates anteriorly in a small papilla, the **incisive papilla** (*papilla incisiva*), corresponding with the inferior opening of the anterior palatine fossa. This papilla receives filaments from the naso-palatine and anterior palatine nerves. The incisive papilla in a recently born child is continuous with the gum and the frenulum of the upper lip. On either side and in front of the raphe the mucous membrane is thick, pale in color, and corrugated; these corrugations, which are composed of fibrous tissue, are the **palatine rugae** (*plicae palatinae transversae*). In very young children the rugae are distinct and definite. In the aged they are indistinct. Behind, it is thin, smooth, and of a deeper color; it is covered with squamous epithelium, and the fibrous tissue beneath it...
contains many mucous glands, the **palatine glands** (*glandulae palatinae*). The palatine vessels and nerves lie in the fibrous tissue beneath the mucous membrane.

**The Soft Palate or Velum Pendulum Palati** (*palatum molle*) (Figs. 831, 832, and 837).—The soft palate is a movable fold suspended from the posterior border of the hard palate, and forming an incomplete septum between the mouth and pharynx. It consists of a fold of mucous membrane enclosing muscular fibres, an aponeurosis, vessels, nerves, adenoid tissue, and mucous glands. When occupying its usual position it is relaxed and pendent and its oral surface is concave, continuous with the roof of the mouth, and marked by a **median ridge** or **raphé**, which indicates its original separation into two lateral halves. Its pharyngeal surface is convex, and continuous with the mucous membrane covering the floor of the posterior nares. Its anterior or upper border is attached to the posterior margin of the hard palate, and its sides are blended with the pharynx. Its posterior or lower border is free. The posterior portion of the soft palate is known as the **vail of the palate** (*velum palatinum*) and terminates posteriorly and externally on each side in a free margin, the posterior arch of the palate.

Hanging from the middle of its lower border is a small, conical-shaped, pendulous process, the **uvula** (*uvula palatina*). The uvula varies greatly in length in different individuals. It is composed of glands and connective tissue, contains a prolongation of the Azygos uvulae muscle and is covered with mucous membrane, and arching outward and downward from the base of the uvula on each side are two curved folds of mucous membrane, containing muscular fibres, called the **arches or pillars of the soft palate** or **pillars of the fauces** (*arcus palatini*).
The Anterior Pillar (*arcus glossopalatinus*) (Figs. 831 and 837).—The anterior pillar on each side runs downward, outward, and forward to the side of the base of the tongue. These pillars are formed by the projection of the Palato-glossi muscles, covered by mucous membrane.

The Posterior Pillar (*arcus pharyngopalatinus*) (Figs. 831 and 837).—The posterior pillar on each side is nearer to its opposite arch than is the anterior pillar to its opposite. These pillars are larger than the anterior; they run downward, outward, and backward to the sides of the pharynx, and are formed by the projection of the Palato-pharyngei muscles, covered by mucous membrane. The anterior and posterior pillars are separated below by a triangular interval in which the tonsils is lodged.

The space left between the arches of the palate on the two sides is called the *isthmus of the fauces (isthmus faecium).* It is bounded, above, by the free margin of the soft palate; below, by the back of the tongue; and on each side by the pillars of the fauces and the tonsils. Through this isthmus the mouth communicates with the pharynx.

The Mucous Membrane of the Soft Palate.—The mucous membrane of the soft palate is thin, and covered with squamous epithelium on both surfaces, excepting near the orifice of the Eustachian tube, where its epithelium is columnar and ciliated. Beneath the mucous membrane on the oral surface of the soft palate is a considerable amount of adenoid tissue. The palatine glands form a continuous layer on the pharyngeal surface and around the uvula.

The Aponeurosis of the Soft Palate.—The aponeurosis of the soft palate is a thin but firm fibrous layer attached above to the posterior border of the hard palate, and becoming thinner toward the free margin of the velum. Laterally, it is continuous with the pharyngeal aponeurosis. It forms the framework of the soft palate, and is joined by the tendons of the Tensor palati muscles.

The Muscles of the Soft Palate.—The muscles of the soft palate are six on each side: the Levator palati, Tensor palati, Azygos uvulae, Palato-glossus, Palato-pharyngeus and Salpingo-pharyngeus (see p. 407). The following is the relative position of these structures in a dissection of the soft palate from the posterior or naso-pharyngeal to the anterior or oral surface: Immediately beneath the pharyngeal mucous membrane is a thin stratum of muscular fibres, the posterior fasciculus of the Palato-pharyngeus muscle, joining with its fellow of the opposite side in the middle line. This posterior fasciculus is joined by the Salpingo-pharyngeus muscle. Beneath this are the Azygos uvulae and Salpingo-pharyngeus muscles, consisting of two rounded fleshy fasciculi, placed side by side in the median line of the soft palate. Next comes the aponeurosis of the Levator palati, joining with the muscle of the opposite side in the middle line. Fourthly, the anterior fasciculus of the Palato-pharyngeus, thicker than the posterior, and separating the Levator palati from the next muscle, the Tensor palati. This muscle terminates in a tendon which, after winding around the hamular process of the internal pterygoid plate of the sphenoid bone, expands into a broad aponeurosis in the soft palate, anterior to the other muscles, which have been enumerated. Finally, we have a thin muscular stratum, the Palato-glossus muscle, placed in front of the aponeurosis of the Tensor palati, and separated from the oral mucous membrane by adenoid tissue.

The Blood-vessels of the Palate (Fig. 832).—The palate is supplied with blood by branches of the posterior or descending palatine branch of the internal maxillary artery (*a. palatina descendens*) and of the ascending or anterior palatine branch of the facial artery (*a. palatina ascendens*). The posterior palatine artery divides into the great and small palatine arteries (*aa. palatinae major et minor*), which run through the

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1 According to Klein, the mucous membrane on the nasal surface of the soft palate in the fetus is covered throughout by columnar ciliated epithelium, which subsequently becomes squamous; and some anatomists state that it is covered with columnar ciliated epithelium, except at its free margin, throughout life. —Ed. of 15th English edition.
palatine canals and after emerging give off branches. Branches from the small palatine go to the soft palate, the large branch passes forward on the hard palate near the alveolar margin. The ascending palatine branch of the facial lies upon the medial surface of the Tensor palati muscle and is distributed to the soft palate and pharynx. A palatine vein corresponding to the descending palatine artery opens into the anterior facial vein. The pharyngeal veins also receive palatine veins.

The Nerves of the Palate.—The large posterior palatine nerve emerges from the posterior palatine canal and accompanies the posterior palatine artery. The naso-palatine nerve emerges from the foramen of Scarpa and is distributed to the anterior portion of the hard palate. The soft palate is supplied by the small posterior palatine and the accessory palatine nerves.

The Tonsil or Amygdala (tonsilla palatina) (Figs. 818 and 824).—The tonsils or amygdalae are two prominent bodies situated one on each side of the fauces, between the anterior and posterior pillars of the soft palate. They are of a rounded form, and vary considerably in size in different individuals. A recess, the supra-tonsillar fossa (fossa supratonsillaris), may be seen, directed upward and backward above the tonsil. His regards this as the remains of the lower part of the second visceral cleft. The recess is covered by a fold of mucous membrane termed the plica triangularis. Externally the tonsil is covered with a fibrous capsule which joins the aponeurosis of the pharynx. The outer surface of the capsule is in relation with the inner surface of the Superior constrictor muscle of the pharynx, to the outer side of which is the Internal pterygoid muscle. The ascending palatine artery is close to the outer surface of the tonsil, the Superior constrictor muscle of the pharynx and the tonsillar capsule intervening. The tonsillar artery, which is sometimes a branch of the ascending palatine, is also close to the outer surface of the tonsil. The internal carotid artery lies behind and to the outer side of the tonsil, and nearly an inch (20 to 25 mm.) distant from it. It corresponds to the angle of the lower jaw. The surface of the tonsil which looks toward the pharynx presents from twelve to fifteen orifices, each leading into a small recess or crypt (fossula tonsillaris). From the crypts numerous follicles branch out into the substance of the tonsil by means of very irregular channels. The crypts are lined with stratified pavement epithelium. The epithelium of the crypts exhibits marked degenerative changes. The degeneration causes the formation of numerous communicating spaces, which contain leukocytes and lymphocytes. The crypts are surrounded with lymphoid tissue. In this are numerous lymphoid follicles (noduli lymphatici), which are placed in the submucous tissue. These follicles are analogous to those of Peyer's glands and consist of adenoid tissue. No openings from the capsules into the follicles can be recognized. They contain a thick grayish secretion.

The Blood-vessels of the Tonsil.—The arteries supplying the tonsils are the dorsalis linguae from the lingual, the ascending palatine and tonsillar from the facial, the ascending pharyngeal from the external carotid, the descending palatine branch of the internal maxillary, and a twig from the parvadural. The veins terminate in the tonsillar plexus, on the outer side of the tonsil, and the tonsillar plexus joins the pharyngeal plexus, which communicates with the pterygoid plexus of the internal jugular or facial vein.

Lymphatics of the Tonsil.—Surrounding each follicle is a close plexus of lymphatic vessels. From these plexuses the lymphatic vessels pass to the submaxillary lymph glands below the angle of the jaw. From the submaxillary glands lymph passes to the deep cervical glands.

The Nerves of the Tonsil.—A branch from the glossopharyngeal nerve by uniting with branches of the pharyngeal plexus forms the tonsillar plexus. The pharyngeal plexus is formed by the pharyngeal branches of the glossopharyngeal and superior cervical ganglia of the sympathetic and the pharyngeal branch of the vagus.
The Salivary Glands (Fig. 833).

Numerous glands exist in the lips, cheeks, palate, and tongue, but by the term salivary glands are usually understood the three chief glandular masses on each side of the face. These are the principal salivary glands. They communicate with the mouth, pour their secretion into its cavity, and are named respectively the parotid, submaxillary, and sublingual.

The Parotid Gland (glandulae parotis).—The parotid gland, so called from being placed near the ear (παρόδ, near; ὄς, ὄς, the ear), is the largest of the three salivary glands, varying in weight from half an ounce to an ounce. It lies upon the side of the face immediately below and in front of the external ear. It is limited above by the zygoma; below, by the angle of the jaw and by a line drawn between the angle and the mastoid process: anteriorly, it extends to a variable extent over the Masseter muscle; posteriorly, it is bounded by the external meatus, the mastoid process, and the Sterno-mastoid and Digastric muscles, slightly overlapping the two muscles.

![Fig. 833.—The salivary glands.](image)

Its anterior surface is grooved to embrace the posterior margin of the ramus of the lower jaw, and advances forward beneath the ramus, between the two Pterygoid muscles and superficial to the ramus over the Masseter muscle. Its outer surface is triangular and convex, slightly lobulated, is covered by the integument and parotid fascia, and has one or two lymphatic glands resting on it. Its inner surface (processus retromandibularis) extends deeply into the neck by means of two large processes, one of which dips behind the styloid process and projects beneath the mastoid process and the Sterno-mastoid muscle; the other is situated in front of the styloid process, and passes into the back part of the glenoid fossa, behind the articulation of the lower jaw. The structures passing through the parotid gland are—the external carotid artery, giving off its three terminal
branches: the posterior auricular artery emerges from the gland behind; the superficial temporal artery above; the transverse facial, a branch of the temporal, in front; and the internal maxillary winds through it as it passes inward, behind the neck of the jaw. Superficial to the external carotid is the trunk formed by the union of the temporal and internal maxillary veins; a branch, connecting this trunk with the internal jugular, also passes through the gland. The gland is also traversed by the facial nerve and its branches, which emerge at its anterior border; branches of the great auricular nerve pierce the gland to join the facial, and the auriculo-temporal branch of the inferior maxillary nerve emerges from the upper part of the gland. The internal carotid artery and internal jugular vein lie close to its deep surface. The triangular space occupied by the greater part of the gland is bounded in front by the posterior margin of the ramus of the jaw and the internal pterygoid muscle, and behind by the anterior edge of the Sternocleido-mastoid muscle, the tympanic portion of the temporal bone and the cartilaginous portion of the external auditory meatus. Its floor is formed by the anterior and posterior walls of the space which meet about the styloid process. These walls are composed of fascia derived from the deep cervical fascia. The remaining side of the space is external and is formed by fascia, derived from the deep cervical fascia and called the parotid fascia. This space is called the parotid recess. Sir Frederick Treves\(^1\) denies that the fascial covering of the space is complete. He says it is deficient above between the anterior edge of the styloid process and the posterior border of the external pterygoid muscle. A portion of the gland does not occupy the space, but projects forward over the Masseter muscle. This projecting portion is the facial process.

Lymph-glands, known as the parotid lymph-glands, are in and about the parotid gland, some being embedded in the outer surface of the parotid fascia, others being in the inner surface of the fascia, others in the gland itself, particularly along the temporo-maxillary vein and external carotid artery. They receive lymph from the anterior and lateral portions of the scalp, both eyelids, a portion of the cheek, the root of the nose, the outer portion of the external ear, the soft palate, the posterior nares, and the external auditory meatus. The vessels from them empty into the superficial cervical glands and the superior deep cervical glands. Between the parotid gland and the pharynx are the subparotid glands. They receive lymph from the nasal fossae, naso-pharynx, and Eustachian tube, and vessels from the glands take lymph to the deep cervical glands.\(^2\)

The Duct of the Parotid Gland, called the Parotid Duct or Stenson’s Duct (ductus parotideus [Stenonis]) (Fig. 833).—The duct of the parotid gland is about two inches and a half in length. It commences by numerous branches from the anterior part of the gland, crosses the Masseter muscle, and at its anterior border dips down into the substance of the Buccinator muscle, which it pierces; it then runs for a short distance obliquely forward between the Buccinator muscle and the mucous membrane of the mouth, and opens upon the inner surface of the cheek by a small orifice opposite the second molar tooth of the upper jaw (Fig. 824). Upon the beginning of Stenson’s duct there is often an accessory parotid gland (glandulae parotis accessorium), which is often called the socia parotidis. It is a portion of the facial process. It is a detached portion of gland, and has a duct which opens into Stenson’s duct. This accessory gland occasionally exists as a separate lobe, just beneath the zygomatic arch. In this position it has the transverse facial artery above it and some branches of the facial nerve below it.

Surface Form.—The direction of the duct corresponds to a line drawn across the face about a finger’s breadth below the zygoma; that is, from the lower margin of the concha to midway between the free margin of the upper lip and the ala of the nose.

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\(^1\) Applied Anatomy.

\(^2\) Poirier and Cunéo, Human Anatomy.
Structure of the Parotid Duct.—The parotid duct is dense, it is of considerable thickness, and its canal is about the size of a crowquill; but at its orifice on the inner aspect of the cheek its lumen is greatly reduced in size. The duct consists of an external or fibrous coat, of considerable density, containing contractile fibres, and of an internal or mucous coat lined with short columnar epithelium.

Vessels and Nerves.—The arteries supplying the parotid gland are derived from the external carotid, and from the branches given off by that vessel in or near its substance. The veins empty themselves into the external jugular through some of its tributaries. The lymphatics terminate in the superficial cervical and the deep cervical glands, passing in their course through several lymphatic glands placed on the surface and in the substance of the parotid. The nerves are derived from the plexus of the sympathetic on the external carotid artery, the facial, the auriculo-temporal, and great auricular nerves. It is probable that the branch from the auriculo-temporal nerve is derived from the glosso-pharyngeal through the otic ganglion. At all events, in some of the lower animals this has been proved experimentally to be the case.

The Parotid Capsule.—The parotid gland is enclosed by two layers of the parotid fascia (fascia parotideomasseterica), which almost completely encompass the gland. The sheath is incomplete at one area toward the pharyngeal wall (see p. 1225).

The parotid fascia comes from the deep cervical fascia. The external layer covers the gland. The internal layer lines the parotid recess. The external layer is the structure usually spoken of as the parotid fascia. Anteriorly it joins the fascia of the masseter; below it is continuous with the deep cervical fascia; above it is attached to the zygoma; behind it is adherent to the external auditory meatus and sheath of the Sternomastoid. The deep layer is adherent above to the external auditory meatus and back of the glenoid fossa; internally to the styloid process; below it is continuous with the deep cervical fascia. The stylomaxillary or stylomandibular ligament comes off from the parotid fascia.

The Submaxillary Gland (glandula submaxillaris) (Fig. S33).—The submaxillary gland is situated below the jaw, in the anterior part of the submaxillary triangle of the neck. It is irregular in form and weighs about two drachms (8 to 10 grammes). It is covered by the integument, Platysma, deep cervical fascia, and the body of the lower jaw, corresponding to a depression on the inner surface of the body of the mandible, and lies upon the Mylo-hyoid, Hypoglossus, and Stylo-glossus muscles, a portion of the gland passing beneath the posterior border of the Mylo-hyoid. In front of it is the anterior belly of the Digastric muscle; behind, it is separated from the parotid gland by the stylomaxillary ligament, and from the sublingual gland in front by the Mylo-hyoid muscle. The facial artery lies embedded in a groove in its posterior and upper border. A process is given off from the deep surface of the anterior portion of the gland. This is the deep process (Cunningham), and it passes with the duct beneath the Mylo-hyoid muscle.

The Duct of the Submaxillary Gland or Wharton's Duct (ductus submaxillaris Whartoni).—The duct of the submaxillary gland is about two inches in length, and its walls are much thinner than those of the parotid duct. It commences by numerous branches from the deep portion of the gland which lies on the upper surface of the Mylo-hyoid muscle, and passes forward and inward between the Mylo-hyoid and the Hyo-glossus and Genio-hyo-glossus muscles, then between the sublingual gland and the Genio-hyo-glossus muscle, and opens by a narrow orifice on the summit of a small papilla (carinaula sublingualis) at the side of the f r a c c u m linguae. On the Hyo-glossus muscle it lies between the lingual and hypoglossal nerves, but at the anterior border of the muscle it crosses under the lingual nerve, and is then placed above it.
Vessels and Nerves.—The arteries supplying the submaxillary gland are branches of the facial and lingual. Its veins follow the course of the arteries. The lymphatics drain into the submaxillary lymph-glands. There are no lymphatic glands in this salivary gland. The nerves are derived from the submaxillary ganglion, through which it receives filaments from the chorda tympani and from the lingual branch of the inferior maxillary, sometimes from the mylo-hyoid branch of the inferior dental and from the sympathetic.

The Sublingual Gland (*glandula sublingualis*) (Fig. 833).—The sublingual gland is the smallest of the salivary glands. It is situated beneath the mucous membrane of the floor of the mouth, at the side of the fraenum linguae, in contact with the inner surface of the lower jaw, close to the symphysis. It is narrow, flattened, in shape somewhat like an almond, and weighs about a drachm. It is in relation, above, with the mucous membrane; below, with the Mylo-hyoid muscle; in front, with the depression on the side of the symphysis of the lower jaw, and with its fellow of the opposite side; behind, with the deep part of the submaxillary gland; and internally, with the Genio-hyo-glossus, from which it is separated by the lingual nerve and Wharton’s duct. Its excretory ducts or ducts of Rivinus (*ductus sublingualis minores*) are from eight to twenty in number.

![Diagram](image)

Fig. 834.—A highly magnified section of the submaxillary gland of the dog, stained with carmine. (Kölliker.)

They open separately into the mouth back of Wharton’s duct and upon a fold of mucous membrane known as the *plica sublingualis*. The plica sublingualis is an elevated crest of mucous membrane caused by the projection of the gland on either side of the fraenum linguae. One or more ducts sometimes join to form a tube which opens into the Whartonian duct or remains independent, opening close to Wharton’s duct on the sublingual papilla. This single duct is called the duct of Bartholin (*ductus sublingualis major*).

Vessels and Nerves.—The sublingual gland is supplied with blood from the sublingual and submental arteries. Its nerves are derived from the lingual.

Structure of Salivary Glands (Fig. 834).—The salivary glands are compound racemose glands, consisting of numerous lobes, which are made up of smaller lobules connected together by dense areolar tissue, vessels, and ducts. Each lobule consists of the ramifications of a single duct, dividing frequently like the branches of a tree, the branches terminating in dilated ends or alveoli, on which the capillaries are distributed. These alveoli, however, as Pflüger points out, are not necessarily spherical, though sometimes they assume that form; sometimes they are perfectly cylindrical, and very often they are mutually compressed. The alveoli are enclosed by a basement membrane which is continuous with the membrana propria of the duct. It presents a peculiar reticulated
structure, having the appearance of a basket with open meshes, and consisting of a network of branched and flattened nucleated cells.

The alveoli of the salivary glands are of two kinds, which differ both in the appearance of their secreting cells, in their size, and in the nature of their secretion. The one variety secretes aropy fluid which contains mucin, and such alveoli have therefore been named the mucous alveoli, whilst the other secretes a thinner and more watery fluid, which contains serum-albumin, and alveoli of this variety have been named serous or albuminous alveoli. The sublingual gland may be regarded as an example of the former variety, the parotid of the latter. The submaxillary is of the mixed variety, containing both mucous and serous alveoli, the latter, however, preponderating.

Both varieties of alveoli are lined by cells, and it is by the character of these cells that the nature of the gland is chiefly to be determined. In addition, however, the alveoli of the serous glands are smaller than those of the mucous ones.

The Mucous Alveoli.—The cells in the mucous alveoli are spheroidal in shape, glassy, transparent, and dimly striated in appearance. The nucleus is usually situated in the part of the cell which is next the basement membrane, against which it is sometimes flattened. The most remarkable peculiarity presented by these cells is, that they give off an extremely fine process which is curved in a direction parallel to the surface of the alveolus, lies in contact with the membrana propria, and overlaps the process of neighboring cells. The cells contain a quantity of mucin, to which their clear, transparent appearance is due.

Here and there in the alveoli are seen peculiar half-moon-shaped bodies lying between the cells and the membrana propria of the alveolus. They are termed the crescents of Gianuzzi or the demilunes of Heidenhain (Fig. 834), and are composed of polyhedral granular cells, which Heidenhain regards as young epithelial cells destined to supply the place of those salivary cells which have undergone disintegration. This view, however, is not accepted by Klein.

Serous Alveoli.—In the serous alveoli the cells almost completely fill the cavity, so that there is hardly any lumen perceptible. Instead of presenting the clear, transparent appearance of the cells of the mucous alveoli, they present a granular appearance, due to distinct granules of an albuminous nature embedded in a closely reticulated protoplasm. The ducts which originate from the alveoli are lined at their commencement by epithelium which differs little from the pavement type. As the ducts enlarge, the epithelial cells change to the columnar type, and the part of the cells next the basement-membrane is finely striated. The lobules of the salivary glands are richly supplied with blood-vessels which form a dense network in the interalveolar spaces. Fine plexuses of nerves are also found in the interlobular tissue. The nerve-fibrils pierce the basement-membrane of the alveoli, and end in branched varicose filaments between the secreting cells. There is no doubt that ganglia are to be found in some salivary glands in connection with the nerve-plexuses in the interlobular tissue; they are to be found in the submaxillary, but not in the parotid.

In the submaxillary and sublingual glands the lobes are larger and more loosely united than in the parotid.

Mucous Glands.—Besides the salivary glands proper, numerous other glands are found in the mouth. They appear to secrete mucus only, which serves to keep the mouth moist during the intervals of the salivary secretion, and which is mixed with that secretion in swallowing. Many of these glands are found at the posterior part of the dorsum of the tongue, behind the circumvallate papillae, and also along its margins as far forward as the apex. Others lie around and in the tonsil

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1 It has been shown by Elsner that many of these glands open into the trenches around the circumvallate papillae, and that their secretion is more watery than that of ordinary mucous glands. He supposes that they assist in the more rapid distribution of the substance to be tasted over the region where the special apparatus of the sense of taste is situated.—Ed. of 15th English edition.
between its crypts, and a large number are present in the soft palate. These glands are of the ordinary compound racemose type. Behind the tip of the tongue on each side, external to the anterior extremity of the genio-glossus muscle, is a mucous gland, the **gland of Nuhn and Blandin** (*glandula lingualis anterior*). Its lower surface is partly covered by muscular fibres from the inferior lingualis and styloglossus muscles, and it opens by several ducts.

**Surface Form.**—The orifice of the mouth is bounded by the lips, two thick, fleshy folds covered externally by integument and internally by mucous membrane, and consisting of muscles, vessels, nerves, arcual tissue, and numerous small glands. The size of the orifice of the mouth varies considerably in different individuals, but seems to bear a close relation to the size and prominence of the teeth. Its corners correspond pretty accurately to the outer border of the canine teeth. In the Ethiopian tribes the front teeth are large and inclined forward, the mouth is large; and this, combined with the thick and everted lips which appear to be associated with prominent teeth, gives to the negro's face much of the peculiarity by which it is characterized. The smaller teeth and the slighter prominence of the alveolar arch of the more highly civilized races render the orifice of the mouth much smaller, and thus a small mouth is an indication of intelligence, and is regarded as an evidence of the higher civilization of the individual.

Upon looking into the mouth, the first thing we may note is the tongue, the upper surface of which will be seen occupying the floor of the cavity. This surface is convex, and is marked along the middle line by a raphé which divides it into two symmetrical portions. The anterior two-thirds is rough and studded with papillae; the posterior third smooth and tuberculated, and covered by numerous glands which project from the surface. Upon raising the tongue the mucous membrane which invests the upper surface may be traced covering the sides of the under surface, and then reflected over the floor of the mouth on to the inner surface of the lower jaw, a part of which it covers. As it passes over the borders of the tongue it changes its character, becoming thin and smooth and losing the papillae which are to be seen on the upper surface. In the middle line the mucous membrane on the under surface of the tip of the tongue forms a distinct fold, the **fraenum linguae**, by which this organ is connected to the symphysis of the jaw. Occasionally it is found that this fraenum is rather shorter than natural, and, acting as a bridle, prevents the complete protrusion of the tongue. When this condition exists and an attempt is made to protrude the organ, the tip will be seen to remain buried in the floor of the mouth, and the dorsum of the tongue is rendered very convex, and more or less extruded from the mouth; at the same time a deep furrow will be noticed to appear in the middle line of the anterior part of the dorsum. Sometimes, a little external to the fraenum, the canine vein may be seen immediately beneath the mucous membrane. The corresponding artery, being more deeply placed, does not come into view, nor can its pulsation be felt with the finger. On either side of the fraenum, in the floor of the mouth, is a longitudinally elevation or ridge, produced by the projection of the sublingual gland, which lies immediately beneath the mucous membrane. And close to the attachment of the fraenum to the tip of the tongue may be seen on either side the slit-like orifices of Wharton's ducts, into which a fine probe may be passed without much difficulty. By everting the lips the smooth mucous membrane lining them may be examined, and may be traced from them on to the outer surface of the alveolar arch. In the middle line, both of the upper and lower lip, a small fold of mucous membrane passes from the lip to the bone, constituting the fraena; these are not so large as the fraenum linguae. By pulling outward the angle of the mouth, the mucous membrane lining the cheeks can be seen, and on it may be perceived a little papilla which marks the position of the orifice of Stenson's duct—the duct of the parotid gland. The exact position of the orifice of the duct will be found to be opposite the second molar tooth of the upper jaw. The introduction of a probe into this duct is attended with considerable difficulty. The teeth are the next objects which claim our attention upon looking into the mouth. These are, as stated above, ten in either jaw in the temporary set, and sixteen in the permanent set. The gums, in which they are implanted, are dense, firm, and vascular.

At the back of the mouth is seen the **isthmus of the fauces**, or, as it is popularly called, "the throat:" this is the space between the pillars of the fauces on either side, and is the means by which the mouth communicates with the pharynx. Above, it is bounded by the soft palate, the anterior surface of which is concave and covered with mucous membrane, which is continuous with that lining the roof of the mouth. Projecting downward from the middle of its lower border is a conical-shaped projection, the uvula. On either side of the isthmus of the fauces are the anterior and posterior pillars, formed by the Palato-glossus and Palato-pharyngeus muscles respectively, covered over by mucous membrane. Between the two pillars on either side is situated the **tonsil**. The extirpation of this body is not unattended with danger of hemorrhage. Dr. Weir has stated that he believes that when hemorrhage occurs after their removal it arises from one of the palatine arteries having been wounded. These vessels are
THE ORGANS OF DIGESTION

large: they lie in the muscular tissue of the palate, and when wounded are constantly exposed to disturbance from the contraction of the palatine muscles. The vessels of the tonsil, Dr. Weir states, are small and lie in the soft tissue, and readily contract when wounded.

When the mouth is wide open a prominent tense fold of mucous membrane may be seen and felt, extending upward and backward from the position of the fang of the last molar tooth to the posterior part of the hard palate. This is caused by the pterygo-maxillary ligament, which is attached by one extremity to the apex of the internal pterygoid plate, and by the other to the posterior extremity of the mylo-hyoid ridge of the lower jaw. It connects the Buccinator with the Superior constrictor of the pharynx. The fang of the last molar tooth indicates the position of the lingual (gustatory) nerve where it is easily accessible, and can with readiness be divided in cases of cancer of the tongue (see page 1043). On the inner side of the last molar tooth we can feel the hamular process of the internal pterygoid plate of the sphenoid bone, around which the tendon of the Tensor palati plays. The exact position of this process is of importance in performing the operation of staphylorrhaphy. About one-third of an inch in front of the hamular process, and the same distance directly inward from the last molar tooth, is the situation of the opening of the posterior palatine canal, through which emerges the posterior or descending palatine branch of the internal maxillary artery and one of the descending palatine nerves from Meckel's ganglion. The exact position of the opening on the subject may be ascertained by driving a needle through the tissues of the palate in this situation, when it will be at once felt to enter the canal. The artery emerging from the opening runs forward in a groove in the bone just internal to the alveolar border of the hard palate, and may be wounded in the operation for the cure of cleft palate. Under these circumstances the palatine canal may require plugging. By introducing the finger into the mouth the anterior border of the coronoid process of the jaw can be felt, and it is especially prominent when the jaw is dislocated. By throwing the head well back a considerable portion of the posterior wall of the pharynx may be seen through the isthmus faucium, and on introducing the finger the anterior surface of the bodies of the upper cervical vertebrae may be felt immediately beneath the thin muscular stratum forming the wall of the pharynx. The finger can be hooked around the posterior border of the soft palate, and by turning it forward the posterior nare, separated by the septum, can be felt, or the presence of any adenoid or other growths in the naso-pharynx can be ascertained.

THE PHARYNX (Figs. 831, 837, 838).

The pharynx (from "phary̑n̑x, the throat") is that part of the alimentary canal which is placed behind and communicates with the nose, mouth, and larynx. It is a musculo-membranous tube, somewhat conical in form, with the base upward and the apex downward, extending from the under surface of the skull to the level of the crioid cartilage in front and that of the intervertebral disk between the fifth and sixth cervical vertebrae behind.

The pharynx is about four inches and a half in length, and broader in the transverse than in the antero-posterior diameter. Its greatest breadth is opposite the cornua of the hyoid bone; its narrowest point, at its termination in the oesophagus. It is attached, above, to the peristome of the petrous portion of the temporal bone and of the basilar process of the occipital bone. To the pharyngeal tubercle of the basilar process of the occipital bone the raphé of the Constrictor muscles is attached. It is bounded above by the body of the sphenoid as well as by the basilar process of the occipital; below, it is continuous with the oesophagus; posteriorly, it is connected by loose areolar tissue with the cervical portion of the vertebral column and the Longi colli and Recti capitis antici muscles; this areolar tissue is contained in what is called the retro-pharyngeal space (spatia retropharyngea); anteriorly, it is incomplete, the gap being occupied by the cavities of the nose, mouth, and larynx. Anteriorly, it is attached in succession to the Eustachian tube, the internal pterygoid plate, the pterygo-maxillary ligament, the posterior termination of the mylo-hyoid ridge of the lower jaw, the mucous membrane of the mouth, the base of the tongue, hyoid bone, the thyroid and criocid cartilages; laterally, it is connected to the styloid processes and their muscles, and is in contact with the common and internal carotid arteries, the internal jugular veins, and the glosso-pharyngeal, vagus, hypoglossal, and sympathetic nerves, and above with a small part of the Internal pterygoid muscles. When the pharynx
is at rest the anterior and posterior walls are near together. Above the larynx they do not come in contact, but leave a channel for air; below the larynx they lie in contact, but open for the passage of food. It has seven openings communicating with it—the two posterior nares, the two Eustachian tubes, the mouth, larynx, and oesophagus. The pharynx may be subdivided from above downward into three parts, nasal, oral, and laryngeal.

The Nasal Part (pars nasalis pharyngis) (Fig. 837).—The nasal part of the pharynx or *naso-pharynx* lies behind the nose and above the level of the soft palate; it differs from the two lower parts of the tube in that its cavity always remains patent. In front it communicates through the *posterior nares* (choanæ) (Fig. 838) with the nasal fossae. On its lateral wall is the *pharyngeal orifice of the Eustachian tube* (ostium pharyngeum tubae auditīvae) (Figs. 835 and 836), which presents the appearance of a vertical or triangular cleft bounded above and behind by a firm prominence. The anterior portion of the prominence (*labium anterius*) is the smaller portion. The posterior portion (*labium posterius*) is large and thick, is called the *Eustachian cushion* (*torus tubarius*), and is caused by the inner extremity of the cartilage of the tube impinging on the deep surface of the mucous membrane (Fig. 836). A vertical fold of mucous membrane, the *salpingo-pharyngeal fold* (*plica salpingo-pharyngea*) (Fig. 836), stretches from the lower part of the cushion to the pharynx; it contains the Salpingo-pharyngeus muscle. A second and smaller mucous fold may be seen stretching from the upper part of the cushion to the palate, the *salpingo-palatine fold* (*plica salpingopalatina*) (Fig. 836). Behind the orifice of the Eustachian tube is a deep recess, the *lateral recess* or fossa of Rosenmüller (*recessus pharyngeus*) (Fig. 836), which represents the remains of the upper part of the second *branchial cleft*. The posterior wall of the naso-pharynx is directed upward and forward, and it meets the superior wall at an angle. This rounded area meeting is the *vault of the pharynx* (*fornix pharyngis*). On the posterior wall, at the level and above the level of the orifices of the Eustachian tubes, there is a collection of lymphoid tissue. This is particularly marked in children, and almost or quite disappears in the aged. Over it the mucous membrane is thick and in folds. This collection of lymphoid tissue is the *pharyngeal tonsil* (*tonsilla pharyngea*) (Fig. 835). The naso-pharynx communicates with the oral pharynx through an aperture between the soft palate and the posterior pharyngeal wall. This aperture is the *isthmus of the pharynx* (*isthmus pharyngonasalis*).

The Oral Part (pars oralis pharyngis).—The oral part of the pharynx reaches from the soft palate to the level of the hyoid bone. It opens anteriorly, through the *isthmus faucium*, into the mouth, while in its lateral wall, between the two
pillars of the fauces, is the tonsil. A triangular area on the lateral wall is known as the **sinus tonsillaris** (Fig. 837). It is bounded anteriorly by the anterior palatine arch, posteriorly by the posterior palatine arch, and below by the side of the pharyngeal portion of the tongue.

**The Laryngeal Part (pars larynea pharyngis).**—The laryngeal part of the pharynx is that division which lies behind the larynx; it is wide above where it is continuous with the oral portion while below at the lower border of the cricoid cartilage it becomes continuous with the oesophagus. In front it presents the triangular aperture of the larynx, the base of which is directed forward and is formed by the epiglottis, while its lateral boundaries are constituted by the aryteno-epiglottidean folds. On either side of the laryngeal orifice is a recess, termed the **sinus pyri-formis** (*recessus piriformis*) (Fig. 837); it is bounded internally by the aryteno-epiglottidean fold, externally by the thyroid cartilage and thyro-hyoid membrane. In the anterior part of the sinus pyriformis is a fold (*plica nervi laryngei*), which passes downward and inward. Extending outward from the epiglottis on each side is a fold, the **pharyngo-epiglottic fold** (*plica pharyngoepiglottica*). This ascends in the lateral wall of the pharynx, nearly to the posterior arch of the fauces.

**Structure.**—The constrictors of the pharynx (see p. 402) are surrounded by a sheath of thin fascia, the **bucco-pharyngeal fascia** (Cunningham). Forward pro-
longations of this fascia overlay the Buccinator muscles. The connective tissue of the retro-pharyngeal space joins the bucco-pharyngeal fascia to the prevertebral fascia, and it is attached by areolar tissue to the other structures to which the pharynx is in contact (Cunningham). The pharynx is composed of three coats — fibrous, mucous and muscular.

The **Pharyngeal Aponeurosis** or **Fibrous Coat** is situated between the mucous and muscular layers. It is thick above, where the muscular fibres are wanting, and is firmly connected to the periosteum of the basilar process of the occipital and petrous portion of the temporal bones. It is united to the Eustachian tube, posterior nares, and other points which the pharynx joins. It is thicker above than below, and above the sinuses of Morgagni there is no muscular coat, and the wall of the pharynx is composed of aponeurosis and mucous membrane. As it descends it diminishes in thickness, and is gradually lost. It is strengthened posteriorly by a strong fibrous band which is attached above to the pharyngeal spine on the under surface of the basilar portion of the occipital bone, and passes downward, forming a **median raphé**, which gives attachment to the Constrictor muscles of the pharynx.

The **Mucous Coat** (*tunica mucosa*).—The mucous coat is continuous with that lining the Eustachian tubes, the nares, the mouth, and the larynx. In the nasopharynx it is covered by columnar ciliated epithelium; in the buccal and laryngeal portions the epithelium is of the squamous variety. Beneath the mucous membrane are found racemose **mucous glands** (*glandulae pharyngeae*); they are especially numerous at the upper part of the pharynx around the orifices of the Eustachian tubes. Throughout the pharynx are also numerous crypts or recesses, the walls.

![Figure 838: The anterior surface of the pharynx. (Sappey.)](image-url)
of which are surrounded by lymphoid tissue similar to that found in the tonsils. Across the back part of the pharyngeal cavity, between the two Eustachian tubes, a considerable mass of this tissue exists, and has been named the pharyngeal tonsil (Fig. 835). Above this in the middle line is an irregular, flask-shaped depression of the mucous membrane, extending up as far as the basilar process of the occipital bone. It is known as the pharyngeal bursa (bursa pharyngea), and was regarded by Luschka as the remains of the diverticulum, which is concerned in the development of the anterior lobe of the pituitary body. Other anatomists believe that it is connected with the formation of the pharyngeal tonsils. The muscular coat (tunica muscularis pharyngis) has been already described (p. 402). The sinuses of Morgagni, referred to on a previous page (p. 404), are intervals between the Superior constrictor muscles and the basilar process of the occipital bone.

The Lymphatic Pharyngeal Ring.—This name was applied by Waldayer to the lymphatic structure gathered into a sort of ring about the pharynx. There are three chief collections of this tissue on each side. The first is known as the lingual tonsil (p. 1098); the second as the palatine tonsil (p. 1222); and the third as the pharyngeal tonsil (p. 1231).

Surgical Anatomy of the Mouth, Cheeks, Lips, Gums, Tonsils, Palate, Salivary Glands, and Pharynx.—The duct of a salivary gland may be blocked by a calculi, and the condition is often productive of severe pain.

A wound of Stenson's duct or of the parotid gland may be followed by a salivary fistula.

The parotid recess is completely lined by fascia, except above. "Between the anterior edge of the styloid process and the posterior border of the external pterygoid muscle there is a gap in the fascia, through which the parotid space communicates with the connective tissue about the pharynx." This explains why there is frequently swelling of the parotid region in post-pharyngeal abscess. A parotid abscess rarely bursts through the skin; it may pass into the temporal fossa, may enter the zygomatic fossa, may advance toward the mouth, pharynx, or neck. Because of the situation of the gland, a parotid abscess may cause inflammation of the temporo-mandibular joint or periostitis of the bone about the meatus, and may even burst into the external auditory meatus (Treves).

The facial nerve passes through the gland, and inflammation or tuberculosis of the gland may cause facial palsy. Some enlargements of the parotid region are due to inflammation of the parotid lymph-glands, and these glands may become tuberculous.

Mumps is characterized by acute inflammation of the parotid gland.

Various tumors occur in the parotid (fibroma, sarcoma, carcinoma, enchondroma, etc.). Most parotid tumors contain more or less cartilage. Complete extirpation of the parotid gland surgically is certainly extremely difficult, and Treves and others maintain that it is impossible.

Ranula is a salivary cyst of the floor of the mouth, due to occlusion of ducts of the sublingual gland or the duct of the submaxillary gland. Mucous cysts occur in the mouth. A mucous cyst of the gland of Nuhn and Blandin is on the under surface of the tongue near the apex. A dermoid cyst of the base of the tongue is occasionally encountered. It is of congenital origin.

What is known as the sublingual bursa is an epithelial-lined space, said to exist between the mucous membrane of the floor of the mouth and the Genio-hyo-glossus muscle. When acutely inflamed, it produces rapidly a marked swelling called acute ranula. Incomplete closure of the oral end of the thyro-glossal duct causes thyro-glossal fistula. If the oral end closes, but a portion of the duct below remains unobliterated, a thyro-glossal cyst forms. Such a cyst or fistula is always in the median line. The reader will remember that this duct runs from the foramen caecum to the isthmus of the thyroid gland.

Harelip is considered on pp. 110 and 111.

The lower lip, more commonly than any other structure, gives origin to cancer. The upper lip is not nearly so often affected. Blocking of mucous glands of the lips causes mucous cysts. A scar of the lip or about the lip disturbs this structure and pulls it far out of place. Thus great deformity is produced. Burns particularly induce hideous cicatrical contraction.

Plastic operations in this region are often successful, because of the great vascularity of the parts, and because adjacent parts admit of being stretched and pulled in.

Cleft palate is a by no means rare congenital deformity. The cleft is in the middle line. It may be a mere cleft of the uvula, it may be limited to the soft palate, or it may involve

1 Applied Anatomy. By Sir Frederick Treves.
the hard palate to but not including the alveolus. It may pass through the alveolus, but if it does so it ceases to be median at this point, and follows the line of suture between the incisive bone and the superior maxillary (pp. 110 and 111). In a complete cleft palate there is apt to be hare-lip at the end of the palate cleft. This cleft in the lip is not median, but is at the termination of the palate cleft. If the cleft of a cleft palate runs along each side of the incisive bone, the bone is isolated from the superior maxillary. In such a case double hare-lip results.

When a tonsil enlarges it projects inward. The deafness which so often attends hypertrophy of the tonsil is not due to blocking of the Eustachian orifice by the tonsil, but is due to thickening of the mucous membrane lining the tube itself. The profuse bleeding which sometimes follows an operation for the removal of the tonsil is very seldom due to injury of the internal carotid artery, but is due to injury of the ascending pharyngeal artery (p. 623) or one of the palatine arteries.

The internal carotid artery is in close relation with the pharynx, so that its pulsations can be felt through the mouth. It has been occasionally wounded by sharp-pointed instruments introduced into the mouth and thrust through the wall of the pharynx. In aneurism of this vessel in the neck the tumor necessarily bulges into the pharynx, as this is the direction in which it meets with the least resistance, nothing lying between the vessel and the mucous membrane except the thin Constrictor muscle, whereas on the outer side there is the dense cervical fascia, the muscles descending from the styloid process, and the margin of the Sterno-mastoid muscle.

The mucous membrane of the pharynx is very vascular, and is often the seat of inflammation, frequently of a septic character, and dangerous on account of its tendency to spread to the larynx. On account of the tissue which surrounds the pharyngeal wall being loose and lax, the inflammation is liable to spread through it far and wide, extending downward into the posterior mediastinum along the oesophagus. Abscess may form in the connective tissue behind the pharynx, between it and the vertebral column, constituting what is known as retro-pharyngeal abscess. This is most commonly due to caries of the cervical vertebrae, but may also be caused by suppuratiion of a lymphatic gland which is situated in this position opposite the axis, and which receives lymphatics from the nares, or by gummi or by acute pharyngitis. In these cases the pus may be easily evacuated by an incision, with a guarded bistoury, through the mouth, but, for aseptic reasons, it is desirable that the abscess should be opened from the neck. In some instances this is perfectly easy; the abscess can be felt bulging at the side of the neck and merely requires an incision for its relief; but this is not always so, and then an incision should be made along the posterior border of the Sterno-mastoid and the deep fascia should be divided. A director is now to be inserted into the wound, the forefinger of the left hand being introduced into the mouth and pressure made upon the swelling. This acts as a guide, and the director is to be pushed onward until pus appears in the groove. A pair of forceps are now inserted along the director and the opening into the cavity dilated.

Foreign bodies not infrequently become lodged in the pharynx and most usually at its termination at about the level of the cricoid cartilage, just beyond the reach of the finger, as the distance from the arch of the teeth to the commencement of the oesophagus is about six inches.

Hypertrophy of the adenoid tissue of the naso-pharynx produces groups of hypertrophic masses known as adenoids. A child with adenoids has a cough, and when awake or asleep, breathes noisily and with the mouth open. The voice is muffled, the hearing is impaired, the expression is vacant, the mind is dull, and the tonsils are enlarged.

THE OESOPHAGUS (Figs. 839, 840, 841, 842).

The oesophagus (oșo, oșo, I carry; qarenu to eat) or gullet is a muscular canal, averaging about nine or ten inches in length, extending from the pharynx to the stomach. It commences at the upper border of the cricoid cartilage, opposite the intervertebral disk between the fifth and sixth cervical vertebrae, descends along the front of the spine through the posterior mediastinum, passes through the Diaphragm, and, entering the abdomen, terminates in the stomach wall at the point known as the cardia opposite the tenth thoracic vertebra or possibly opposite the intervertebral disk between the tenth and eleventh thoracic vertebrae. The general direction of the oesophagus is vertical, but it presents two or three slight curves in its course. At its commencement it is placed in the median line, but it inclines to the left side as far as the root of the neck, gradually passes to the middle line again, and finally again deviates to the left as it passes forward to
the oesophageal opening of the Diaphragm (*hiatus oesophageus*). The oesophagus also presents an antero-posterior flexure, corresponding to the curvature of the cervical and thoracic portions of the spine. It is the narrowest part of the alimentary canal, being most contracted at its commencement and at the point where it passes through the Diaphragm.

The diameter of the largest portion of the oesophagus where it is contracted is about half an inch; when it is fully dilated, an inch or even more.

In the neck the oesophagus, when at rest, is flattened, the anterior and posterior walls approaching each other. The canal in the neck is round or oval, and the lumen is stellate (Cunningham). The oesophagus is somewhat constricted at three points. One constriction is at the very beginning of the tube; another is where the left bronchus crosses it; another is at the point where the oesophagus passes through the Diaphragm. The tube at each constricted point is distinctly flattened. The diameter of each of these constricted parts is slightly under one-half inch, the diameter of the rest of the tube when contracted is one-half inch, but when dilated may reach or exceed one inch. The average distance from the upper incisor teeth to the beginning of the gullet is about six inches; the average distance from the incisor teeth to the cardiac opening of the stomach is fifteen or sixteen inches. The portion of the oesophagus which is in the neck is called the **cervical portion** (*pars cervicalis*); the portion in the thorax, the **thoracic portion** (*pars thoracalis*), and the portion which lies in the oesophageal opening of the Diaphragm, the **diaphragmatic portion**. The margin of the oesophageal orifice in the Diaphragm is narrow in front, thicker behind and to the sides. Behind and to the sides the diaphragmatic portion of the oesophagus is about half an inch in length. In front there is only a thin edge of Diaphragm in contact with the gullet. The oesophagus is connected to the margins of the diaphragmatic orifice by connective tissue. The so-called **abdominal portion of the oesophagus** (*pars abdominalis*) is not over half an inch in length, and is limited to the small portion of the anterior and left lateral surface observed when a stomach which is completely empty is drawn downward with considerable force. The abdominal portion of the oesophagus is covered with peritoneum; the corresponding portions of the right lateral and posterior walls are not covered by peritoneum. This uncovered portion of the oesophagus runs downward and to the left and lies directly
behind the **oesophageal groove** on the posterior surface of the left lobe of the liver, but does not actually touch the groove, which in reality holds the thick, right edge of the oesophageal opening of the Diaphragm. When the stomach is distended the abdominal portion of the gullet ceases to exist and becomes part of the stomach wall.

**Relations.**—In the **neck** the oesophagus is in relation, **in front**, with the trachea, and it is connected to the posterior wall of the trachea by areolar tissue. At the lower part of the neck, where it projects to the left side, it is in relation in front with the thyroid gland and thoracic duct; **behind**, it rests upon the vertebral column and Longi colli muscles; **on each side**, it is in relation with the common carotid artery (especially the left, as the gullet inclines to that side) and part of the lateral lobes of the thyroid gland; the recurrent laryngeal nerves ascend between it and the trachea.

In the thorax, it is at first situated a little to the left of the median line; it then passes behind the aortic arch, being separated from it by the trachea, and descends in the posterior mediastinum, along the right side of the aorta, nearly to the Diaphragm, where it passes in front and a little to the left of the artery, previous to entering the abdomen. It is in relation, **in front**, with the trachea, the arch of the aorta, the left common carotid and left subclavian arteries, which incline toward its left side, the left bronchus, the pericardium, and the Diaphragm; **behind**, it rests upon the vertebral column, the Longi colli muscles, the right intercostal arteries, and the vena azygos minor; and **below**, near the Diaphragm, upon the front of the aorta; **laterally**, it comes in contact with both pleurae, especially with the left pleura above and the right pleura below; it overlaps the vena azygos major, which lies on its right side, while the descending aorta is placed on its left side. The vagus nerves descend in close contact with it, the right nerve passing down behind, and the left nerve in front of it, each nerve spreading out into a plexus, the **oesophageal plexus**, around the tube. The two plexuses are joined to each other. The right nerve forms the **posterior oesophageal plexus** (*plexus oesophageus posterior*); the left nerve the **anterior oesophageal plexus** (*plexus oesophageus anterior*).

In the lower part of the posterior mediastinum the thoracic duct lies to the right side of the oesophagus; higher up, it is placed behind it, and, crossing about the level of the fourth thoracic vertebra, is continued upward on its left side.

Above the aortic arch and the arch of the great azygos vein above the root of the right lung, the pleurae are close to but not in actual contact with the oesophagus.

Below the arch of the great azygos vein the right side of the oesophagus is covered with pleura nearly to the diaphragmatic opening. The posterior surface of the gullet also may be covered with pleura. Below the arch of the aorta on the left side the pleura covers only a small portion of the oesophagus, that is, a portion of the left wall, a little above the diaphragmatic opening.
**Anomalies.**—There may be openings of the oesophagus into the trachea. A diverticulum or pressure pouch may exist. Such a pouch is usually placed upon the posterior wall near the pharynx. There may be congenital constriction, tubular or annular.

**Structure.**—The oesophagus is fastened to adjacent structures by connective tissue called the tunica adventitia. The tube has three coats—an external or muscular, a middle or areolar, and an internal or mucous coat.

**The Muscular Coat (tunica muscularis).**—The muscular coat is composed of two planes of fibres of considerable thickness, an external plane of longitudinal and an internal plane of circular fibres.

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**Fig. 841.**—The position and relation of the oesophagus in the cervical region and in the posterior mediastinum. Seen from behind. (Poirier and Charpy.)

The Longitudinal Fibres are arranged, at the commencement of the tube, in three fasciculi: one in front, which is attached to the vertical ridge on the posterior surface of the cricoid cartilage; and one at each side, which is continuous with the fibres of the Inferior constrictor of the pharynx; as they descend they blend together and form a uniform layer, which covers the outer surface of the tube.

Accessory slips of muscular fibres are described by Cunningham as passing between the oesophagus and the left pleura (m. pleurooesophagus), where it covers the thoracic aorta, or between the oesophagus and the root of the left bronchus (m. bronchooesophagus), or the back of the pericardium, as well as other still more...
rare accessory fibres. In Fig. 842, taken from a dissection in the Museum of the Royal College of Surgeons of England, several of these accessory slips may be seen passing from the oesophagus to the pleura, and two slips passing to the back of the trachea just above its bifurcation. These slips of muscular fibres which pass to adjacent structures give support to the oesophagus. Below, the longitudinal fibres of the oesophagus are continued into the longitudinal fibres of the stomach.

The Circular Fibres are continuous above with the Inferior constrictor of the pharynx; their direction is transverse at the upper and lower parts of the tube, but oblique in the central part. Below, the circular fibres pass into the circular and oblique fibres of the stomach.

The muscular fibres in the upper part of the oesophagus are of a red color, and consist chiefly of the striped variety, but below they consist for the most part of involuntary muscular fibre. At the cardia they act as a sphincter to solid food. Some maintain that this sphincter is closed tonically, others that it opens and closes rhythmically during gastric digestion.

The Submucous or Areolar Coat (tela submucosa).—The submucous or areolar coat connects loosely the mucous and muscular coats. It consists of dense connective tissue and contains blood-vessels, nerves, and oesophageal glands (glandulae oesophageae). The glands are mucous glands and are found throughout the length of the gullet. The ducts of the glands pass through the muscularis mucosae. These ducts are surrounded by adenoid tissue.

The Mucous Coat (tunica mucosa).—The mucous coat is thick, of a reddish color above and pale below. It is disposed in longitudinal folds, which disappear on distention of the tube. Its surface is studded with minute papillae, and is covered throughout with a thick layer of stratified pavement epithelium. The mucous coat contains glands which differ from the mucous glands of the submucous tissue. They are branched and tubular (Hewlett) and are called the superficial glands. There are two chief groups of superficial glands; one near the beginning, and the other near the termination of the oesophagus. The ducts of the superficial glands are not surrounded by lymphoid tissue (Hewlett). Beneath the mucous membrane, between it and the submucous coat, is a layer of longitudinally arranged non-striped muscular fibres. This is the muscularis mucosae (lamina muscularis mucosae). At the commencement it is absent, or only represented by a few scattered bundles; lower down it forms a considerable stratum.

Vessels of the Oesophagus.—The larger vessels are in the submucosa and send branches to the mucosa and muscularis. The arteries supplying the oesophagus are derived from the inferior thyroid branch of the thyroid axis of the subclavian, from the descending thoracic aorta and the bronchial arteries, and from the gastric branch of the coeliac axis, and from the left inferior phrenic of the abdominal aorta. They have for the most part a longitudinal direction. The veins are gathered into a plexus on the outer surface of the oesophagus. This plexus receives the venous blood from the walls of the tube. From the lower portion of the plexus branches go to the coronary vein of the stomach. Higher up branches go to the azygos veins.
and thyroid veins. In this manner a communication is opened between the portal veins and the systemic veins.

**Lymphatics of the Oesophagus.**—The lymphatics drain into the inferior deep cervical glands and the glands of the posterior mediastinum.

**Nerves of the Oesophagus.**—The nerves are derived from the vagus and from the sympathetic; they form a plexus in which are groups of ganglion-cells between the two layers of the muscular coats. From this fibres pass to supply the muscle, and others go to the submucous tissue to form a secondary plexus. It is usual to regard the plexus as consisting of two parts, a **ventral or anterior oesophageal plexus**, derived from the left vagus, and a **dorsal or posterior oesophageal plexus**, derived from the right vagus. These two plexuses are in the posterior mediastinum; they communicate with each other and contain sympathetic fibres.

**Movements and Innervation of the Oesophagus.**

**Movements.**—When liquid is swallowed it is, as pointed out by Kronecker and Meltzer, suddenly forced into the gullet by the contraction of the Mylo-hyoid muscle, the tube playing a practically passive part.1 In the passage of solid and semisolid food the oesophagus contracts. It does not contract, as was once thought, in sections, but there is a peristaltic wave. "The wave at a given point lasts in the neck region about 3.5 seconds, and from five to nine seconds in the thoracic region."2 The lower end of the oesophagus or cardia has a sphincter, the cardiac sphincter. It is usually taught that this sphincter is tonically contracted. When a mouthful of food is swallowed it rests above the sphincter for a moment and is then forced through by muscular contractions (Kronecker and Meltzer). If several acts of swallowing follow each other rapidly the sphincter relaxes so that there is no resistance to the passage of food. In cats Dr. Walter B. Cannon3 has demonstrated "rhythmic relaxations of the cardia, so that fluid food streams from the stomach into the oesophagus even above the level of the heart, then is pressed into the stomach again by a peristaltic wave, only to be released a moment later to pour into the oesophagus anew."

**Innervation.**—There is in the oesophagus a local reflex, but peristalsis is dominated by the central nerve system. "It seems probable that the peristaltic contractions of the oesophagus, to be efficient, must be supported by nervous influences from outside. In this respect the oesophagus is different from the remainder of the alimentary canal."4

**Surgical Anatomy.**—The relations of the oesophagus are of considerable practical interest to the surgeon, as he is frequently required, in cases of **stricture** of this tube, to dilate the canal by a bougie, when it is of importance that the direction of the oesophagus and its relations to surrounding parts should be remembered. In cases of **malignant disease** of the oesophagus, where its tissues have become softened from infiltration of the morbid deposit, the greatest care is requisite in directing the bougie through the strictured part, as a false passage may easily be made, and the instrument may pass into the mediastinum, or into one or the other pleural cavity, or even into the pericardium.

The student should also remember that obstruction of the oesophagus, and consequent symptoms of stricture, are occasionally produced by **aneurism** of some part of the aorta pressing upon the tube. In such a case the passage of a bougie could only hasten the fatal issue.

In passing a bougie the left forefinger should be introduced into the mouth and the epiglottis felt for, care being taken not to throw the head too far backward. The bougie is then to be passed beyond the finger until it touches the posterior wall of the pharynx. The patient is now asked to swallow, and at the moment of swallowing the bougie is passed gently downward, all violence being carefully avoided.

It occasionally happens that a **foreign body** becomes impacted in the oesophagus and can neither be brought upward nor moved downward. When all ordinary means for its removal have failed, and the body is lodged above the lower one-third of the gullet, external **oesophagotomy** is performed. If the foreign body is lodged in the lower one-third of the gullet the stomach is opened (gastroctomy) and the foreign body is extracted. If the foreign body is allowed to remain lodged in the oesophagus, extensive inflammation and ulceration may ensue. In one case the foreign body ultimately penetrated the intervertebral substance, and destroyed life by inflammation of the membranes and substance of the cord.

The operation of **oesophagotomy** is thus performed: The patient being placed upon his back, with the head and shoulders slightly elevated, an incision, about four inches in length,

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1 Recent Advances in the Knowledge of the Movements and Innervation of the Alimentary Canal. By Walter B. Cannon, M.D., in Medical News, May 20, 1905.
2 Ibid.
3 Ibid.
4 Ibid.
THE ABDOMEN

should be made on the left side of the trachea, from the thyroid cartilage downward, dividing the skin, Platysma, and deep fascia. The edges of the wound being separated, the Omohyoid muscle should, if necessary, be divided, and the fibres of the Sternohyoid and Sternothyroid muscles drawn inward; the sheath of the carotid vessels, being exposed, must be drawn outward, and retained in that position by retractor: the oesophagus will now be exposed, and should be divided over the foreign body, which can then be removed. Great care is necessary to avoid wounding the thyroid vessels, the thyroid gland, and the laryngeal nerves.

The oesophagus may be obstructed not only by foreign bodies, but also by changes in its coats, producing stricture, or by pressure on it from without of new-growths or aneurism, etc. The different forms of stricture are: (1) the spasmoid, occurring in neurotic individuals, and intermittent in character, so that the dysphagia is not constant. Spasmoid stricture of the oesophagus sometimes occurs in cases of cancer of the stomach and cancer of the liver; (2) fibrous, due to cicatrization after injuries, such as swallowing corrosive fluids or boiling water; and (3) malignant, usually epitheliomatous, in its nature. Cancer is most common either at the upper end of the tube, opposite to the cricoid cartilage, or at its lower end at the cardiac orifice. Cicatricial stricture may be treated by gradual dilatation. If a stricture is impassible from above, the stomach may be opened, an instrument passed from below, and a string used to divide the stricture.

The operation of oesophagostomy has occasionally been performed in cases where the stricture in the oesophagus is at the upper part, with a view to making a permanent opening below the stricture through which to feed the patient, but the operation has been far from a successful one, and the risk of setting up diffuse inflammation in the loose planes of connective tissue deep in the neck is so great that it would appear to be better, if any operative interference is undertaken, with the idea of forming a mouth to introduce food, to perform gastrostomy. The operation of oesophagostomy is performed in the same manner as oesophagotomy, but the edges of the opening in the oesophagus are stitched to the skin incision. Gastrostomy is the only operation to be thought of in malignant stricture.

THE ABDOMEN.

The abdomen (from abdo, I put away or hide, or possibly from adeps, fat) is the largest cavity in the body. It is of an oval form, the extremities of the oval being directed upward and downward; the upper one being formed by the under surface of the Diaphragm, the lower by the upper concave surface of the Levati ani muscles. In order to facilitate description, it is artificially divided into two parts: an upper and larger part, the abdomen proper; and a lower and smaller part, the pelvis. These two cavities are not separated from each other, but the limit between them is marked by the brim of the true pelvis. The space is wider above than below, and measures more in the vertical than in the transverse diameter.

The abdomen proper differs from the other great cavities of the body in being bounded for the most part by muscles and fasciae, so that it can vary in capacity and shape according to the condition of the viscera which it contains; but, in addition to this, the abdomen varies in form and extent with age and sex (Fig. 844). In the adult male, with moderate distention of the viscera, it is oval or barrel-shaped, but at the same time flattened from before backward. In the adult female, with a fully developed pelvis, it is conical with the apex above, and in young children it is conical with the apex below.

Boundaries.—The boundary between the thorax and abdomen is the Diaphragm. This muscle forms a dome over the abdomen, and the cavity extends high into the bony thorax, reaching to the level of the junction of the fourth costal cartilages with the sternum. The lower end of the abdomen is limited by the structures which elute the inner surface of the bony pelvis, principally the Levatores ani and Coccygei muscles on either side. These muscles are sometimes termed the Diaphragm of the pelvis. The abdomen proper is bounded in front and at the sides by the lower ribs, the abdominal muscles, and the venter ilii; behind, by the vertebral column and the Psoas and Quadratus lumborum muscles; above, by the Diaphragm; below, by the brim of the pelvis. The muscles forming the
boundaries of the cavity are lined upon their inner surface by a layer of fascia, differently named, according to the part which it covers.
The abdomen contains (Fig. 843) the greater part of the alimentary canal; some of the accessory organs to digestion—viz., the liver and pancreas, the spleen, the kidneys, and suprarenal capsules. Most of these structures, as well as the wall of the cavity in which they are contained, are covered by an extensive and complicated serous membrane, the peritoneum (Fig. 856).

The Apertures in the Walls of the Abdomen.—The apertures found in the walls of the abdomen, for the transmission of structures to or from it, are the umbilicus, for the transmission (in the foetus) of the umbilical vessels; the caval opening in the Diaphragm, for the transmission of the postcava; the aortic opening, for the passage of the aorta, vena azygos major, and thoracic duct; and the oesophageal opening, for the oesophagus and vagus nerves. Below, there are two apertures on each side: one for the passage of the femoral vessels, and the other for the transmission of the spermatic cord in the male, and the round ligament in the female.

Regions (Fig. 846).—For convenience of description of the viscera, as well as of reference to the morbid conditions of the contained parts, the abdomen is artificially divided into nine regions. Thus, if two circular lines are drawn around the body, the one through the extremities of the ninth ribs where they join their costal cartilages, and the other through the highest points of the crests of the ilia, the abdominal cavity is divided into three zones—an upper, a middle, and a lower. If two parallel lines are drawn perpendicularly upward from the centre of Poupart's ligament, each of these zones is subdivided into three parts—a middle and two lateral.¹

The middle region of the upper zone is called the epigastric (ἐπί, over; γαστήρ, the stomach); and the two lateral regions, the right and left hypochondriac (ὑπο, under; χονδρια, the cartilages). The central region of the middle zone is the mesogastric or umbilical; and the two lateral regions, the right and left lumbar. The middle region of the lower zone is the hypogastric or pubic region; and the lateral regions are the right and left inguinal or iliac. The viscera contained in these different regions are the following (Fig. 846):

¹ Anatomists are far from agreed as to the best method of subdividing the abdominal cavity. Cunningham suggests that the lower line should encircle the body on a level with the highest point of the iliac crest, as seen from the front—a point corresponding with a prominent tubercle on the outer lip of the iliac crest about two inches behind the anterior superior spine. Addison (Journal of Anatomy and Physiology, vols. xxxiv. and xxxv.), in a careful analysis of the abdominal viscera in forty subjects, adopts the following lines: (1) a median, from the symphysis pubis to the ensiform cartilage; (2) two lateral lines drawn vertically through a point midway between the anterior superior iliac spine and the symphysis pubis; (3) an upper transverse line half-way between the symphysis pubis and the suprasternal notch; and (4) a lower transverse line midway between the last and the upper border of the symphysis pubis.—Pp. of 15th English edition.

Joessel draws a line through the cartilaginous ends of the tenth ribs; a line through the two anterior superior spines of the ilia. On each side he carries a perpendicular line from the iliopectineal eminence to the horizontal line connecting the tenth ribs. By this plan the highest plane is subcostal.
Right Hypochondriac.
The greater part of the right lobe of the liver, the hepatic flexure of the colon, and part of the right kidney.

Epigastric Region.
The greater part of the stomach, including both cardiac and pyloric orifices, the left lobe and part of the right lobe of the liver and the gall-bladder, the pancreas, the duodenum, the suprarenal capsules, and parts of the kidneys.

Left Hypochondriac.
The fundus of the stomach, the spleen, the extremity of the pancreas, the splenic flexure of the colon, and part of the left kidney.

Right Lumbar.
Ascending colon, part of the right kidney, and some convolutions of the small intestines.

Umbilical Region.
The transverse colon, part of the great omentum and mesentery, transverse part of the duodenum, and some convolutions of the jejunum and ileum, and part of both kidneys.

Left Lumbar.
Descending colon, part of the omentum, part of the left kidney, and some convolutions of the small intestines.

Right Inguinal or Iliac.
The caecum and vermiform appendix and a portion of the ascending colon.

Hypogastric Region.
Convolutions of the small intestines, the bladder in children, and in adults if distended, and the uterus during pregnancy.

Left Inguinal or Iliac.
Sigmoid flexure of the colon and a portion of the descending colon.

The regions of the abdomen as described in the new nomenclature are shown in Fig. 845.

If the anterior abdominal wall is reflected in the form of four triangular flaps by means of vertical and transverse incisions—the former from the ensiform cartilage to the symphysis pubis, the latter from flank to flank at the level of the umbilicus—the abdominal or peritoneal cavity is freely opened into and the contained viscera are in part exposed.\footnote{1}

Above and to the right side is the liver, situated chiefly under the shelter of the right ribs and their cartilages, but extending across the middle line, and reaching for some distance below the level of the ensiform cartilage. Below and to the left of the liver is the stomach, from the lower border of which an apron-like fold of peritoneum, the great omentum, descends for a varying distance, and obscures, to a greater or lesser extent, the other viscera (Fig. 874). Below it, however, some of the coils of the small intestine can generally be seen, while in the right and left iliac regions respectively the caecum and the sigmoid flexure of the colon are exposed. The bladder occupies the anterior part of the pelvis, and, if distended, will project above the symphysis pubis; the rectum lies in the concavity of the sacrum, but is usually obscured by the coils of the small intestine.

If the stomach is followed from left to right it will be found to be continuous with the first part of the small intestine, or duodenum, the point of continuity being marked by a thickened ring which indicates the position of the pyloric valve.

\footnote{1 It must be borne in mind that, although the term abdominal cavity is used, there is, under normal conditions, only a potential cavity or lymph-space, since the viscera are everywhere in contact with the parietes.—Ed. of 15th English edition.}
The duodenum passes toward the under surface of the liver, and then, curving downward, is lost to sight. If, however, the great omentum be thrown upward over the chest, the terminal part of the duodenum will be observed passing across the spine toward the left side, where it becomes continuous with the coils of the small intestine. These measure some twenty feet in length, and if followed downward will be seen to end in the right iliac fossa by opening into the caecum, the commencement of the large intestine. From the caecum the large intestine takes an arched course, passing at first upward on the right side, then across the middle line and downward on the left side, and forming respectively the ascending, transverse, and descending parts of the colon. In the left iliac region it makes still another bend, the sigmoid flexure, and then follows the curve of the sacrum as far as the rectum.

The spleen lies behind the stomach in the left hypochondriac region, and may be in part exposed by pulling the stomach over toward the right side. The glistening appearance of the deep surface of the abdominal wall and of the exposed viscera is due to the fact that the former is lined and the latter more or less completely covered by a serous membrane, the peritoneum.

Development of the Alimentary Canal, Viscera and Peritoneum.—When the paraxial mesoblast of the embryo has developed a series of transverse segmentations it becomes converted into a row of dark, square segments known as the protovertebrae or the mesoblastic somites, which are separated by clear, transverse intervals. They appear first in the region that is to become the neck, and from there extend back along the entire length of the trunk. These bodies are not solely the representatives of the future permanent vertebrae, but differentiate partly into muscles and true skin.

On each side of the protovertebrae the lateral mesoblast splits into two layers. The upper layer is applied to the epiblast, and forms with it the somatopleure or body-wall. The lower layer becomes adherent to the hypoblast, and forms the splanchnopleure or wall of the alimentary canal. The space between these two
layers is the **caelum** or the **pleuropertitoneal cavity**. This body-cavity is of large size in the early stages of the development of the embryo.

Anteriorly—or, if the body is in the erect posture, superiorly—there is developed a comparatively large space called the **pericardiothoracic cavity**; and a transverse fold develops, which marks off this cavity from the future abdominal cavity. This fold, with many veins of large size, develops into the primary Diaphragm, although its dorsal part remains incomplete. The dorsal part is completed at a later period, constituting the Diaphragm as we see it in the adult. As Dr. Frederick J. Brockway expresses it: "The Diaphragm is thus made up of a ventral, younger part, and a dorsal, older part. When this posterior part fails to develop, there is opportunity for a congenital diaphragmatic hernia to be present."

The pericardiothoracic cavity becomes divided into three cavities, and the two lateral ones are for a time continuous with the abdominal cavity. This continuation is, however, but temporary, and they are afterward separated. In this manner, four large serous sacs are formed. The two **lateral thoracic sacs** are known as the **pleural sacs**, and are lined with the pleura; the **median thoracic sac** is the **pericardial sac**, and is lined with the pericardium; and the **abdominal sac** forms the abdominal cavity, and is lined with the peritoneum.

The primitive alimentary canal, which was formed early by the closure within the embryo of a portion of the blastodermic vesicle, consists of three parts: first, the **fore-gut**, within the cephalic flexure, dorsal to the heart; second, the **mid-gut**, opening freely into the yolk-sac; and third, the **hind-gut**, within the caudal flexure. In the fore-gut are developed the back portion of the mouth, the tongue, the pharynx, the oesophagus, the stomach, the larger part of the duodenum, and the

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**Fig. 846.**—The regions of the abdomen and their contents. Edge of costal cartilages in dotted outline.
organs that have grown out from these structures. The hind-gut forms a portion of the colon and the rectum, with the exception of the latter's anal end; and the mid-gut gives rise to the remainder of the digestive tube.

**Development of the Alimentary Canal.**—The fore-gut and hind-gut end blindly, there being at first neither mouth nor anus (Figs. 847 and 848). The upper part of the fore-gut becomes dilated to form the pharynx, in relation to which the branchial arches are developed (Fig. 850); the succeeding part remains tubular, and with the descent of the stomach is elongated to form the esophagus. Soon a fusiform dilatation, the future stomach, makes its appearance, and beyond this the mid-gut opens freely into the yolk-sac (Figs. 850 and 851).

This opening is at first wide, but, as the body-walls close in around the umbilicus, it is gradually narrowed into a tubular stalk, the **yolk-stalk** or **vitello-intestinal duct.**

At this stage, therefore the alimentary canal forms a nearly straight tube in front of the notochord and primitive aorta (Fig. 848). From the stomach to the rectum it is attached to the notochord by a band of mesoblast, from which the common

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![Diagram](image-url)
mesentery of the gut is subsequently developed. The stomach undergoes a further dilatation, and its two curvatures can be recognized (Figs. 852 and 855), the greater directed toward the vertebral column and the lesser toward the anterior wall of the abdomen, while of its two surfaces one looks to the right and the other to the left. The mid-gut also undergoes great elongation, and forms a V-shaped loop which projects downward and forward; from the bend or angle of the loop the vitello-intestinal duct passes to the umbilicus (Fig. 855). For a time a part of the loop extends beyond the abdominal cavity into the umbilical cord, but by the end of the third month this is withdrawn. With the lengthening of the tube, the mesoblast, which attaches it to the future vertebral column and which carries the blood-vessels for the supply of the gut, is thinned and drawn out to form the **primitive or common mesentery**. The portion of this mesentery which is attached to the greater curvature of the stomach is named the **mesogastrium**, and the parts which suspend the colon and rectum are respectively termed the **mesocolon** and **mesorectum** (Fig. 855). About the sixth week a lateral diverticulum makes its appearance a short distance beyond the vitello-intestinal duct, and indicates the future
caecum or boundary between the small and the large intestine. This caecal diverticulum has at first a uniform calibre, but its blind extremity remains rudimentary and forms the vermiform appendix (Figs. 855 and 856). Changes also take place in the position and direction of the stomach. It falls over on its right surface, which henceforth is directed backward, while its original left surface looks
forward; further, its greater curvature is drawn downward and to the left, away from the vertebral column, while its lesser curvature is directed, upward, and the commencement of the duodenum is pushed over to the right side of the middle line. The mesogastrium, being attached to the greater curvature, must necessarily follow its movements, and hence it becomes greatly elongated and drawn outward from the vertebral column, and, like the stomach, what was originally its right surface is now directed backward and its left forward. In this way a pouch, the bursa omentalis, is formed behind the stomach; this pouch is the future lesser sac of the peritoneum, and it increases in size as the alimentary tube undergoes further development; the entrance to the pouch constitutes the future foramen of Winslow (Figs. 852, 856, and 859). The remainder of the mid-gut becomes greatly increased in length, so that the tube is coiled on itself, and this increase in length demands a corresponding increase in the width of the intestinal attachment of the mesentery, so that it becomes plaited or folded.

At this stage the small and the large intestines are attached to the vertebral column by a common mesentery, the coils of the small intestine falling to the right of the middle line, while the large intestine lies on the left side.1

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1 Sometimes this condition persists throughout life, and it is then found that the duodenum does not cross from the right to the left side of the vertebral column, but lies entirely on the right side of the mesial plane, where it is continued into the jejunum; the arteries to the small intestine (rami intestini tenuis) also arise from the right instead of the left side of the superior mesenteric artery.
The abdomen grows downward to form the great omentum, and this downward extension lies in front of the transverse colon and the coils of the small intestine. The anterior layer of the transverse mesocolon is at first quite distinct from the posterior wall of the bursa omentalis, but ultimately the two blend, and hence the great omentum appears as if attached to the transverse colon (Figs. 859, 860, and 861). The mesentery of the duodenum, in which the rudiment of the pancreas is enclosed, disappears, and so this part of the gut becomes fixed to the posterior abdominal wall, and the pancreas lies entirely behind the peritoneal membrane. The mesenteries of the ascending and descen-
ing parts of the colon disappear in the majority of cases, while that of the small intestine assumes the oblique attachment characteristic of its adult condition.

The small omentum is formed by a thinning of the mesoblast or anterior primitive mesentery, which attaches the lesser curvature of the stomach to the anterior abdominal wall. By the subsequent growth of the liver this leaf of mesoblast is divided into two parts—viz., the small omentum between the stomach and liver, and the falciform ligament between the liver and the abdominal wall and Diaphragm (Fig. 858).

The anus is developed as a slight invagination of the epiblast a short distance in front of the posterior end of the hind-gut. This invagination is termed the proctodaeum, the mesoblast between it and the hypoblastic lining of the hind-gut is thinned, and ultimately the septum breaks down and disappears, and the hind-gut opens on the surface; into this part of the hind-gut the urinary and generative organs open for a time, and so constitutes a common cloaca. The small portion of the hind-gut behind the orifice of the anus is named the caudal or post-anal gut; it communicates with the neural tube by means of a canal, the neurenteric canal, already referred to. Ultimately the post-anal gut becomes obliterated, and it, together with the neurenteric canal, finally disappears.
The peritoneal cavity is the space left between the visceral and parietal layers of the mesoblast, and the serous membrane is developed from these layers.

The tongue originates from the floor of the pharynx. The anterior or papillary portion first appears as a rounded elevation, the tuberculum impar, between the ventral ends of the mandibular and hyoid arches (Fig. 862). Between the third and fourth arches a second larger elevation arises, in the centre of which is a median groove or furrow. This second elevation is termed the furcula, and from it the epiglottis is developed, while the median furrow becomes the entrance to the larynx (Fig. 863). The tuberculum impar and the furcula are at first in apposition, but are soon separated by a ridge produced by the forward growth of the second and third arches. This ridge gives rise to the posterior part of the tongue and extends forward in the form of a V, so as to embrace between its two limbs the tuberculum impar. At the apex of the V there is a pit-like invagination to form the middle thyroid rudiment, and this depression persists as the foramen caecum of the adult. The union of the two parts of the tongue is indicated even in the adult by a V-shaped depression, the apex of which is at the foramen caecum, while the two limbs run outward and forward parallel to but a little behind the circumvallate papillæ, which are therefore developed from the tuberculum impar (Figs. 862, 863, and 864). The tonsils are developed from the second branchial cleft, and make their appearance between the fourth and fifth months.

The liver arises in the form of two diverticula or hollow outgrowths from the ventral surface of that portion of the fore-gut which afterward becomes the duodenum (Figs. 850 and 851). The outgrowths, which represent the right and the left lobes, respectively, of the adult liver, give off solid buds of cells, which grow into columns or cylinders; these unite with one another in every direction to form a close network, in the meshes of which are contained the capillary blood-vessels. Some of these columns become hollowed out and form the bile-ducts, while the remainder constitute the secreting structure. The minute ducts thus produced unite to form the right and left hepatic ducts; while the common bile-duct is developed as a protrusion from the duodenal wall, and as it grows the liver becomes shifted away from the duodenum. The gall-bladder and cystic duct are formed by

Fig. 859.—Schematic figure of the bursa omentalis, &c. Human embryo of eight weeks. (Kollmann.)
a hollow evagination from the wall of the common bile-duct. About the third month the liver almost fills the abdominal cavity. From this period the relative
devolution of the liver is less active, more especially that of the left lobe, which now becomes smaller than the right; but up to the end of foetal life the liver remains relatively larger than in the adult.

The pancreas is also an early formation, being far advanced in the second month. It originates as a hollow projection from the hypoblast of the dorsal wall of the duodenum (Figs. 851 and 852), opposite the hepatic diverticula, which, as we have already seen, spring from its ventral wall. This hollow process grows between the two layers of the dorsal mesentery and sends out offshoots, which
branch abundantly and form a complicated tubular gland. As torsion of the stomach takes place, the pancreas assumes a transverse position and becomes fixed across the dorsal wall of the abdomen, the posterior layer of its mesentery undergoing absorption. Its duct ultimately opens into the duodenum together with the common bile-duct.

The spleen, on the other hand, is of mesoblastic origin, for there is never any connection between the intestinal cavity and the substance of this organ. It originates in the mesenteric fold which connects the stomach to the vertebral column (mesogastrium) (Fig. 855).

The peritoneum (TUNICA SEROSA).

During life and in the uncut corpse the peritoneal cavity (cavum peritonaei) is air-tight. It is not a real cavity, as muscular tension and atmospheric pressure permit no vacant space to form. When the surgeon or anatomist opens the abdomen, the peritoneal cavity is at that moment produced.

The peritoneum (from περί, about, and τεντόνιο, I stretch) is the largest serous membrane in the body, and consists, in the male, of a closed sac, a part of which is applied against the abdominal parietes, while the remainder is reflected over the contained viscera. In the female the peritoneum is not a closed sac, since the free extremities of the Fallopian tubes open directly into the peritoneal cavity. The portion of the peritoneum applied against the abdominal parietes constitutes the parietal peritoneum; the portion reflected over the viscera, the visceral peritoneum. The free surface of the membrane is smooth, covered by a layer of flattened endothelium, and lubricated by a small cavity of serous fluid. Hence the viscera can glide freely against the wall of the cavity or upon one another with the least possible amount of friction. Its attached surface is rough, being con-
nected to the viscera and inner surface of the parieties by means of areolar tissue termed the subserous areolar tissue (tela subserosa). The parietal portion is loosely connected with the fascia lining the abdomen and pelvis, but more closely to the under surface of the Diaphragm and also in the middle line of the abdomen.

The peritoneum differs from the other serous membranes of the body in presenting a much more complex arrangement—an arrangement which can only be clearly understood by following the changes which take place in the alimentary canal during its development; and therefore the student is advised to preface his study of the peritoneum by reviewing the remarks on Embryology.

**Structure of the Peritoneum.**—It is a thin, glistening serous membrane and consists of a connective-tissue layer and one layer of flat endothelial cells upon the free surface of the membrane. The connective-tissue layer consists of bundles of connective tissue which contain many connective-tissue cells and elastic fibres. It contains a multitude of lymph-spaces, lymph-vessels, and lymph-capillaries. Beneath the peritoneum is a layer of lax and spongy connective tissue which serves to bind the serous membrane to parts beneath. This layer is called the subserous connective tissue. In some regions it is plentiful; in others, as over the liver and intestine, it is very scantily developed. The endothelial cells are flat and polygonal. Some hold that they are joined together by cement-substance. Robinson asserts that there is no cement-substance, but rather an organized connection between the protoplasmic processes of adjacent cells.

On the surface of the endothelium between the cells numerous apertures or interruptions are to be seen. These openings which many think are due to retracted epithelium communicate with lymph-spaces beneath the epithelial layer. The idea is held by some that the openings are permanent stomata and join lymphatic capillaries. Some openings which are noted, the stigmata or pseudo-stomata, are mere interruptions in the endothelial layer, and are occupied by processes of the branched connective-tissue corpuscle of the subjacent tissue.

The amount of fluid contained in the closed sac is, in most cases, only sufficient to moisten the surface, but not to furnish any appreciable quantity of free liquid. When a small quantity can be collected, it is found to resemble lymph, and, like that fluid, coagulates spontaneously; but when present in large quantities, as in dropsy, it is a more watery fluid, but still contains a considerable amount of proteid which is coagulated on boiling.

The peritoneum contains a great quantity of lymphatic structures. In the subserous tissue the numerous lymph-spaces obtain fluid from the peritoneal cavity. The subendothelial interstitial lymph-spaces intercommunicate and can take up an immense quantity of fluid from the peritoneal cavity. Normally the spaces contain both nutrient material and waste products. Lymphatics are particularly plentiful in—1, the tendinous portion of the Diaphragm; 2, the ligamenta lata; 3, the omentum; 4, the ventral surface of the small intestine; 5, the liver and spleen.

The lymph from this region reaches the mediastinal or diaphragmatic glands. The serous surface of the Diaphragm is the region chiefly efficient in absorption from the peritoneum, and there is a current in the peritoneal cavity directed toward the Diaphragm. Absorption from the peritoneal cavity is very active. Wegner has shown that an amount of fluid equal to from 3 to 8 per cent. of the body weight may be absorbed in one hour. Absorption is most active from the region of the Diaphragm and least active from the region of the pelvis. There are a multitude of nerves in the peritoneum, and it seems probable that each endothelial cell receives a nerve ending. The minute arteries of the peritoneum are surrounded by nerve-plexuses. According to Robinson, the nerves of the peritoneum are:

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1 The Peritoneum. By Byron Robinson.
2 Ibid.
3 Ibid.
1. Myelinic. 2. Amyelinic. 3. Fibres of Remak. 4. The Vater-Pacinian corpuscles and other varieties of nerve endings. 5. Nerve-cells. The visceral peritoneum contains many more nerves than the parietal peritoneum.

The **parietal peritoneum** (*peritonaeum parietale*) lines the wall of the abdominal cavity. The **visceral peritoneum** (*peritonaeum viscerale*) covers the viscera. Back of the parietal peritoneum is a space, the **retro-peritoneal space** (*spatium retro-peritoneale*), which contains the great vessels and nerves, the suprarenal capsules, the kidney, and ureters (Figs. 866, 867, 868, 869, and 870).

We describe the peritoneum as consisting of two saes, a **greater sac** and a **lesser sac** (Fig. 866). The larger part of the abdominal cavity is lined by the greater sac, as most of the viscera are covered by it. The lesser sac is placed largely behind the stomach. These two saes are not two distinct cavities which communicate. They constitute one cavity, a portion of which has been formed into a diverticulum or recess by a process of constriction, the result of changes produced in the position of adjacent viscera by development. Prof. Birmingham says: "If the great sac be compared to a bag, the lesser sac might be represented as a pocket lying behind, and opening into it by a narrow orifice, the **foramen of Winslow**, on its posterior wall."

The greater sac lines the walls of the abdominal cavity and covers the viscera which are invested by peritoneum, except the posterior portion of the stomach, the suprarenal capsule of the left side, the superior surface of the pancreas, the Spigelian lobe and the caudate lobes of the liver, and portions of the spleen, left kidney, and transverse colon, which are covered by peritoneum of the lesser sac.²

To trace the continuity of the membrane from one viscus to another, and from the viscera to the parietes, it is necessary to follow its reflections in the vertical and horizontal directions, and in doing so it matters little where a start is made.

If the stomach is drawn downward, a fold of peritoneum will be seen stretching from its lesser curvature to the transverse fissure of the liver (Figs. 866 and 872). This is the **gastro-hepatic** or **lesser omentum**, and consists of two layers; these, on being traced downward, split to envelop the stomach, covering respectively its anterior and posterior surfaces. At the greater curvature of the stomach they again come into contact and are continued downward in front of the transverse colon, forming the anterior two layers of the **great** or **gastro-colic omentum** (Figs. 866 and 874). Reaching the free edge of this fold they are reflected upward as its two posterior layers, and thus the great omentum consists of four layers of peritoneum. Followed upward the two posterior layers separate so as to enclose the transverse colon, above which they once more come into contact and pass backward to the abdominal wall as the **transverse mesocolon** (*mesocolon transversum*) (Fig. 866). Reaching the abdominal wall about the level of the transverse part of the duodenum, the two layers of the transverse mesocolon become separated from each other and take different directions; the upper or anterior layer, known as the **ascending layer of the transverse mesocolon**, ascends in front of the pancreas, and its further course will be followed presently (Fig. 866). The lower or posterior layer is carried downward, as the anterior layer of the mesentery, by the superior mesenteric vessels to the small intestine, around which it may be followed and subsequently traced upward as the posterior layer of the mesentery to the abdominal wall. From the posterior abdominal wall it sweeps downward over the aorta into the pelvis, where it invests the first part of the rectum and attaches it to the front of the sacrum by a fold termed the **mesorectum** (Fig. 866). Leaving first the sides and then the front of the second part of the rectum it is reflected on to the back of the bladder, and, after covering the posterior and upper aspects of this viscus, is carried by the **urachus** and **obliterated hypogastric arteries** as folds,

¹ Prof. Cunningham's Text-book of Human Anatomy.
² Ibid.
on to the posterior surface of the anterior abdominal wall (Fig. 865). The fold upon the urachus is the plica urachi (plica umbilicalis media); the fold on each obliterated hypogastric artery is the plica hypogastrica (plica umbilicalis lateralis). Between the rectum and bladder it forms a pouch, the recto-vesical pouch (excavatio rectouderina), bounded on the sides by two crescentic or semilunar folds (plicae rectovesicales), which pass from the posterior surface of the bladder to the sides of the rectum; the bottom of this pouch is about on a level with the middle of the vesiculae seminales—i. e., three inches or so from the orifice of the anus. When the bladder is distended the peritoneum is carried up with the expanded viscus, so that a considerable part of the anterior surface of the latter lies directly against the abdominal wall without the intervention of the peritoneal membrane. When the bladder is empty the peritoneum forms a transverse fold over its upper surface (plica vesicalis transversa).

In the female the peritoneum is reflected from the rectum on the upper part of the posterior vaginal wall, forming the recto-vaginal pouch or pouch of Douglas (excavatio rectouterina) (Fig. 866). In the pouch of Douglas are two folds of peritoneum (plica rectouterinae), which begin at the posterior surface of the cervix, extend back to the sides of the rectum, and bound above the deepest portion of the pouch. The pouch is then carried over the posterior aspect and fundus of the uterus on to its anterior surface, which it covers as far as the junction of the body and cervix uteri, forming here a second but shallower depression, the utero-vesical pouch (excavatio vesicouterina). It is also reflected from the sides of the uterus to the lateral wall of the pelvis on each side as an expanded fold, the broad ligament of the uterus (ligamentum latum uteri), in the free margin of each broad ligament can be felt a thickened cord-like structure, the Fallopian tube (tuba uterina [Fallopii]).

When the peritoneum lining the anterior abdominal wall is examined from behind, it is noticed that certain structures which lie in front of it form five peritoneal ridges (Fig. 865). The structure in the middle line is the urachus, which is the remains of the fectal allantois. In the adult it is a fibrous cord which passes from the umbilicus to the summit of the bladder. This cord is slender above, but broader below. External to the urachus are the fibrous cords which resulted from obliteration of the hypogastric arteries (arteriae umbilicales). These cords become more slender as they ascend toward the sides of the urachus and pass to the umbilicus. More external still are the folds formed by the deep epigastric arteries. The fold over each epigastric artery is the plica epigastrica; the fold over each obliterated hypogastric artery is the plica hypogastrica; the fold over the obliterated urachus is the plica urachi.

The five peritoneal ridges formed by the above-named structures create three peritoneal fossae on each side, called the inguinal fossae or pouches (fovea inguinales). The external inguinal fossa (fovea inguinalis lateralis) is external to the deep epigastric artery and corresponds to the internal abdominal ring. There is a funnel-shaped depression in its floor marking the point at which the inguinal process passed down. This depression, if marked, predisposes to oblique inguinal hernia. The middle inguinal fossa (fovea inguinalis medialis) is placed between the deep epigastric arteries and the obliterated hypogastric vessels. The internal inguinal fossa or the supravescical fossa (fovea supravescicalis) is between the obliterated hypogastric artery and the urachus. Just beneath the inner termination of Poupart's ligament there is another fossa, the femoral or crural fossa (fovea femoralis), which corresponds to the situation of the femoral ring. The obliterated hypogastric artery is to the inner side of this fossa.

On following the parietal peritoneum upward on the back of the anterior abdominal wall it is seen to be reflected around a fibrous band, the ligamentum teres or obliterated umbilical vein (Figs. 868, 869, and 870), which reaches from the
umbilicus to the under surface of the liver. Here the membrane forms a somewhat triangular fold, the falciform or suspensory ligament of the liver (ligamentum falciforme hepatis), which attaches the upper and anterior surfaces of that organ to the Diaphragm and abdominal wall. With the exception of the line of attachment of this ligament the peritoneum covers the under surface of the anterior part of the Diaphragm and is reflected from it on to the upper surface of the liver as the anterior or superior layer of the coronary ligament (ligamentum coronarium hepatis anterior). Covering the upper and anterior surfaces of the liver it is reflected around its sharp margin on to its under surface as far as the transverse fissure, where it is continuous with the anterior layer of the small omentum from which a start was made (Fig. 866). The posterior layer of this omentum is carried backward from the transverse fissure over the under surface and Spigelian lobe of the liver, and is then reflected, as the posterior or inferior layer of the coronary ligament (ligamentum coronarium hepatis posterior), on to the Diaphragm and is prolonged downward over the pancreas to become continuous with the ascending layer of the transverse mesocolon (Fig. 866). Between the two layers of the coronary ligament there is a triangular surface of the liver which is devoid of peritoneum; it is named the bare area of the liver, and is attached to the Diaphragm by connective tissue. If, however, the two layers of the coronary ligaments are traced toward the right and left margins of the liver, they approach each other, and, ultimately fusing, they form the right and left lateral ligaments of the liver and attach its right and left lobes respectively to the Diaphragm.

If the small omentum is followed toward the right side it is seen to form a distinct free edge around which its anterior and posterior layers are continuous
with each other and between which are situated the portal vein, hepatic artery, and bile-duct. If the finger is introduced behind this free edge, it passes through a somewhat constricted ring, the foramen of Winslow (foramen epiploicum [Winslow]) (Figs. 866, 868, and 871). This is the communication between what are termed the greater and lesser sacs of the peritoneum and has the following boundaries: in front, the free edge of the gastro-hepatic omentum. This free edge is called the ligamentum hepatoduodenale. The gastro-hepatic omentum has the portal vein, hepatic artery, and bile-duct between its two layers (Fig. 872); behind the foramen of Winslow is the postcava; above, are the Spigelian and caudate lobes of the liver; below, the duodenum and the hepatic artery, as the latter passes forward and upward from the coeliac axis.

The lesser peritoneal cavity or the lesser sac of the peritoneum (bursa omentalís) (Figs. 866, 868, and 871), therefore, lies behind the small omentum and has the following dimensions: above, it is limited by the portion of the liver which lies behind the transverse fissure; below, it extends downward into the great omentum, reaching, in the foetus, as far as its free edge (Fig. 860); in the adult, however, its vertical extent is limited by adhesions between the layers of the omentum. In front, it is bounded by the small omentum, stomach, and anterior two layers of the great omentum; behind, by the two posterior layers of the great omentum, the transverse colon, and ascending layer of the transverse mesocolon which passes upward in front of the pancreas as far as the posterior surface of the liver. Laterally the lesser sac reaches from the foramen of Winslow on the right side as far as the spleen on the left (recessus lienalís) (Fig. 873), where it is limited by the lienorenal ligament. The extent of the lesser sac and its relations to surrounding parts can be definitely made out by tearing through the small omentum and inserting the hand through the opening thus made. A passage (vestibulum bursae omentalís) leads out from the foramen of Winslow over the head of the pancreas to the left as far as the median vascular gastro-pancreatic fold (plica gastropancreatíca) (Fig. 871). This fold carries the gastric artery and the coronary vein. From the vestibule there is a narrow and upward prolongation behind the lesser omentum and caudate lobe of the liver and in front of the lumbar portion of the Diaphragm. This prolongation is the superior omental recess (recessus omentalís superior). The chief part of the lesser peritoneal cavity extends downward from the gastro-pancreatic fold and is called the inferior omental recess (recessus omentalís inferior). The constriction which separates the two recesses is due to the passage around the lesser sac and to the front of the gastric and hepatic arteries. “The former winds around its left side, the latter around its right, and each raises up a fold of peritoneum which projects strongly into the sac and partially divides it into two” (Cunningham). A small projection of the lesser sac passes to the right side behind the beginning of the duodenum. The splenic artery in its course to the spleen lies back of the posterior layer of the lesser sac.

It should be stated that during a considerable part of foetal life the transverse colon is suspended from the posterior abdominal wall by a mesentery of its own—the two posterior layers of the great omentum passing, at this stage, in front of and above the colon (Fig. 860). This condition sometimes persists throughout adult life, but, as a rule, adhesion occurs between the mesentery of the transverse colon and the posterior layer of the great omentum, with the result that the colon appears to receive its peritoneal covering by the splitting of the two posterior layers of the latter fold.

In addition to tracing the peritoneum vertically, it is necessary to trace it horizontally (Figs. 867, 868, 869, and 870). If this is done below the transverse colon, the circle is extremely simple, as it includes only the greater sac of the peritoneum (Fig. 867). Above the level of the transverse colon the arrangement is more complicated, on account of the existence of the two sacs.
Starting from the linea alba, below the level of the transverse colon, and tracing the continuity in a horizontal direction to the right, the peritoneum covers the internal surface of the abdominal wall almost as far as the anterior border of the Quadratus lumborum muscle; it encloses the caecum, and is reflected over the sides and anterior surface of the ascending colon, fixing it to the abdominal wall, from which it can be traced over the kidney to the front of the bodies of the vertebrae. It then passes along the mesenteric vessels to invest the small intestine, and back again to the spine, forming the mesentery, between the layers of which are contained the mesenteric blood-vessels, nerves, lacteals, and glands. Lastly, it passes over the left kidney to the sides and anterior surface of the descending colon, and, reaching the abdominal wall, is continued along it to the middle line of the abdomen.

Above the transverse colon (Fig. 868) the peritoneum can be traced, forming the greater and lesser cavities, and their communication through the foramen of Winslow can be demonstrated. Commencing in the middle line of the abdomen, the membrane may be traced lining its anterior wall, and sending a process backward to encircle the obliterated umbilical vein (the round ligament of the liver), forming the falciform or longitudinal ligament of the liver. Continuing its course to the right, it is reflected over the front of the upper part of the right kidney, across the postcava and aorta, and over the left kidney to the hilum of the spleen, forming the anterior layer of the lienorenal ligament, the posterior layer being formed by the termination of the cul-de-sac of the greater cavity between the kidney and spleen. From the hilum of the spleen it is reflected to the stomach, forming the posterior layer of the gastro-splenic omentum (ligamentum...
gastrolieneale). It covers the posterior surface of the stomach, and from its lesser curvature it passes around the portal vein, hepatic artery, and bile-duct, and back again to the stomach, as the lesser omentum, and thus it forms the anterior boundary of the foramen of Winslow. It now covers the front of the stomach, and upon reaching the cardiac extremity it passes to the hilum of the spleen, forming the anterior layer of the gastro-splenic omentum. From the hilum of the
spleen it can be traced over the surface of this organ, to which it gives a serous covering; it is then reflected from the posterior border of the hilum on to the left kidney, forming the posterior layer of the lienorenal ligament.

Numerous folds, formed by the peritoneum, extend between the various organs or connect them to the parietes. These serve to hold the organs in position, and at the same time enclose the vessels and nerves proceeding to each part. Some of these
folds are called ligaments, such as the ligaments of the liver and the false ligaments of the bladder. Others, which connect certain parts of the intestine with the abdominal wall, constitute the mesenteries; and lastly, those which proceed from the stomach to certain viscera in its neighborhood are called omenta.

The Ligaments of the Peritoneum.—The ligaments, formed by folds of the peritoneum, include those of the liver, spleen, bladder, and uterus. They will be found described with their respective organs.

The Omenta.—The omenta are: the lesser omentum, the great omentum, and the gastro-splenic omentum.

The Lesser or Gastro-hepatic Omentum (omentum minus) (Figs. 866 and 871) is the duplicature which extends between the transverse fissure of the liver and the right side of the abdominal portion of the oesophagus, the lesser curvature of the stomach, and the upper portion of the superior surface of the duodenum. The portion going to the oesophagus and stomach is called the hepato-gastric ligament (ligamentum hepatogastricum). The division of the ligament which goes to the oesophagus is strong and dense; the division which goes to the lesser curvature of the stomach is thin and relaxed. The portion of the lesser omentum which goes to the duodenum is continuous with the first-named portion. It is called the hepato-duodenal ligament (ligamentum hepatoduodenale). The right margin of this ligament is free and concave. The hepato-colic ligament (ligamentum hepaticocolicum) is not invariably present. It is a fold of the hepato-duodenal ligament and runs from the posterior surface of the gall-bladder to the descending portion of the duodenum or possibly to the transverse colon. From the free margin of the termination of the hepato-duodenal ligament a fold often passes to the front of the right kidney. It is known as the duodeno-renal ligament (ligamentum duodenorenale). The lesser omentum is extremely thin, and consists of two layers of peritoneum; that is, the two layers covering respectively the anterior and
posterior surfaces of the stomach. The posterior layer is part of the wall of the lesser peritoneal cavity; the anterior layer, of the greater peritoneal cavity. When the two layers reach the lesser curvature of the stomach, they join together and ascend as the double fold to the transverse fissure of the liver; to the left of this fissure the double fold is attached to the fissure of the ductus venosus as far as the Diaphragm, where the two layers separate to embrace the end of the oesophagus. At the right border the lesser omentum is free, and the two layers of which it is composed are continuous. The anterior layer, which belongs to the greater sac, turns around the hepatic vessels to become continuous with the posterior layer belonging to the lesser one. They here form a free, rounded margin, which contains between its layers the hepatic artery, the common bile-duct, the portal vein, lymphatics, and the hepatic plexus of nerves (Fig. 872)—all these struc-
tures being enclosed in loose areolar tissue, called Glisson's capsule. Between the layers where they are attached to the stomach lie the gastric artery and the pyloric branch of the hepatic artery, anastomosing with it. From the left side of the greater curvature of the stomach a fold passes to the gastric surface of the spleen, covers the spleen, and passes from the renal surface of the spleen around the left kidney to the Diaphragm. The fold passing to the spleen is known as the gastro-splenic ligament or the gastro-splenic omentum (Fig. 873). The portion passing to the Diaphragm is known as the spleno-phrenic ligament (ligamentum phrenicolienale). The gastric veins or vasa brevia pass from the left side of the greater curvature of the stomach toward the spleen in the gastro-splenic omentum.

The Great or Gastro-colic Omentum (omentum majus) (Figs. 866 and 874) is the largest peritoneal fold. It consists of four layers of peritoneum, two of which descend from the stomach, one from its anterior, the other from its posterior surface, and, uniting at its lower border, descend in front of the small intestines, sometimes as low down as the pelvis; they then turn upon themselves, and ascend again as far as the transverse colon, where they separate and enclose that part of the intestine. These separate layers may be easily demonstrated in the young subject, but in the adult they are more or less inseparably blended. At the free margins the two outer layers and the two inner layers become continuous. The left border of the great omentum is continuous with the gastro-splenic omentum; its right border extends as far only as the duodenum. The great omentum is usually thin, presents a cribriform appearance, and always contains some adipose tissue, which in fat subjects accumulates in considerable quantity. Between its two anterior layers is the anastomosis between the right and left gastro-epiploic arteries. In opening the abdomen the great omentum is rarely found spread out evenly over the intestines. It often projects between intestinal coils, or is largely gathered in some one region, or is pushed in front of the stomach by distention of the colon.

The lower portion of the lesser sac of the peritoneum continues for a distance between the ascending and descending layers of the great omentum (Fig. 866). The portion of the lesser peritoneal cavity within the great omentum is more or less obliterated in the adult by adhesion between its opposing layers. At birth the omentum is very short and barely reaches the umbilicus. In adults its length varies greatly. In some individuals it is very short; in others it passes into the pelvis. Mr. Lockwood points out that in persons under forty-five years of age the omentum can rarely be pulled down below the level of the pubic spine; it generally can be in older persons.

The Gastro-splenic Omentum is the fold which connects the margins of the hilum of the spleen to the cul-de-sac of the stomach, being continuous by its lower border with the great omentum. It was described as the gastro-splenic ligament (Fig. 873).

The Mesenteries.—The mesenteries are: the mesentery proper, the transverse mesocolon, the sigmoid mesocolon, the mesorectum (p. 1269), and the mesentery of the vermiform appendix. In addition to these there are sometimes present an ascending and a descending mesocolon.

The Mesentery (mesenterium) (µεσον ἑπερον) (Figs. 866, 875, and 876), so called from being connected to the middle of the cylinder of the small intestine, is the broad fold of peritoneum which connects the convolutions of the jejunum and ileum with the posterior wall of the abdomen. It consists of a layer of connective tissue, each side of which is covered with peritoneum. In the connective tissue there are fatty masses. Its root (radix mesenterii), the part connected with the vertebral column, is narrow, about six inches in length, and directed obliquely

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from the left side of the second lumbar vertebra to the right sacro-iliae symphysis (Fig. 876). Its intestinal border is vastly broader (measures about twenty feet); and here its two layers separate so as to enclose the intestine, and form its peritoneal coat. Its breadth, between its vertebral and intestinal border, is about eight inches. Its upper border is continuous with the under surface of the transverse mesocolon; its lower border, with the peritoneum covering the caecum and

ascending colon. The origin of the mesentery above is just beyond the termination of the duodenum, and it terminates below in the angle formed by the junction of the ileum and the colon. It serves to retain the small intestines in their position, and contains between its layers the mesenteric vessels and nerves, the lymphatic vessels and mesenteric glands. These glands number from 50 to 150. Occasionally congenital mesenteric openings exist. In stout individuals the mesentery contains much fat. If there is much fat the mesentery is not translucent; if there is little fat it is translucent. It may be actually transparent above and translucent or opaque below. The thinnest part of the mesentery is above. As we descend it becomes thicker, because of the presence of fat, fibrous ligament, and muscular tissue.1

In most cases the peritoneum covers only the front and sides of the ascending and descending parts of the colon. Sometimes, however, these are surrounded by the serous membrane and attached to the posterior abdominal wall by an ascending mesocolon (mesocolon ascendens) and a descending mesocolon (mesocolon descendens) respectively. At the place where the transverse colon turns downward to form the descending colon, a fold of peritoneum is continued to the under surface of the Diaphragm opposite the tenth and eleventh ribs. This is the phreno-colic ligament (ligamentum phrenicoocolicum); it passes below the spleen, and serves to support this organ, and therefore it has received the second name of sustentaculum lienis.

The Transverse Mesocolon (mesocolon transversum) (Fig. 876) is a broad fold, which connects the transverse colon to the posterior wall of the abdomen. It is formed by the two ascending or posterior layers of the great omentum, which, after separating to surround the transverse colon, join behind it, and are continued backward to the spine, where they diverge in front of the duodenum. This fold contains between its layers the vessels which supply the transverse colon.
The Sigmoid Mesocolon (mesocolon sigmoideum) (Fig. 876) is the fold of peritoneum which retains the sigmoid flexure in connection with the left iliac fossa. This portion of intestine remains always freely movable.

The Mesorectum is really only the lower portion of the sigmoid mesocolon. It is the name formerly given to the narrow fold which, according to the old defini-

![Diagram](https://via.placeholder.com/150)

**FIG. 876.—Diagram devised by Dr. Delépine to show the lines along which the peritoneum leaves the wall of the abdomen to invest the viscera.**
fold of peritoneum covering the caecum. As a rule, the entire appendix is covered with peritoneum; sometimes a portion of the base is uncovered, and this portion of the diverticulum is then extraperitoneal. The tip is never extraperitoneal. The mesoappendix may be attached to the entire length of the appendix, but, as a rule, the tip is free. In fact, one-third, one-half, or two-thirds may be free and occasionally the mesoappendix is a mere vestige. Between the two peritoneal layers of the mesoappendix there is connective tissue, and often fat. In the connective tissue are the appendicular blood-vessels, lymph-vessels, and nerves.

The Appendices Epiploicae are small pouches of the peritoneum filled with fat and situated along the colon and upper part of the rectum. They are chiefly appended to the transverse colon.

**Retro-peritoneal Fossae.**—In certain parts of the abdominal cavity there are recesses of peritoneum forming culs-de-sac or pouches, which are of surgical interest in connection with the possibility of the occurrence of retro-peritoneal hernia. One of these, which was previously described, is the lesser sac of the peritoneum (Figs. 866 and 868), which may be regarded as a recess of peritoneum through the foramen of Winslow, in which a hernia may take place, but there are several others, of smaller size, which require mention.

These recesses of fossae may be divided into three groups, viz.: (1) the duodenal fossae; (2) pericæal fossae; and (3) the intersigmoid fossa.

1. Duodenal Folds and Fossae. —Moynihan has described no less than nine fossæ as occurring in the neighborhood of the duodenum. Three of these are fairly constant. Five of the fossæ are here considered. (a) The inferior duodenal fossa or fossa of Treitz (Fig. 877) is the most constant of all the peritoneal fossæ in this region, being present in from 70 to 75 per cent. of cases. It is situated opposite the third lumbar vertebra on the left side of the ascending portion of the duodenum. The opening into the fossa is directed upward, and is bounded by a thin, sharp fold of peritoneum with a concave free upper margin. This fold of peritoneum is called the inferior duodenal fold (*plica duodenomesocolica*). The tip of the index finger introduced into the fossa under the fold passes some little distance up behind the ascending or fourth portion of the duodenum. One margin of the fold is attached to the ascending portion of the duodenum; another margin is attached to the parietal peritoneum. (b) The superior duodenal fossa (Fig. 877) is the next most constant pouch or recess, being present in from 40 to 50 per cent. of cases. It often coexists with the inferior one, and its orifice looks downward, in the opposite direction to the preceding fossa. It lies to the left of the ascend-
ing portion of the duodenum. It is bounded in front by the superior duodenal fold (plica duodenojejunalis), which is triangular and has a free semilunar base; to the right it is blended with the peritoneum covering the ascending duodenum, and to the left with the peritoneum covering the perirenal tissues. The fossa is bounded in front by the superior duodenal fold; behind by the second lumbar vertebra; to the right by the duodenum. Its depth is 2 cm., and it terminates in the angle formed by the left renal vein crossing the aorta. This fossa is of importance, as it is in relation with the inferior mesenteric vein; that is to say, the vein almost always corresponds to the line of union of the superior duodenal fold with the posterior parietal peritoneum. (c) The duodeno-jejunal fossa or mesocolic fossa (recessus duodenojejunalis) is formed where the duodeno-jejunal angle enters the root of the transverse mesocolon. There are two forms: (1) a single fossa and (2) a double fossa. It can be seen by pulling the jejunum downward and to the right, after the transverse colon has been pulled upward. It will appear as an almost circular opening, looking downward and to the right, and bounded by two free borders or folds of peritoneum, the duodeno-mesocolic ligaments. The opening admits the little finger into the fossa to the depth of from 2 to 3 cm. The fossa is bounded above by the pancreas, to the right by the aorta, and to the left by the kidney; beneath is the left renal vein. The fossa exists in from 15 to 20 per cent. of cases, and has never yet been found in conjunction with any other form of duodenal fossa. (d) Paraduodenal fossa or the fossa of Landzert (recessus duodenoejunalis) is most distinct in the infant, and is to the left of the ascending portion of the duodenum. The fold of peritoneum to its outer side and above is produced by the inferior mesenteric vein. Its lower limit is a fold called the mesenterico-mesocolic fold. (e) The retroduodenal fossa (Fig. 878) was described in 1893 by Jonnesco. It is a peritoneal cul-de-sac, sometimes found behind the horizontal and ascending portions of the duodenum.

2. Pericæal Folds and Fossae.—There are at least three pouches or recesses to be found in the neighborhood of the caecum, which are termed pericæal fossæ. (1)
The ilio-colic fossa or superior ilio-caecal (recessus ileocaecalis superior) (Fig. 879) is formed by a fold of peritoneum, the ilio-colic fold, arching over a branch of the ilio-colic artery, which supplies the ilio-colic junction, and appears to be the direct continuation of the artery. The fossa is a narrow chink situated between the ilio-colic fold in front, and the mesentery of the small intestine, the ileum, and a small portion of the caecum behind. (2) The ilio-caecal, inferior ilio-caecal or ilio-appendicular fossa (recessus ileocaecalis inferior) (Fig. 880) is situated behind the angle of junction of the ileum and caecum. It is formed by a fold of peritoneum, the ilio-caecal fold (plica ileocaecalis), which Treves called the “bloodless fold.” Tuffier denies its non-vascularity, and Lockwood and Rolleston state that it contains fat, muscular fibres, and arteries and veins derived from the appendicular vessels and the anterior and posterior ilio-caecal vessels.¹ The upper border of the fold is attached to the ileum, opposite its mesenteric attachment, and the lower border, passing over the ilio-caecal junction, joins the mesentery of the appendix, and sometimes the appendix itself; hence this fold is sometimes called the ilio-appendicular fold. Between the ilio-caecal fold and the mesentery of the vermiform appendix is the ilio-caecal fossa. It is bounded above by the posterior surface of the ileum and the mesentery; in front and below by the ilio-caecal fold, and behind by the upper part of the mesentery of the appendix. (3) The retro-caecal or retro-colic

¹The Caecal Folds and Fossae. By Richard J. A. Barry.
fossae (recessus retrocaecalis) (Fig. 881) are situated behind the caecum and ascending colon. There may be no fossa present. There may be one fossa; there are usually two (external and internal retrocolic fossae); occasionally there are more than two. The fossae are brought into view by raising the caecum. According to Berry, one or other of the fossa is present in 30 per cent. of cases. Treves thinks the retrocolic fossae are extremely rare. There may be one fossa (20 per cent. of cases) or two fossae (10 per cent. of cases). If there is but one fossa it is the internal that exists three times as often as the external. The retro-colic space, if present, varies much in size and extent. In some cases it is sufficiently large to admit the index finger and extends upward behind the ascending colon in the direction of the kidney; in others it is merely a shallow depression. The external retro-colic fossa is bounded and formed by two folds: one, the external parieto-colic fold or the superior caecal fold, which is the outer layer of the ascending mesocolon, and is attached by one edge to the abdominal wall from the lower border of the kidney to the iliac fossa and by the other to the postero-

Fig. 881.—The retro-caecal fossa. The ileum and caecum are drawn backward and upward. (Souligoux.)

external aspect of the colon; and the other, the internal parieto-colic fold or inferior caecal fold, which is the inner layer of the ascending mesocolon. The internal retrocolic fossa is bounded externally by the internal parieto-colic fold, and is bounded internally by the mesenterico-parietal fold, which is the insertion of the mesentery into the iliac fossa.

3. The Intersigmoid Fossa (recessus intersigmoidus).—The intersigmoid fossa is constant in the foetus and common during infancy, but disappears in a large percentage of cases as age advances. Upon drawing the sigmoid flexure upward, the left surface of the sigmoid mesocolon is exposed, and on it will be seen a funnel-shaped recess of the peritoneum, lying on the external iliac vessels, in the interspace between the Psoas and Iliacus muscles. This is the orifice leading to the fossa intersigmoididea, which lies behind the sigmoid mesocolon, and in front of the parietal peritoneum. This fossa is produced by the incomplete fusion in the foetus of the descending mesocolon with the parietal peritoneum. The fossa varies

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1 The Caecal Folds and Fossae. By Richard J. A. Barry.
in size; in some instances it is a mere dimple, whereas in others it will admit the whole of the index finger.

Any of these fossae may be the site of a retro-peritoneal hernia. The periceliac fossae are of especial interest, because hernia of the vermiform appendix frequently takes place into one of them, and may there become strangulated. The presence of these pouches also explains the course which pus has been known to take in cases of perforation of the appendix, where it travels upward behind the ascending colon as far as the Diaphragm.1

Surgical Anatomy.—Study of the peritoneum by Robinson and others shows that absorption takes place most rapidly from the region of the Diaphragm, less rapidly but still very actively from the region of the small intestine, slowly from the pelvic region. Clinically we know that pelvic peritonitis is not nearly so dangerous as peritonitis in the small intestine or Diaphragm areas, and that peritonitis in the region of the Diaphragm is the most fatal form of the infection. After abdominal operations in infected cases, it is well to elevate the head of the bed (Fowler’s position), so as to obtain the aid of gravity in draining septic fluids away from the dangerous region and toward the safer region.2 In areas which absorption is rapid, protective exudation is not apt to form. In areas in which absorption is slow, inflammatory exudation is apt to circumscribe the area and prevent diffusion. After an operation in a non-infected case, if salt solution has been left in the abdominal cavity because of shock or hemorrhage, raising the foot of the bed will aid rapid absorption of the fluid by favoring the natural current toward the Diaphragm and hurrying the fluid to a region in which absorption is rapid. Dr. John B. Murphy’s plan of treating general peritonitis has proved remarkably successful. He does not remove the exudation of lymph which is seen upon the peritoneum. This exudation is conservative, blocks up lymph spaces, and lessens the absorption of dangerous toxins. He inserts a drainage tube into the peritoneal cavity above the pubes, puts the patient erect or semi-erect in bed (Fowler’s position), and administers salt solution continuously by low pressure protolysis. According to Murphy the lymph circulation is reversed and the peritoneum becomes a secreting surface. Certain it is that the salt solution absorbed from the rectum reaches the peritoneal cavity in large amounts and flows out of the drainage tube.

The great omentum stores up fat, and, being movable, it is able to pass to different parts of the peritoneal cavity. Dr. Robinson, in his work on the Peritoneum, describes its functions as follows: “The omentum is the great protector against peritoneal infectious invasions. It builds barriers of exudates to check infection. It is like a man-of-war, ready at a moment’s notice to move to invaded parts. It circumscribes abscesses; it repairs visceral wounds, and prevents adhesions of mobile viscera to the anterior abdominal wall. It resists infectious invasions by typical peritoneal exudates, and not by succumbing to absorbed sepsis. It is a director of peritoneal fluids, a peritoneal drain.”

In abdominal wounds the omentum often protrudes: This structure frequently constitutes or is part of a hernia, and is almost invariably present in unbilical hernia. As a result of inflammation, it may become adherent to adjacent structures. Adhesions may be of service by matting together the intestines and circumscribing infections. They may be harmful by constraining the bowels and producing obstruction. A portion of the omentum may become adherent to some other part and form a band, and under this band the gut may be caught and strangulated. Omentum may adhere to and plug a perforation in a hollow viscus, and the surgeon may utilize it for the same purpose, or to cover a raw surface or overlie a suture line. The omentum may be in the surgeon’s way while operating. If it is, the patient is placed in the Trendelenburg position (pelvis elevated).

Any tear or opening found by the surgeon in the great omentum must be closed with sutures, because of the danger that intestine might enter and be caught in such an opening. A tumor cut off from its proper blood-supply, for instance, an ovarian cyst with a twisted pedicle, may continue to receive nourishment from adherent omentum, and gangrene may thus be prevented. The lax character and shifting tendency of the subserous tissue explains the occurrence of ptosis of the abdominal viscera and kidneys.

The vast number of nerves in the peritoneum accounts for the profound shock which follows a wound, attends an intraperitoneal calamity, or which develops from infection. An infective process of any portion of the peritoneum produces pain and reflex symptoms (vomiting, abdominal rigidity, intestinal paresis, etc.).

The parietal peritoneum is very sensitive to pain, but not to touch; hence, after injecting a local anesthetic and opening the abdomen, a fairly satisfactory exploration can be made with the finger.

The intestine, the mesentery, the stomach, the anterior margin of the liver, and the gall-bladder are insensitive, and may be cut or even burned without pain.3

1 On the anatomy of these fossae, see the Arris and Gale Lectures by Moynihan, 1899.
2 George R. Fowler, in Medical Record, April 14, 1900.
3 Dr. K. E. L. Lennander, in Mitteilungen aus dem Grenzgebieten der Medizin und Chirurgie, Band x., Heft 1, 2.
Figs. 882, 883, 884, 885, 886, 887.—Diagrams showing the arrangement and variations of the loops of the mesenteric vessels for various segments of the small intestine of average length. Nearest the duodenum the mesenteric loops are primary, the vasa recta are long and regular in distribution and the translucent spaces (lunettes) are extensive. Toward the ileo-colic junction, secondary and tertiary loops are observed, the vessels are smaller and become obscured by numerous fat-tabs. (After Monks.)
Viscera which obtain their innervation purely from visceral nerves are insensitive; those which receive branches from somatic nerves are sensitive (Lenander).

The oblique origin of the mesentery causes this structure to form a sort of shelf. A hemorrhage or extravasation into the abdomen, to the right of the mesentery, tends to flow into the right iliac fossa; one occurring on the left side flows into the pelvis. Monks points out that in flushing the abdominal cavity the tube should not be aimlessly introduced, but should utilize the mesentery on each side of an intestinal loop, to "conduct the tip of the irrigating tube to the bottom of the two fossae." Monks also shows how the mesentery can be utilized to determine the direction of an intestinal loop:

"Now, let us suppose that the surgeon has between his fingers a loop of bowel, and wishes to determine its direction. He knows that one side of the loop is the left side of the intestine, and that the corresponding side of the mesentery, if closely followed down to the mesenteric root, will conduct him into the left fossa; he also knows that the other side of the bowel is its right side, and that the mesentery on that side will conduct him into the right fossa. Now, if his finger goes into the great fossa on the left side of the abdomen, after having closely followed the mesentery down to its root and arranged his loop to be parallel with that root, he then knows that the left and right sides of the intestine face to the left and right sides of the abdomen respectively, and that the end of the loop which points downward is the end nearest the ileo-cecal valve. He can determine the direction of the gut in a similar way in case his finger enters the right fossa. All this would seem very simple were it not for the twists in mesentery and intestine, which tend to mislead one. A little practice will usually enable one to recognize a twist in the mesentery. This should be untwisted by rotation of the gut, after which the direction is determined by another palpation of the mesenteric root."

The studies made of the arrangement and variations of the loops of the mesenteric vessels by Dr. Thomas Dwight have been utilized and expanded by Dr. George H. Monks in laying down rules for the determination of the exact portion of small intestine which may be in the surgeon's hand. His views are as follows:

"General Vascularity of the Mesentery near the Bowel.—Opposite the upper part of the bowel the mesenteric vessels are distinctly larger than opposite any other part of it. These vessels grow smaller and smaller as we pass downward until the lower third of the gut is reached, where they remain about the same size as far as the ileo-cecal valve. The arrangement of the mesenteric vessels has some features which intimately concern the subject in hand, and which I shall describe with some detail. Diagrammatically speaking, the main branches of the superior mesenteric artery unite with each other by means of loops, which are called for convenience 'primary loops;' in some parts of the tube, 'secondary loops,' and even, occasionally, 'tertiary loops' are superimposed upon these. From these loops little straight vessels—the vasa recta already referred to—run to the bowel, upon which they ramify, alternating, as a rule, as to the side of the intestine which they supply. The mesenteric veins are arranged in a manner somewhat similar to the arteries.

"The Loops of the Mesenteric Vessels (Figs. 882, 883, 884, 885, and 886).—Opposite the upper part of the bowel there are only primary loops. Occasionally a secondary loop appears, but it is small and insignificant as compared with the primary loops, which are large and quite regular. As we proceed down the bowel secondary loops become more numerous, larger, and approach nearer to the bowel than the primary loops in the upper part. As a rule, secondary loops become a prominent feature at about the fourth foot. As we continue farther downward, the secondary loops (and, possibly, tertiary loops) become still more numerous and the primary loops smaller, the loops all the time getting nearer and nearer to the gut. Opposite the lower part of the gut the loops generally lose their characteristic appearance, and are represented by a complicated network.

"The Vasa Recta.—Opposite the upper part of the intestine the vasa recta are from three to five centimetres long, when the loop of small intestine to which they run is lifted up so as to put them gently on the stretch. They are straight, large, and regular, and rarely give off branches in the mesentery. In the lower third they are very short, being generally less than one centimetre in length. Here they are less straight, smaller, less regular, and have frequent branches in the mesentery."

The translucency of the mesentery varies greatly; in some parts it may be almost transparent, in others almost or quite opaque. Its thinnest part is above. It is thickened below by fat, fibrous tissue, and muscular tissue. In very fat subjects it may be impossible to see the vessels (Monks). According to Monks, if a loop is raised and looked at against the light close to the gut "little transparent spaces" are seen between the vasa recta, and even in the thickest mesentery; some of these "hunettes" exist along the upper portion of the intestine. As we descend in our examination, they grow smaller and become fatty, and disappear about the eighth foot of the intestines.

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1 Intestinal localization, by George H. Monks, Annals of Surgery, October, 1903.
2 Ibid.
3 Reports of the Meeting of American Anatomists, 1897.
4 Annals of Surgery, 1903.
THE STOMACH (VENTRICULUS) (Figs. 874, 888, 889, 891, 892).

The stomach is the principal organ of digestion. It is the most dilated part of the alimentary canal, and is situated between the termination of the oesophagus (cardia) and the commencement of the small intestine. Its form varies because of varied conditions, but, as a rule, it is somewhat pyriform. It is placed, in part, immediately behind the anterior wall of the abdomen and beneath the Diaphragm. Viewing the stomach from in front it appears that the right margin of the oesophagus is continued downward as the upper two-thirds of the lesser curvature of the stomach, the remaining third of this border bending sharply backward and to the right, to complete the smaller curvature (Fig. 888). The greater curvature begins at the left border of the termination of the oesophagus in a somewhat acute angle; it then passes upward and to the left to the under surface of the Diaphragm, with which it lies in contact for some distance, and then sweeps downward with a convexity to the left, and, continued across the middle line of the body, finally turns upward and backward, to terminate at the commencement of the small intestine. It will thus be seen that the stomach may be divided into a fundus (fundus ventriculi) and a middle portion or body (corpus ventriculi). The portion of the body adjacent to the cardia being known as the cardiac portion (pars cardiaca), the long axis of which is directed downward with a slight inclination forward and to the right; and the portion adjacent to the pylorus being known as the pyloric portion (pars pylorica), the long axis of which is horizontal or rather upward with an inclination backward. Of the two openings, the cardiac orifice, by which it communicates with the oesophagus, is situated slightly to the left of the middle line of the body to the right of the fundus, or dilated upper extremity of the stomach, and is directed downward; the other, the pyloric orifice, by which it communicates with the small intestine, is on a lower plane, close to the right of the mid-line, and looks directly backward.

Relations of the Stomach.—The stomach lies in a space or chamber called the stomach chamber (Fig. 874). When distended the viscus completely fills the space. When the stomach is empty it lies upon the floor of the chamber, and the portion it has vacated is occupied by the transverse colon, which ascends in front of the stomach and finally gets above it. The anterior wall of the stomach chamber is formed by the anterior abdominal wall. The roof is formed by the under surface of the Diaphragm and the under surface of the left lobe of the liver. The floor is formed by the left suprarenal capsule and the summit of the left kidney, the gastric face of the spleen, the upper surface of the pancreas, the transverse mesocolon, and the colon.2

Surfaces.—The stomach has two surfaces, called anterior and posterior surfaces, and two borders, termed the greater and lesser curvatures.

In regard to the so-called anterior and posterior surfaces of the stomach, it must be borne in mind that these names are not strictly correct, as the anterior surface has a certain amount of inclination upward and the posterior downward.

1 Annals of Surgery, October, 1903.
2 Prof. Birmingham in Prof. Cunningham's Text-book of Anatomy.
The Anterior, Upper or Parietal Surface (paries anterior).—The anterior surface is directed forward and to the right side. It has a somewhat flattened appearance when the stomach is empty, but when it is full the surface becomes convex. It is in relation with the Diaphragm; the thoracic wall formed by the anterior parts of the seventh, eighth, and ninth ribs of the left side; the left lobe of the liver; and the anterior abdominal wall. Between the part covered by the liver and that covered by the left ribs there is a triangular segment of the anterior wall of the stomach, which is in contact with the abdominal wall and is the only part of the stomach which is visible when the abdominal wall is removed and the viscera allowed to remain in situ. Its area is about 40 sq. cm., and it is of great importance to the surgeon, as the stomach can readily be reached in this situation. Occasionally the transverse colon may be found lying in front of the lower part of the anterior surface of the stomach. The whole of this surface of the stomach is covered by peritoneum.

The Posterior, Lower or Visceral Surface (paries posterior).—The posterior surface of the stomach is directed backward and to the left. It is in relation with the Diaphragm, the gastric surface of the spleen, the left suprarenal capsule, the upper part of the left kidney, the anterior surface of the pancreas, the splenic flexure of the colon, and the ascending layer of the transverse mesocolon. These structures form a shallow concavity or bed, on which this surface of the stomach rests. The transverse mesocolon intervenes between the stomach and the duodeno-jejunal junction and commencement of the ileum. Its greater curvature is in relation with the transverse colon and has attached to it the anterior two layers of the great omentum. Almost the whole of this surface is covered with peritoneum, but behind the cardiac orifice there is a small portion of the stomach which is uncovered by peritoneum and is in contact with the Diaphragm and frequently with the upper portion of the left suprarenal capsule.

The Lesser Curvature (curvatura ventriculi minor).—The lesser curvature of the stomach extends between the cardiac and pyloric orifices along the right border of the organ. It descends in front of the left crus of the Diaphragm, along the left side of the eleventh and twelfth thoracic vertebrae, and then turning to the right it crosses the first lumbar vertebra and ascends to the pylorus. It gives attachment to the two layers of the gastro-hepatic omentum, between which blood-vessels and lymphatics pass to reach the organ.

The Greater Curvature (curvatura ventriculi major).—The greater curvature of the stomach is directed to the left, and is four or five times as long as the lesser curvature. Starting from the cardiac orifice, it forms an arch to the left with its convexity upward, the highest point of which is on a level with the costal cartilage of the sixth rib of the left side. It then passes nearly straight downward, with a slight convexity to the left, as low as the costal cartilage of the ninth rib, and then turns to the right to end at the pylorus. As it crosses the median line the lowest edge of the greater curvature is about two fingers’ breadth above the umbilicus. The lower part of the greater curvature gives attachment to the two anterior layers of the great omentum, between which layers vessels and lymphatics pass to the organ.

The Cardia (Fig. 889).—The cardia is the point at which the oesophagus enters the stomach wall. The opening is called the cardiac orifice or the oesophageal opening. At the cardia the circular muscular fibres constitute a sphincter.

The Cardiac Orifice (Fig. 889).—The cardiac orifice is the opening by which the oesophagus communicates with the stomach. It is therefore sometimes termed the oesophageal opening. It is the most fixed part of the stomach, and is situated about two inches below the highest part of the fundus on a level with the body of the tenth or eleventh thoracic vertebra to the left and a little in front of the aorta. This would correspond on the anterior surface of the body to the articulation of
the seventh left costal cartilage to the sternum. It is placed far off from the surface and is at least four inches back of the seventh left chondro-sternal articulation.

The Pylorus (Fig. 889).—The pylorus is the point at which the stomach passes into the duodenum. The opening of communication is called the pyloric orifice. At the pylorus the muscular fibres constitute a sphincter.

The Pyloric Orifice (Fig. 889).—The pyloric orifice communicates with the duodenum, the aperture being guarded by a valve (Fig. 890). Its position varies with the movements of the stomach. When the stomach is empty the pylorus is situated just to the right of the medium line of the body, on a level with the upper border of the first lumbar vertebra. On the anterior surface of the body its position would be indicated by a point one inch below the tip of the ensiform cartilage and a little to the right. As the stomach becomes distended the pylorus moves to the right, and in a fully distended stomach may be situated two or three inches to the right of the median line. The direction of the pylorus is upward and to

Fig. 889.—The mucous membrane of the stomach and duodenum with the bile-ducts.

the right, which position prevents "the weight of the gastric contents bearing directly on the sphincter apparatus." The pylorus is on a somewhat higher level than the lowest point of the stomach. Near the pylorus the stomach frequently exhibits a slight dilatation, which is named the antrum of the pylorus (antrum pyloricum). The pylorus is indicated by a constriction, the direction of which is circular. The pylorus lies upon the neck of the pancreas behind. Above it and in front of it is the liver.

The size of the stomach varies considerably in different subjects. When moderately distended its greatest length, from the top of the fundus to the lowest part of the greater curvature, is from ten to twelve inches and its diameter at the

1 W. J. Mayo, Medical Record, June 11, 1904.
widest part from four to five inches. The distance between the two orifices is three to six inches, and the measurement from the anterior to the posterior wall three and a half inches. Its weight, according to Clendinning, is about four ounces and a half, and its capacity in the adult male is five to eight pints. The stomach of a newborn child holds about one ounce.

Alterations in Position.—There is no organ in the body the position and connections of which present such frequent alterations as the stomach. When empty, it lies at the back part of the abdomen, some distance from the surface, and is in the left hypochondriac region and the left portion of the epigastric region. Its fundus is directed upward and backward toward the Diaphragm. The long axis of the viscus is nearly horizontal. Its pyloric end is directed upward and backward, is situated close to or very slightly to the right of the middle line, covered in front by the left lobe of the liver, and being on a level with the first lumbar vertebra. When empty, the stomach assumes a more or less cylindrical form, especially noticeable at its pyloric end. The entire viscus is small and contracted, and the pyloric region resembles the intestine. When the stomach is distended, its surfaces, which are flattened when the organ is empty, become convex and the shape becomes pyriform. The viscus becomes very oblique and approaches the vertical, its long axis being downward, forward, and to the right. The greater curvature is elevated and carried forward, so that the anterior surface is turned more or less upward and the posterior surface downward, and the stomach is brought well against the anterior wall of the abdomen. Its fundus expands and rises considerably above the level of the cardiac orifice; in doing this the Diaphragm is forced upward, contracting the cavity of the chest; hence the dyspnea complained of, from inspiration being impeded. The apex of the heart is also tilted upward; hence the oppression in this region and the palpitation experienced in extreme distention of the stomach. The left lobe of the liver is pushed to the right side. When the stomach becomes distended the change in the position of the pylorus is very considerable; it is shifted to the right, some two or three inches from the median line, and lies under cover of the liver, near the neck of the gall-bladder. In consequence of the distention of the stomach the lesser cul-de-sac bulges over the pylorus, concealing it from view, and causing it to undergo a rotation, so that its orifice is directed backward. When the stomach is greatly distended its lower border may enter the umbilical and the left lumbar regions. During inspiration the stomach is displaced downward by the descent of the Diaphragm, and it is elevated by the pressure of the abdominal muscles during expiration. Pressure from without, as from tight lacing, pushes the stomach down toward the pelvis. In fact, in the female, because of tight lacing, the stomach may be to the left side of the vertebral column and nearly vertical in direction, the lower portion being sharply angled upward toward the pylorus, which lies underneath the liver. Besides the angulation, the lower end, the stomach may have a median constriction, and there may even be an hour-glass stomach. The descent of the stomach from tight lacing may cause the pancreas to become nearly vertical. In disease the position and connection of the stomach may be greatly changed, from the accumulation of fluid in the chest or abdomen, or from alteration in size of any of the surrounding viscera.

Variations according to Age.—In an early period of development the stomach is vertical, and in the newborn child it is more vertical than later on in life, as owing to the large size of the liver it is more pushed over to the left side of the abdomen, and the whole of the anterior surface is covered by the left lobe of this organ.

On looking into the pyloric end of the stomach, the mucous membrane is found projecting inward in the form of a circular fold, the pyloric valve (Fig. 890), leaving a narrow circular aperture, about half an inch in diameter, by which the stomach communicates with the duodenum.

The Pyloric Valve (valvula pylori) (Fig. 890).—The pyloric valve is formed by a reduplication of the mucous membrane of the stomach, containing numerous circular fibres, which are aggregated into a thick circular ring, the pyloric sphincter (m. sphincter pylori); the longitudinal fibres and serous membrane being continued over the fold without assisting in its formation (Fig. 890). The pylorus is normally kept closed by the action of this aggregation of circular fibres which constitutes the Sphincter muscle. During the early stage of digestion it remains closed, but after a time opens now and then. The opening becomes more frequent and the period of patency is prolonged as digestion advances.
The diameter of the pylorus is uncertain. It is usually said to be half an inch. But it is closed when the pylorus is at rest, and it can certainly dilate even in a child to at least an inch and let bodies of this size pass through.

The Peritoneum.—The *great omentum* comes off from the greater curvature of the stomach and passes to the transverse colon. The *lesser omentum* comes off from the lesser curvature and passes to the liver. The *gastro-splenic ligament* or *omentum* passes from the under surface of the stomach just below the greater curvature to the spleen. A fold of peritoneum passes up from the stomach along the left side of the oesophagus to the Diaphragm. This is the *gastro-phrenic ligament*.

**Supports of the Stomach.**—The stomach lies on the bed of the stomach chamber, which was described on p. 1277. The great omentum gives no support to the stomach, neither does the gastro-splenic ligament, because of the movability of the spleen. The *lesser omentum* does give support to the stomach and so do

![Diagram of the stomach](image)

**Fig. 891.**—The superficial muscular layer of the stomach, viewed from above and in front. (Spalteholz.)

the *gastro-phrenic ligament* and the *hepato-duodenal ligament*. The two chief points of support are the attachment of the oesophagus to the Diaphragm and the fixation of the duodenum to the front of the vertebral column.

**Structure.**—The wall of the stomach consists of four coats: *serous, muscular, areolar,* and *mucous,* together with vessels and nerves.

The Peritoneal or Serous Coat (*tunica serosa*).—The peritoneal or serous coat covers the entire surface of the organ, excepting along the greater and lesser curvatures, at the points of attachment of the greater and lesser omenta; at each curvature the two layers of peritoneum leave a small triangular space, to which the peritoneum is not attached, although it is attached in front of it and
back of it. Along these spaces the nutrient vessels and nerves pass. On the posterior surface of the stomach, close to the cardiac orifice and below and to the left of it, there is a smaller triangular area uncovered by peritoneum, where the organ is in contact with the under surface of the Diaphragm, and it may be with the left suprarenal body and the summit of the left kidney. When the stomach is moderately distended this uncovered area measures about one and a half inches from above downward, and about two inches from before backward. At the left angle of this uncovered area the insertion of the great omentum begins. At the right angle the gastric artery reaches the stomach.

The Muscular Coat (tunica muscularis) (Figs. 891 and 892).—The muscular coat is situated immediately beneath the serous covering, to which it is closely connected. It consists of three sets of fibres—longitudinal, circular, and oblique.

The Longitudinal Fibres (stratum longitudinale) are most superficial; they are continuous with the longitudinal fibres of the oesophagus, radiating in a stellate manner from the cardiac orifice. They are most distinct along the curvatures, especially the lesser, but are very thinly distributed over the surfaces. At the pyloric end they are more thickly distributed, and continuous with the longitudinal fibres of the small intestine. The bundles of longitudinal muscle-fibre on the upper and lower surfaces of the pylorus are particularly firm and distinct, and are called the pyloric ligaments (ligamenta pylori).

The Circular Fibres (stratum circulare) form a uniform layer over the whole extent of the stomach, except the fundus, beneath the longitudinal fibres. At the pylorus they are most abundant, and are aggregated into a circular ring or sphincter, which projects into the cavity, and forms, with the fold of mucous membrane covering its surface, the pyloric valve (Fig. 890). They are continuous with the circular fibres of the oesophagus.
The Oblique Fibres (fibrae obliquae) arise at the left side of the cardia from the circular fibres of the oesophagus. The fibres pass down in the anterior and posterior walls. Those of the anterior wall are parallel to the lesser curvature and almost reach the pylorus. Those of the posterior wall are more nearly transverse to the long axis of the stomach (Spalteholz). These fibres gradually assume the direction of the circular fibres and terminate in them. The layer of oblique fibres is beneath the circular layer. Certain oblique muscular fibres encircle the fundus of the stomach in a series of rings.

The Areolar or Submucous Coat (tela submucosa).—The areolar or submucous coat consists of loose, filamentous, areolar tissue, connecting the mucous and muscular layers. It supports the blood-vessels previous to their distribution to the mucous membrane; hence it is sometimes called the vascular coat.

The Mucous Membrane (tunica mucosa) (Figs. 893, 894, and 895).—The mucous membrane is thick; its surface smooth, soft, and velvety. In the fresh state it is of a pinkish tinge at the pyloric end, and of a red or reddish-brown color over the rest of the surface. In infancy it is of a brighter hue, the vascular redness being more marked. It is thin at the cardiac extremity, but thicker toward the pylorus. During the contracted state of the organ it is thrown into numerous plaits or rugae (plicae mucosae) (Figs. 893 and 895, A), which for the most part have a longitudinal direction, and are most marked toward the lesser end of the stomach and along the greater curvature, and which contain also submucous tissue. These folds are entirely obliterated when the organ becomes distended. A constant fold exists at the pylorus (Fig. 890). It is called the pyloric valve, and is produced by the presence beneath it of the Sphincter muscle.

Besides the large folds or rugae and the pyloric valve, there are numerous small elevations of mucous membrane known as gastric areas (areae gastricae), which are partly separated from each other by furrows and which vary greatly in shape (Fig. 893). According to Spalteholz, each one of these elevations has an area of several square millimetres.
Structure of the Mucous Membrane.—When examined with a lens the inner surface of the mucous membrane presents a peculiar honeycomb appearance, from being covered with small shallow depressions or alveoli (foveolae gastricae) (Figs. 894 and 895, B) of a polygonal or hexagonal form, which vary...
from $\frac{1}{10}$ to $\frac{3}{10}$ of an inch in diameter, and are separated by slightly elevated ridges (plicae villosae). The ridges are most distinct at the pylorus. These foveolae are within the areae gastricae. The ridges on section resemble villi. In the bottom of the alveola are seen the orifices of minute tubes, the gastric glands (Fig. 895 B), which are placed perpendicularly side by side throughout the entire substance of the mucous membrane. The surface of the mucous membrane of the stomach is covered by a single layer of columnar epithelium; it lines the alveoli, and also for a certain distance the mouths of the gastric glands. This epithelium commences very abruptly at the cardiac orifice, where the cells suddenly change in character from the stratified epithelium of the oesophagus. The cells are elongated, and consist of two parts, the inner or attached portions being granular, and the outer or free parts being clear and occupied by a mucosaluminous substance.

The Gastric Glands.—The gastric glands are of three kinds: the true gastric glands, the pyloric glands, and the cardiac glands.

The True Gastric Glands (Fig. 897) are called also the oxyntic glands, the fundus glands, and the peptic glands (glandulae gastricae propriae). They are distributed throughout the entire fundus and body, and may be found even at the pylorus. They are tubular in character, and are formed of a delicate basement-membrane, lined with epithelium. The basement-membrane consists of flattened transparent endothelial cells, with processes which extend between and support the epithelium. Into the crypt of a true gastric gland three or more caecal tubes, branched or unbranched, empty. The duct, however, in these glands is shorter than in the other variety, sometimes not amounting to more than one-sixth of the whole length of the gland; it is lined throughout by columnar epithelium. At the point where the terminal tubes open into the duct, and which is termed the neck, the epithelium alters, and consists of short columnar or polyhedral, granular cells, which almost fill the tube, so that the lumen becomes suddenly constricted, and is continued down as a very fine channel. They are known as the chief or the peptic or the central cells of the glands, and furnish pepsin. Between these cells and the basement-membrane are found other darker granular-looking cells, studded throughout the tubes at intervals, and giving it a beaded or varicose appearance. These are known as the parietal or oxyntic cells. Some of the parietal cells empty directly into the lumen of the gland by secretory capillaries; others empty by a duct which divides into secretory capillaries. The parietal cells secrete the acid of the gastric juice. Between the glands the mucous membrane consists of a connective-tissue framework with lymphoid tissue. In places this latter tissue, especially in early life, is collected into little masses, which to a certain extent resemble the solitary glands of the intestine, and are by some termed the lenticular glands of the stomach. They are not, however, so distinctly circumscribed as the solitary glands.

The Pyloric Glands (glandulae pyloricae) (Fig. 896) are the branched tubular glands, and secrete mucus.

They are placed most plentifully about the pylorus, but between the fundus and pylorus, in the region known as the transitional or intermediate zone, both true gastric glands and pyloric glands are found. Each pyloric gland consists of two or three short, closed tubes opening into a common duct, the external orifice of which is situated at the bottom of an alveolus. The caecal tubes are wavy, and are of about equal length with the duct. The tubes and duct are lined throughout with epithelium, the duct being lined by columnar cells continuous with the epithelium lining the surface of the mucous membrane of the stomach, the tubes with shorter and more cubical cells, which are finely granular. The pyloric glands branch more frequently, are more curved in direction, and open into deeper foveolae than the true gastric glands (Szymonowicz). They contain only chief or peptic cells and do not possess parietal cells.
The **Cardiac Glands** are found about the oesophageal orifice. They resemble the pyloric glands.

Beneath the mucous membrane, and between it and the submucous coat, is a thin stratum of involuntary muscular fibre (*muscularis mucosae*), which in some parts consists only of a single longitudinal layer; in others, of two layers, an inner circular, and an outer longitudinal.

**Vessels and Nerves.**—The arteries supplying the stomach are—the *gastric* or *coronary*, the *pyloric* and the *right gastro-epiploic branch of the gastro-duodenal*, the *left gastro-epiploic* and *vasa brevia* from the splenic. The gastric artery passes to the lesser curvature just below the cardia. It gives off the *oesophageal branch*, and passes from left to right along the lesser curvature of the stomach beneath the peritoneum between the two layers of the lesser omentum and upon the wall of the stomach. It may in this course be a single vessel, or may divide into two branches, which run along each side of the lesser curvature (Fig. 899). If there is a single artery it gives off six or seven descending branches to the anterior wall and about the same number to the posterior wall of the stomach. It also gives branches to the lesser omentum. If two *vascular arches* form, one gives branches to the anterior wall of the stomach, the other to the posterior wall, and both to the lesser omentum. The termination of the gastric anastomoses with the pyloric branch or two rami of the pyloric branch of the hepatic artery. From each arch six or seven *descending branches* come off to the anterior and posterior walls of the stomach. The *gastro-duodenal artery* is given off by the hepatic. From the gastro-duodenal comes the right gastro-epiploic. The left gastro-epiploic comes from the splenic. The **right gastro-epiploic artery** passes from right to left in the gastro-colic omentum below the greater curvature of the
stomach. The left gastro-epiploic artery passes forward in the gastro-splenic ligament to below the greater curvature of the stomach, and passes from left to right along that curvature in the gastro-colic omentum, and joins the right gastro-epiploic artery. The gastro-epiploic arteries are not upon but are distinctly below the stomach wall. From them numerous gastric branches are sent to the anterior and posterior walls of the stomach, and they anastomose with branches of the gastric and pyloric. Vasa brevia, four or five in number, arise from the splenic, pass forward in the gastro-splenic ligament, and supply the fundus. The arteries of the stomach lie first beneath the peritoneum, but soon enter the muscular coat, supply it, pierce it, ramify in the submucous coat, and are finally distributed to the mucous membrane. The arrangement of the vessels in the mucous membrane is somewhat peculiar (Fig. 898). The arteries break up at the base of the gastric tubules into a plexus of fine capillaries which run upward between the tubules, anastomosing with each other, and ending in a plexus of larger capillaries, which surround the mouths of the tubes and also form hexagonal meshes around the alveoli.

The capillary networks about the glands give origin to the veins. The various small veins unite and form a plexus in the submucous tissue (Fig. 898). From this plexus come branches which pass through the muscular coat and terminate in the right gastro-epiploic branch of the superior mesenteric, the left gastro-epiploic branch of the splenic, the veins to the splenic which correspond to the vasa brevia arteries, and the gastric or coronary branch of the portal.

The lymphatics (Figs. 505 and 506) arise in the mucous membrane and terminate in a network in the submucous tissue. From this network trunks arise which perforate the muscular coat in the regions of the curvatures and terminate in the sero-muscular collecting trunks.¹

According to Cunéo, there are three groups of these collectors. Those from the lesser curvature pass to the point where the gastric artery reaches the stomach and enter the glands along the gastric artery. Those from the greater curvature pass from left to right and enter the sub-pyloric glands. Those from the fundus pass from right to left and end in the splenic glands. Cunéo further pointed out that the region drained by the collectors of the lesser curvature is divided from the others by the line shown in Fig. 506. This division exists on both surfaces of the stomach. The limit between the collectors which drain into the splenic glands and those which drain into the sub-pyloric glands is also shown in Fig. 506. Along the lesser curvature the lymph-glands are few in number and are limited to the pyloric region, and the lymph-vessels are placed directly upon the stomach wall. The lymph-glands and vessels are not upon but are distinctly below the greater curvature.

The subserous and submucous lymphatic networks of the stomach communicate with the corresponding networks of the oesophagus, but in all probability do not communicate with the networks of the duodenum.

The nerves of the stomach come from the right and left vagus and from the solar plexus of the sympathetic. The left vagus passes to the front of the stomach, and the right nerve passes to the back, and they unite with the fibres of the sympathetic. The fibres thus formed are mostly amylenic. They form Auerbach's plexus in the muscular coat between the circular and longitudinal fibres and Meissner's plexus in the submucous coat, the latter plexus being formed by fibres from the former. Fibres from Meissner's plexus ramify in the submucous coat and terminate in the muscularis mucosae and the mucous membrane, branches passing to the gastric glands and to just beneath the epithelium.

¹ The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
THE ORGANS OF DIGESTION

Movements and Innervation of the Stomach.

Movements.—It has apparently been demonstrated that the stomach "consists of two parts physiologically distinct." The cardiac portion of the stomach is a food reservoir in which salivary digestion continues; the pyloric portion is the seat of active digestion. Cannon affirms that there are no peristaltic waves in the cardiac portion, but that as the food passes from the pyloric portion into the intestines, tonic contraction of the muscles of the fundus squeezes the contents of the pyloric portion. Moritz, Levan, and Cannon assert that muscular activity is chiefly manifested in the pyloric portion. In this portion during digestion there is a succession of peristaltic waves, which waves in the human being pass at the rate of three per minute (Moritz). Cannon points out that the efficiency of peristalsis in mixing the food depends upon the contraction of the pyloric sphincter. So long as the sphincter holds, each constriction-ring coursing from the middle to the end of the stomach presses the food into a blind pouch; the food, unable to escape through the pyloric opening, has as its only outlet the opening in the advancing ring. This is an admirable device for bringing the food under the influence of the glandular secretions of the pyloric region. For, as a constriction occurs, the secreting surface enclosed by the narrowed muscular ring is pressed close around the food within the ring. As the constriction advances it continually presses inward fresh glandular tissue, and further-more, as the constriction advances, a thin stream of food is continuously forced back through the ring and thus past the mouths of the glands. The old view that the pyloric sphincter only opens after several hours' continuance of the process of digestion and that then the stomach empties at once is incorrect. It is emptied in small amounts which escape at frequent intervals because of the intermittent opening of the pylorus. When the pylorus is open a wave of peristalsis forces some of the material from the stomach into the duodenum (Cannon).

Cannon is of the opinion that the pyloric sphincter is caused to relax by the presence of free hydrochloric acid in the pyloric portion of the stomach. When the pylorus is open acid chyme passes into the duodenum and acid in the duodenum causes the pylorus to close. The acid in the duodenum causes a flow of alkaline pancreatic juice and the acid is neutralized. "As the neutralizing proceeds the stimulus closing the pylorus is weakened until the acid in the stomach again opens the sphincter."1

Innervation.—The stomach, as previously shown, has nerve plexuses in its walls and is connected to the brain, spinal cord, and sympathetic system. It is probable that gastric peristalsis is due to a local reflex from Auerbach's plexus (Magnus), the local reflex being inaugurated by local stimulation, which stimulation, in the words of Bayliss and Starling, "produces excitation above and inhibition below the excited spot."2 Reversed peristalsis cannot occur if "the reflex mechanism is intact" (Cannon). Cannon in the previously quoted article states that cutting the vagus or splanchnic nerves does not destroy the reflex mechanism of the pylorus, but, nevertheless, it is markedly affected by the central nervous system.

Surface Form (see p. 1280).—The cardiac orifice corresponds to the articulation of the seventh left costal cartilage with the sternum. The pyloric orifice of the empty stomach is in a vertical line drawn from the right border of the sternum, two and a half or three inches below the level of the sterno-xiphoid articulation. According to Braune, when the stomach is distended, the pylorus moves considerably to the right, as much sometimes as three inches. The fundus of the stomach reaches, on the left side, as high as the level of the sixth costal cartilage of the left side, being a little below and behind the apex of the heart. The portion of the distended stomach which is in contact with the abdominal walls, and is therefore accessible for opening in the operations of gastrotomy and gastrostomy, is represented by a triangular space, the base of which is formed by a line drawn from the tip of the tenth costal cartilage on the left side to the tip of the ninth costal cartilage on the right, and the sides by two lines drawn from the extremity of the eighth costal cartilage on the left side to the ends of the base line.

Surgical Anatomy.—Operations on the stomach are frequently performed, ulcers are excised, malignant growths are removed with the associated lymphatic involvement, the entire stomach may be removed for cancer, etc. By "gastrotomy" is meant an incision into the stomach for the removal of a foreign body, or the arrest of hemorrhage or for exploration, the opening being immediately afterward closed—in contradistinction to "gastrostomy," the making of a more or less permanent fistulous opening. Gastrotomy is probably best performed by an incision in the linea alba, especially if the foreign body is large. The cut may reach from the ensiform cartilage to the umbilicus. The incision may be made over the body itself, where this can be felt, or by one of the incisions for gastrostomy, to be mentioned shortly. The peritoneal cavity is opened, and the point at which the stomach is to be incised decided upon. This portion is then brought out of the abdominal wound and sponges carefully packed around. The stomach is now opened by a transverse incision and the foreign body extracted. The wound in the stomach is then closed by Lembert sutures—t. c., by sutures passed through the peritoneal,

1 Walter B. Cannon, Medical News, May 20, 1905. 2 Ibid. 3 Ibid.
muscular and submucous coats in such a way that the peritoneal surfaces on each side of the wound are brought into apposition. \textit{Gastrectomy} was formerly done in two stages by the \textit{direct} method. The first stage consisted in opening the abdomen, drawing up the stomach into the external wound, and fixing it there; and the second stage, performed from two to four days afterward, consisted in opening the stomach. The operation is now done by a \textit{valvular} method. The following plan is known as the Saabanejew-Frank operation. An incision is commenced opposite the eighth intercostal space, two inches to the left of the median line, and carried downward for three inches. By this incision the fibres of the Rectus muscle are exposed and these are separated from each other in the same line. The posterior layer of the sheath, the transversalis fascia and the peritoneum, are then divided, and the peritoneal cavity is opened. Instead of the above incision, the curved incision of Fenger can be made at the margin of the left costal cartilages. The anterior wall of the stomach is now seized and drawn out of the wound and a silk suture passed through its submucous, muscular, and serous coats at the point selected for opening the viscus. This is held by an assistant so that a long conical diverticulum of the stomach protrudes from the external wound, and the parietal peritoneum and the posterior layer of the sheath of the rectus are sutured to the base of the cone. A second incision is made through the skin, over the margin of the costal cartilage, \textit{above and a little to the outer side of the first incision}. If Fenger’s incision were used, the second incision should be above the margin of the cartilages. With a pair of dressing forceps a track is made under the skin through the subcutaneous tissue from the one opening to the other and the diverticulum of the stomach is drawn along this track by means of the suture inserted into it; so that its apex appears at the second opening. A small perforation is now made into the stomach through this protruding apex and its margin carefully and accurately sutured to the margin of the external wound. The remainder of this incision and the whole of the first incision are then closed in the ordinary way and the wound dressed.

In cases of \textit{gastric ulcer}, perforation sometimes takes place, and this was formerly regarded as an almost fatal complication. In the present day, by opening the abdomen and closing the perforation, which is generally situated on the anterior surface of the stomach, a considerable percentage of cases are cured, provided the operation is undertaken within twelve to fifteen hours after the perforation has taken place. The opening is best closed by bringing the peritoneal surfaces on either side into apposition by means of Lembert sutures.

\textit{Pylorectomy} or excision of the pylorus is performed, particularly for early cancer, but is also done for cicatricial stricture and for ulcer. The mortality after operation for cancer was, until recently, very great, but of late years it has been notably reduced, though it is still much higher than that which follows operation for any non-malignant condition.

In operating for cancer, bear in mind Cuneo’s study of the lymphatics (page 806). These observations indicate that the fundus and two-thirds of the greater curvature are free from lymphatic involvement in pyloric cancer.\textsuperscript{1} In every operable case of cancer of the pylorus the lesser curvature must be removed up to the gastric artery (Mikulicz’s point), and the greater curvature must be removed to the left of the involved glands (Hartmann’s rule).

\textit{Gastro-enterostomy} is an operation which establishes a fistulous communication between the stomach and jejunum. The operation is often called \textit{gastro-jejunostomy}. The opening may be made upon either the anterior or the posterior wall of the stomach, between the cardia and the seat of pyloric disease. The operation is employed for stricture of the pylorus (benign or malignant), and occasionally for ulcer of the stomach.

\textit{Loreta’s operation} is digital division of the pylorus for cicatricial stricture, the stomach being incised transversely near the pylorus to admit the finger, and the wound in the stomach being sutured after division has been effected. The operation has been abandoned, because contraction recurs.

\textit{Pyloroplasty}, or the Heineke-Mikulicz operation, displaced Loreta’s operation. In this procedure an incision is made through the stricture in the direction of the long axis of the stomach and bowel. By making traction on each side of the incision, the longitudinal wound assumes a vertical direction, and sutures are inserted so as to close the wound in a vertical line. The method of pyloroplasty devised by Finney, of Baltimore, makes a large permanent opening at the most dependent part of the stomach, and is the most satisfactory method of which we are possessed.\textsuperscript{2}

\textit{Total gastrectomy} is the removal of the entire stomach. It is only used for cancer. It was first performed by Conner, of Cincinnati. The first successful operation was done by Schlatter, of Zurich, in 1898. A number of successes have been reported. It is a justifiable operation only in a case in which almost the entire stomach is cancerous, in which the vices is movable, in which there are no secondary deposits, and no irremovable diseased glands.

\textit{Gastro-gastrectomy} is an operation employed in hour-glass stomach. In this operation an anastomosis is made between the pyloric and cardiac ends of the stomach.

\textsuperscript{1} William J. Mayo, Annals of Surgery, March, 1904.

\textsuperscript{2} Johns Hopkins Hospital Bulletin, July, 1902.
**Gastroplication** is the operation of suturing the stomach wall into folds or reefs, in order to lessen its size. It is employed in some cases of gastric dilatation.

**Gastroptosis** is a condition in which the stomach is displaced downward. In some of these cases the greater curvature almost reaches the level of the symphysis pubis, and the lesser curvature is midway between the umbilicus and ensiform cartilage. The condition is usually associated with **enteroptosis** and **movable kidney** (nephroptosis). In this condition the gastro-hepatic omentum and the gastro-phrenic ligament are pulled upon and lengthened. The best operation for gastroptosis was devised by Beyea. He applies sutures so as to make folds in and thus shorten the stretched ligament and omentum. Thus the stomach is elevated to its proper position, and its mobility is not lessened, as it is in other operations which suture it to the abdominal wall.

**THE SMALL INTESTINE (INTESTINUM TENUE).**

The small intestine is a convoluted tube, extending from the pylorus to the ileo-caecal valve, where it terminates in the large intestine. It fills up the greater part of the abdominal cavity and of the pelvic cavity. It is about twenty feet in length, and gradually diminishes in size from its commencement to its termination. The diameter of the duodenum is almost two inches; the diameter of the lower portion of the small intestine is little more than one inch. It is contained in the central and lower part of the abdominal cavity, and is surrounded above and at the sides by the large intestine; a portion of it extends below the brim of the pelvis and lies in front of the rectum; it is in relation, in front, with the great omentum and abdominal parietes; and connected to the spine by a fold of peritoneum, the **mesentery** (p. 1266). The small intestine is divisible into three portions — the **duodenum**, the **jejunum**, and **ileum**.

The **Duodenum** (Figs. 900, 905, 906, 907, 908).

The duodenum has received its name from being about equal in length to the breadth of twelve fingers (ten inches). It is the shortest, the widest, and the most fixed part of the small intestine, being closely and firmly attached to the posterior abdominal wall. It does not possess a mesentery. Somewhat more than the upper half of the duodenum is placed in the epigastric region; the remainder is in the umbilical region. The duodenum, with the exception of the ascending portion, is to the right of the median line. Its course presents a remarkable curve, which in the adult, as regards the greater part of its extent, is horseshoe-shaped, though sometimes, in consequence of the transverse portion being very short or altogether wanting, it partakes more of the character of the letter V. The opening of the horseshoe being directed upward and to the left. In children up to the age of about seven the duodenum is annular. The two extremities of the duodenum are nearly on the same level, the exit being slightly lower than the entrance. The two ends are about two inches apart; and between them it describes a regular curve embracing the head of the pancreas, the neck of which lies between the two extremities of the ring.

In the adult the course of the duodenum is as follows: commencing at the pylorus the direction of the first portion depends upon the amount of distention of the stomach and therefore upon the position of the pylorus. When the stomach is empty and the pylorus is situated at the right of the upper border of the first lumbar vertebra, it is nearly horizontal and transverse; but where the stomach is distended, in consequence of the alteration of the position of the pylorus to the right the proximal end of the duodenum also becomes altered in position, while the

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1 Treves states that in one hundred cases the average length of the small intestine in the adult male was 22 feet 6 inches, and in the adult female 23 feet 4 inches; but that it varies very much, the extremes in the male being 31 feet 10 inches in one case and 15 feet 6 inches in another, a difference of over 15 feet. He states that he has convinced himself that the length of the bowel is independent, in the adult, of age, height, and weight.—Ed. of 15th English edition.
THE DUODENUM

distal end remains fixed and the direction of this portion of the bowel is now antero-posterior. Whether directed transversely or antero-posteriorly, it reaches

Tributary to vena cava.

Hepatic artery, portal vein, and bile duct.
Supra-renal capsule.
Right renal vessels.

Crura of Diaphragm.
Gastric artery.
Splenic artery.
Splenic vein.

FIG. 900.—Relations of duodenum, pancreas, and spleen. (From a cast by Professor Birmingham.)
The dotted line represents the line of attachment of the transverse mesocolon.

the under surface of the liver, where it takes a sharp curve and descends along the right side of the vertebral column, for a variable distance, generally to the body of

1 In the subject from which the cast was taken the left kidney was lower than normal.
the fourth lumbar vertebra. It now takes a second bend, and passes across the front of the vertebral column from right to left and finally ascends on the left side of the vertebral column and aorta to the level of the upper border of the second lumbar vertebra and there terminates in the jejunum. As it unites with the jejunum it often turns abruptly forward, forming the duodeno-jejunal angle. Prof.

Birmingham points out that the incomplete ring formed by the duodenum does not lie throughout in the same plane. "Its greater part is placed in a transverse vertical plane; the middle portion bends strongly backward, around the right side of the vena cava, and lies almost in a sagittal plane." From the above description it will be seen that the duodenum may be divided for purposes of description into four portions—superior, descending, transverse and ascending.

The First or Superior Portion (pars superior) (Figs. 900, 905, and 907) is very variable in length, but is usually estimated as being about two inches. Beginning at the pylorus, it ends at the level of the neck of the gall-bladder.

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1 Prof. Cunningham's Text-book of Anatomy.
When the stomach is empty this portion of the duodenum is horizontal and transverse; when the stomach is distended it extends from before backward. It is the most movable of the four portions. It is almost completely covered by peritoneum derived from the two layers of the lesser omentum. A small part of its posterior surface is not completely covered by peritoneum (Fig. 901). The first inch of the superior portion of the duodenum is completely covered by peritoneum; the lesser omentum is attached above and the greater omentum below (Fig. 901). The other portion has only its anterior wall covered by peritoneum. The posterior and lateral surfaces are uncovered by peritoneum and are near the neck of the gall-bladder and the posteava. The first portion of the duodenum is in such close relation with the gall-bladder that it is usually found to be stained by bile after death, especially on its anterior surface. It is in relation above and in front with the quadrate lobe of the liver, lying in a slight concavity, the impression duodenalis. It is also in relation above in part with the gall-bladder; behind with the gastro-duodenal artery, the common bile-duct, and the portal vein; and below with the head of the pancreas. The superior portion of the duodenum crosses the transverse fissure of the liver, and by means of the superior flexure of the duodenum (flexura duodeni superior) passes into the second or descending portion beneath the caudate lobe.

The Second or Descending Portion (pars descendens) (Figs. 900, 905, and 907) is between three and four inches in length, and extends from the neck of the gall-bladder on a level with the first lumbar vertebra along the right side of the vertebral column as low as the body of the fourth lumbar vertebra. It is crossed in its middle third by the transverse colon, the posterior surface of which is uncovered by peritoneum and is connected to the duodenum by a small quantity of connective tissue. The portions of the descending part of the duodenum above and below this interspace are named the supracolic and infracolic portions, and are covered in front by peritoneum (Fig. 902). The right side of the supracolic portion is covered by peritoneum derived from the anterior surface of the right kidney, the left side of the same portion being covered by the peritoneum forming the lesser sac. The infracolic part is covered by the right leaf of the mesentery. Posteriorly the descending portion of the duodenum is uncovered by peritoneum. The descending portion of the duodenum is in relation, in front, with the transverse colon, and above this with the right lobe of the liver, where it lies in the impression duodenalis for the second part of the duodenum; behind with the front of the right kidney, to which it is connected by loose areolar tissue, the renal vessels and the postcava; at its inner side is the head of the pancreas, and the ductus communis choledochus; to its outer side is the hepatic flexure of the colon. The common bile-duct passes downward behind the first portion of the duodenum, descends to the inner side of the second portion, is joined by the pancreatic duct, and the two ducts perforate the inner side of this portion of the intestine obliquely, and empty into the duodenum by a common opening or by two openings at the summit of a papilla, some three or four inches below the pylorus. The relations of the second portion of the duodenum to the right kidney present considerable variations. The descending portion passes into the transverse portion by means of the flexura duodeni inferior.

The Third, Pre-aortic, Horizontal or Transverse Portion (pars horizontalis inferior) (Figs. 900, 905, and 907) varies much in length; when the duodenum assumes the ordinary horseshoe form, it measures from two to three inches; but when it presents the rarer V-shaped form, it is practically wanting or very much reduced in length. The transverse portion is described as the horizontal part of the ascending or last portion by those authors who divide the duodenum into three parts instead of four. It commences at the right side of the fourth lumbar vertebra and passes from right to left, with a slight inclination upward, in front of the great
vessels and crura of the Diaphragm, and ends in the fourth portion in front of or just to the left of the abdominal aorta. It is crossed by the superior mesenteric vessels and mesentery. The *posterior surface* rests upon the aorta, the post-cava, and the crura of the Diaphragm. By its upper surface this portion of the duodenum is in relation with the head of the pancreas. The front of the third portion of the duodenum is covered by peritoneum except where the mesenteric vessels and root of the mesentery cross it (Fig. 903). The left side of the termination of the ascending portion is also covered by peritoneum, and in this region the *duodenal fossae* are found (p. 1270).

The **Fourth or Ascending Portion of the Duodenum** (*pars ascendens*) (Figs. 900, 905, and 907) is about two inches long. It ascends on the left side of the vertebral column and aorta, as far as the level of the upper border of the second lumbar vertebra, where it turns abruptly to the right and forward to become the jejunum, forming the *duodeno-jejunal angle* or *flexure* (*flexura duodenojejunalis*) (Fig. 905). It is covered entirely in front and partly at the sides by peritoneum, derived from the left portion of the mesentery (Fig. 904). The superior mesenteric artery and vein are in front of it. It touches the left kidney, slightly overlapping its inner margin, and rests upon the left crus of the Diaphragm.

The first part of the duodenum, as stated above, is somewhat movable, but the rest is practically fixed and is bound down to neighboring viscera and the posterior abdominal wall by the peritoneum. In addition to this, the fourth part of the duodenum and the duodeno-jejunal flexure is further bound down and fixed by a structure called the **Suspensory muscle of the duodenum** or the ** suspensory ligament of Treitz** (*m. suspensorius duodeni*) (Fig. 905). This structure commences in the connective tissue around the coeliac axis and left crus of the Diaphragm, and passes downward to be inserted into the superior border of the duodeno-jejunal curve and a part of the ascending duodenum, and from this it is continued into the mesentery. It possesses, according to Treitz, some few plain muscular fibres mixed with the
fibrous tissue, of which it is principally made up. It is of little importance as a muscle, but acts as a suspensory ligament.

Fig. 906.—The interior of the duodenum. (Spalteholz.)

Fig. 907.—The duodenum, its four parts marked a, b, c, d. The liver is lifted up; the greater part of the stomach is removed, broken lines indicating its former position. (Testut.)
**Interior of the Duodenum** (Fig. 906).—In the beginning of the duodenum valvulae conniventes are absent. They begin to appear in the lower half of the first portion, being at first trivial elevations irregularly placed. They become higher, regular, and more numerous lower down, and near the termination of the duodenum are strongly marked and closely placed transverse or spiral folds (Fig. 906 and p. 1260). In the descending portion (Fig. 906) to the side and rear is a longitudinal fold (plica longitudinalis duodeni), which is formed by the projection of the bile-duct and pancreatic duct beneath the mucous membrane.

The **caruncula major of Santorini** or the **bile papilla** is a projection or pit in the lower part of the longitudinal fold. At the summit of this papilla are seen two openings, if the bile-duct and pancreatic duct have not united, or one common opening for both of them, if they have united. One inch above and half an inch or more in front of the bile papilla is a much smaller papilla, the **caruncula minor of Santorini** (papilla duodeni [Santorini]), on the summit of which the accessory pancreatic duct of Santorini opens.

**Structure of the Duodenum.**—The peritoneal coat (tunica serosa) has been described. The **muscular coat** (tunica muscularis) is practically identical with the muscular coat of the balance of the intestine. The bile-duct and pancreatic duct pass through it. The **submucous coat** (tela submucosa) contains lymph-nodes and **glands of Brunner** (glandulae duodenales). These glands are particularly plentiful in the first half of the duodenum (p. 1303). The mucous membrane is thicker in the duodenum than in the rest of the small intestine, is covered with villi, and from the lower half of the first portion down is formed into circular folds or valvulae conniventes. In the descending part it exhibits the previously described longitudinal fold.

**Vessels and Nerves.**—The **arteries** (Fig. 908) supplying the duodenum are the pyloric and pancreatico-duodenal branches of the hepatic, and the **inferior pancreatico-duodenal branch of the superior mesenteric**. The **veins** (Fig. 908) correspond to the arteries. The **superior duodenal vein** passes into the superior mesenteric, and the **inferior duodenal vein** passes into the portal. The **lymphatics** pass along with the pancreatico-duodenal arteries, glands being present here and there, and terminate in the glands about the coeliac axis. The **duodenal fossae** are described on p. 1270. The **nerves** are derived from the solar plexus.
The Jejunum and Ileum (Figs. 875, 877, 878, 880, 905).

The remainder of the small intestine from the termination of the duodenum comprises the jejunum and ileum; the former name being given to the upper two-fifths and the latter to the remaining three-fifths. Spalteholz and others call all of the small intestine below the duodenum the intesinum tenue mesenteriale. There is no morphological line of distinction between the jejunum and ileum, and the division is arbitrary; but at the same time it must be noted that the character of the intestine gradually undergoes a change from the commencement of the jejunum to the termination of the ileum, so that a portion of the bowel taken from these two situations would present characteristic and marked differences. These are briefly as follows:

**Differences between the Jejunum and Ileum.**—If the jejunum high up is contrasted with the ileum low down, it is noted that the former is thicker, of greater diameter, contains more blood-vessels, and hence is more distinctly red, has well-marked valvulae conniventes, but a few small-sized Peyer’s patches, and the villi are short and broad. In the ileum large Peyer’s patches are present in numbers, and the villi are thin (Prof. Birmingham).

**The Jejunum (intestinum jejunum).**—The jejunum, which derives its name from the Latin word jejunus (empty), because it was formerly supposed to be empty after death, is wider, its diameter being about one inch and a half, and is thicker, more vascular, and of a deeper color than the ileum, so that a given length weighs more. Its valvulae conniventes are large and thickly set and its villi are larger than in the ileum. The glands of Peyer are almost absent in the upper part of the jejunum, and in the lower part are less frequently found than in the ileum, and are smaller and tend to assume a circular form. Brunner’s glands are only found in the upper part of the jejunum. By grasping the jejunum between the finger and thumb the valvulae conniventes can be felt through the walls of the gut; these being absent in the lower part of the ileum, it is possible in this way to distinguish the upper from the lower part of the small intestine.

**The Ileum (intestinum ileum).**—The ileum (so called from the Greek word εἰλεῖος, to twist, on account of its numerous coils and convolutions) is placed below and to the right of the jejunum. It is narrower, its diameter being one inch and a quarter, and its coats are thinner and less vascular than those of the jejunum. It possesses but few valvulae conniventes, and they are small and disappear entirely toward its lower end, but Peyer’s patches are larger and more numerous. The jejunum for the most part occupies the umbilical and left iliac regions, while the ileum occupies chiefly the umbilical, hypogastric, right iliac, and pelvic regions, and terminates in the right iliac fossa by opening into the inner side of the commencement of the large intestine. The upper portion of the jejunum passes to the left of the duodeno-jejunal flexure, and is in relation with the under surface of the pancreas and the transverse mesocolon. The lower portion of the ileum is in the pelvis and rises from above the brim, passing upward, backward, and to the right to reach the ileo-cecal opening. Treves points out that another portion of the small intestine may be in the pelvis, viz., the portion with the longest mesentery. This is a portion somewhere between a point six feet from the duodenum and a point eleven feet from the duodenum. The jejunum and ileum are attached to the posterior abdominal wall by an extensive fold of peritoneum, the mesentery (p. 1266), which allows the freest motion, so that each coil can accommodate itself to changes in form and position. The mesentery is fan-shaped; its posterior border, about six inches in length, is attached to the abdominal wall from the left side of the second lumbar vertebra to the right iliac fossa (Fig. 875). Its length is about eight inches from its commencement to its termination at the intestine, and it is rather longer about its centre than at either end of the bowel. According to Lockwood,
it tends to increase in length as age advances. Between the two layers of which it is composed are contained blood-vessels, nerves, lacteals, and lymphatic glands, together with a variable amount of fat.

**Meckel's Diverticulum (diverticulum ilei).**—Occasionally there may be found connected with the lower part of the ileum, on an average about three feet from its termination, a blind diverticulum or tube, varying in length, but averaging about two inches, and being of about the same diameter as the piece of intestine of which it is a part. Sometimes only a portion of the proximal end is open and the balance of the structure is obliterated and shrunk to a fibrous cord. In other cases the diverticulum is actually of greater diameter than the intestine. It usually is at a right angle to the intestine, but may take almost any direction. In most cases it has a mesentery. It is attached to and communicates with the lumen of the bowel by one extremity, and by the other is unattached or may be connected with the abdominal wall or with some other portion of the intestine by a fibrous band. This is Meckel's diverticulum, and represents the remains of the vitelline or omphalo-mesenteric duct, the duct of communication between the umbilical vesicle and the alimentary canal in early foetal life.

**Structure of the Small Intestine, including the Duodenum.**—The wall of the small intestine is composed of four coats—serous, muscular, areolar or submucous, and mucous.

**The Serous Coat (tunica serosa).**—The relation of the peritoneum to the duodenum has been described. The remaining portion of the small intestine is surrounded by the peritoneum, excepting along its attached or mesenteric border; here a space is left for the vessels and nerves to pass to the gut.

**The Muscular Coat (tunica muscularis).**—The muscular coat consists of two layers of fibres, an external or longitudinal layer and an internal or circular layer.

The **Longitudinal Fibres** (stratum longitudinale) are thinly scattered over the surface of the intestine, and are more distinct along its free border.

The **Circular Fibres** (stratum circulare) form a thick, uniform layer; they surround the cylinder of the intestine in the greater part of its circumference, and are composed of plain muscle-cells of considerable length. The muscular coat is thicker at the upper than at the lower part of the small intestine.

**The Areolar or Submucous Coat (tela submucosa).**—The areolar or submucous coat connects together the mucous and muscular layers. It consists of loose, filamentous areolar tissue, which forms a bed for the subdivision of the nutrient vessels, previous to their distribution to the mucous surface.

The submucous coat contains **lymph-nodules** (noduli lymphatici). Each nodule is pyramidal or pear-shaped, and the apex lies in the mucous membrane and forms a rounded elevation. These rounded elevations mark the solitary glands and Peyer's patches (Figs. 909, 911, and 918), and in nowise resemble villi. In the duodenum the submucous tissue contains the **duodenal glands**. The submucous tissue is prolonged into the **valvulae conniventes**. It contains blood-vessels, Meissner's plexus of nerves, and lymph-vessels.

**The Mucous Membrane (tunica mucosa).**—The mucous membrane is thick and highly vascular at the upper part of the small intestine, but somewhat paler and thinner below. It consists of the following structures: next the areolar or submucous coat is a layer of unstriped muscular fibres, the **muscularis mucosae**; internal to this is a quantity of retiform tissue, enclosing in its meshes lymph-corpuscles, and in which the blood-vessels and nerves ramify. Lastly, a basement-membrane, supporting a single layer of epithelial cells, which throughout the intestines are columnar in character. They are granular in appearance, and each possesses a clear, oval nucleus. At their superficial or unattached end they present a distinct layer of highly refracting material, marked by vertical striae, which were formerly
believed to be minute channels by which the chyle was taken up into the interior of the cell, and by them transferred to the lacteal vessels of the mucous membrane.

The mucous membrane presents for examination the following structures contained within it or belonging to it:

Valvulae conniventes. Duodenal glands.
Villi. Lymphatic nodules
Simple follicles. Solitary glands.

The Valvulae Conniventnes or the Valves of Kerkring (plicae circulares [Kerkringi]) (Fig. 910) are large folds or valvular flaps projecting into the lumen of the bowel. They are composed of reduplications or folds of the mucous membrane, the two layers of the fold being bound together by submucous tissue; they contain no muscular fibres, and, unlike the folds in the stomach, they are permanent, and are not obliterated when the intestine is distended. The majority extend transversely across the cylinder of the intestine for about one-half or two-thirds of its circumference, but some form complete circles, and others have a spiral direction; the latter usually extend a little more than once around the bowel, but occasionally two or three times. The spiral arrangement is the characteristic one of the shark family of fishes. The larger folds are about one-third of an inch in depth at their broadest part; but the greater number are of smaller size. The larger and smaller folds alternate with each other. They are not found at the commencement of the duodenum, but begin to appear about one or two inches beyond the pylorus. In the lower part of the descending portion, below the point where the bile and pancreatic ducts enter, the intestine, they are very large and closely approximated. In the transverse portion of the duodenum and upper half of the jejunum they
are large and numerous; and from this point, down to the middle of the ileum, they diminish considerably in size. In the lower part of the ileum they almost entirely disappear; hence the comparative thinness of this portion of the intestine as compared with the duodenum and jejunum. The valvulae conniventes retard the passage of the food along the intestine, and afford a more extensive surface for absorption.

The villi (villi intestinales) (Figs. 909, 911, 912, 913, and 918) are minute, highly vascular processes, never larger than one millimetre, projecting from the mucous membrane of the small intestine throughout its whole extent, and giving to its surface a velvety appearance. They spring from the valvulae conniventes and also from the spaces between them. In shape, according to Rauber, they are short and leaf-shaped in the duodenum, tongue-shaped in the jejunum, and filiform in the ileum. They are largest and most numerous in the duodenum and jejunum, and become fewer and smaller in the ileum. Krause estimates their number in the upper part of the small intestine at from fifty to ninety in a square line; and in the lower part from forty to seventy, the total number for the whole length of the intestine being about four millions.

Structure of the Villi (Figs. 912 and 913).—The structure of the villi has been studied by many eminent anatomists. We shall here follow the description of Watney, whose researches have a most important bearing on the physiology of that which is the peculiar function of this part of the intestine, the absorption of fat.

The essential parts of a villus are—the lacteal vessel, the blood-vessels, the epithelium, the basement-membrane and muscular tissue of the mucosa, these structures being supported and held together by retiform lymphoid tissue.

1 Phil. Trans., vol. clxv. part ii.
These structures are arranged in the following manner: situated in the centre of the villus is the lacteal, terminating near the summit in a blind extremity;
running along this vessel are unstriped muscular fibres; surrounding it is a plexus of capillary vessels, the whole being enclosed by a basement-membrane, and covered by columnar epithelium. Those structures which are contained within the basement-membrane—namely, the lacteal, the muscular tissue, and the blood-vessels—are surrounded and enclosed by a delicate reticulum which forms the matrix of the villus, and in the meshes of which are found large, flattened cells with oval nuclei, and, in smaller numbers, lymph-corpuscles. These latter are to be distinguished from the larger cells of the villus by their behavior with reagents, by their size, and by the shape of the nucleus, which is spherical. Transitional forms, however, of all kinds are met with between the lymph-corpuscles and the proper cells of the villus. Nerve-fibres are contained within the villi; they form ramifications throughout the reticulum.

The lacteals are in some cases double, and in some animals multiple. Situated in the axis of the villi, they commence by dilated caecal extremities near to, but not quite at, the summit of the villus. The walls are composed of a single layer of endothelial cells, the interstitial substance between the cells being continuous with the reticulum of the matrix.

The muscular fibres are derived from the muscularis mucosae, and are arranged in bundles around the lacteal vessel, extending from the base to the summit of the villus, and giving off laterally individual muscle-cells, which are enclosed by the reticulum, and by it are attached to the basement-membrane.

The blood-vessels form a plexus between the lacteal and the basement-membrane, and are enclosed in the reticular tissue; in the interstices of the capillary plexus, which they form, are contained the cells of the villus.

These structures are surrounded by the basement-membrane, which is made up of a stratum of endothelial cells, and upon which is placed a layer of columnar epithelium. The reticulum of the matrix is continuous through the basement-membrane (that is, through the interstitial substance between the individual endothelial cells) with the interstitial cement substance of the columnar epithelial cells on the surface of the villus. Thus we are enabled to trace a direct continuity between the interior of the lacteal and the surface of the villus by means of the reticular tissue, and it is along this path that the chyle passes in the process of absorption by the villi; that is to say, it passes first of all into the columnar epithelial cells, and, escaping from them, is carried into the reticulum of the villus, and thence into the central lacteal.
The Simple Follicles, Intestinal Glands, Crypts or Glands of Lieberkühn (glandulae intestinales [Lieberkühni]) (Figs. 914, 915, and 918) are found in considerable numbers over every part of the mucous membrane of the small intestine. They consist of minute tubular depressions of the mucous membrane, arranged perpendicularly to the surface, upon which they open by small circular apertures. They may be seen with the aid of a lens, their orifices appearing as minute dots scattered between the villi (Fig. 909). Their walls are thin, consisting of a basement-membrane lined by columnar epithelium, and covered on their exterior by capillary vessels.

The Duodenal or Brunner's Glands (glandulae duodenales [Brunneri]) are limited to the duodenum and commencement of the jejunum. They are small, flattened, granular bodies embedded in the submucous areolar tissue, and open upon the surface of the mucous membrane by minute excretory ducts. They are most numerous and largest near the pylorus. They are small, compound, acino-tubular glands, and much resemble the small glands which are found in the mucous membrane of the mouth. They are believed by Watney to be direct continuations of the pyloric glands of the stomach. They consist of a number of tubular alveoli, lined by epithelium, and opening by a single duct on the inner surface of the intestine.

The Lymph Nodules (noduli lymphatici) are small pyriform structures. The bodies of the nodes are in the submucous coat; the apices are in the mucous membrane, which is thrown by them into rounded elevations. They are divided into solitary glands and Peyer's glands.

The solitary glands (noduli lymphatici solitarii) (Figs. 909 and 911) are found scattered throughout the mucous membrane of the small intestine and the large intestine. In the small intestine they are most numerous in the lower part of the ileum, upon and between the valvulae conniventes. They are small, round, whitish bodies, from one-twenty-fourth of an inch to one-quarter of an inch in diameter. Their free surface is covered with villi, and each gland is surrounded by the openings of the follicles of Lieberkühn. They are now recognized as lymph-
nodules. They consist of a dense interlacing retiform tissue closely packed with lymph-corpuscles and permeated with an abundant capillary network. The interspaces of the retiform tissue are continuous with larger lymph-spaces at the base of the gland, through which they communicate with the lacteal system. They are situated partly in the submucous tissue, partly in the mucous membrane, whence they form slight projections of its epithelial layer, after having penetrated the muscularis mucosae. The villi situated on them are generally absent from the very summit (or "cupola," as Frey calls it) of the gland.

**Peyer's glands, Peyer's patches**, the agminated glands or the tonsillae intestinales (noduli lymphatici aggregati [Peyerii]) (Figs. 916, 917, and 918) may be regarded as aggregations of solitary glands, forming circular or oval patches from twenty-five to forty in number, and varying in length from half an inch to four inches. They are largest and most numerous in the ileum. In the lower part of the jejunum they are small, of a circular form, and few in number. They are occasionally seen in the duodenum. They are placed lengthwise in the intestine, and are situated

![Diagram of Peyer's patch](image)

in the portion of the tube most distant from the attachment of the mesentery. Each patch is formed of a group of the above-described solitary glands covered with mucous membrane, and in almost every respect are similar in structure to them. They do not, however, as a rule, possess villi on their free surface. Each patch is surrounded by a circle of the crypts of Lieberkühn. They are best marked in the young subject, becoming indistinct in middle age, and sometimes altogether disappearing in advanced life. They are largely supplied with blood-vessels, which form an abundant plexus around each follicle and give off fine branches which permeate the lymphoid tissue in the interior of the follicle. The lacteal plexuses which are found throughout the small intestine are especially abundant around these patches; here they form rich plexuses with sinuses around the glands (Fig. 918). In typhoid fever there is ulceration of Peyer's patches.

**Vessels and Nerves.**—The arteries (vasa intestini tenues) are branches of the superior mesenteric (Fig. 423) and ascend within the mesentery, forming single, double, or even tertiary loops (Figs. 882, 883, 884, 885, 886, 887, and 919). The terminal branches reach the intestine, and each branch divides into two, one going to each side of the intestine and passing transversely around it. At first they are
directly beneath the peritoneum, but after a time they pass to the submucosa and form a plexus, from which branches go to the mucous membrane. Some of these enter the villi; others form plexuses about the glands of Lieberkühn (Birmingham).

Dr. George H. Monks\(^1\) points out that opposite the upper portion of the bowel the mesenteric vessels form only primary loops; as we pass down secondary loops appear, become larger and more and more numerous, and actually prominent features about the fourth foot. As we descend the secondary loops become larger and more numerous and the primary become smaller. All the time the loops get nearer and nearer to the bowel. Tertiary loops may appear. Opposite the lower part of the ileum the loops cease to be characteristic and they form a network. (Monks's views are fully set forth on p. 1276.) In the upper part of the gut the vasa recta are from 3 to 5 cm. long, when the loop of small intestine to which they run is lifted up so as to put them gently on the stretch. They are straight, large, and regular, and rarely give off branches in the mesentery. In the lower third they are very short, being generally less than 1 cm. in length. Here they are less straight, smaller, less regular, and have frequent branches in the mesentery.

The veins correspond to the arteries, and the venous blood passes to the superior mesenteric vein, which, it will be remembered, unites with the splenic vein to form the portal vein. The mesenteric veins are devoid of valves.

The lacteals are lymphatics (Figs. 911, 912, 913, and 918) which arise in the villi. Lymphatics also begin in sinuses at the base of the solitary glands and as lymph-nodes in the submucous coat. Peyer's patches are aggregations of lymph-nodes. There is an extensive lymphatic plexus in the submucous coat, another in the muscular coat, another under the peritoneum. The submucous plexus is formed by lymphatics from the villi and mucous membrane. This plexus is joined by lymphatics from the bases of the solitary glands, and the lymph passes by vessels to larger vessels at the mesenteric border of the gut. The muscular lymphatics are placed between the two muscular layers. They

\(^1\) Annals of Surgery, May, 1903.
form a plexus and communicate freely with the lymphatics from the mucous membrane, and empty themselves in the same manner into the commencement

Fig. 921.—Meissner's plexus. (Ramón y Cajal.)

Fig. 922.—Meissner's plexus. (Klein and Noble Smith.)
of the lacteal vessels at the attached border of the gut. The vessels from all sources of lymphatic supply pass up between the two layers of the mesentery, being connected with the mesenteric glands (Fig. 507), and unite to form a trunk, the intestinal lymphatic trunk, which opens into the receptaculum chyli, or the vessels unite to form several trunks, which open separately into the receptaculum chyli.

The nerves of the small intestine (Figs. 920, 921, and 922) are derived from the coeliac plexus about the superior mesenteric artery, which is one of the divisions of the solar plexus. They pass along within the mesentery with the superior mesenteric artery and reach the intestine. They pass to the plexus of nerves and ganglia situated between the circular and longitudinal muscular fibres (Auerbach's plexus), from which the nerve branches are distributed to the muscular coats of the intestine. From this plexus a secondary plexus is derived (Meissner's plexus). It is formed by branches which have perforated the circular muscular fibres (Fig. 922). This plexus lies between the muscular and mucous coats of the intestine. It is also gangliated, and from it the ultimate fibres pass to the muscularis mucosae, to the villi, and to the mucous membrane. The nerves of the intestine are amyelinic, and some of the fibres are derived from the vagus.

THE LARGE INTESTINE (INTESTINUM CRASSUM) (Figs. 812, 874, 875, 923, 924).

The large intestine extends from the termination of the ileum to the anus. It is about five feet or more in length, being one-fifth of the whole extent of the intestinal canal. It is largest at its commencement at the caecum, and gradually diminishes as far as the rectum, where there is a dilatation of considerable size just above the anus. The diameter of the distended caecum is usually about three inches; the diameter of the descending colon is about one and one-half inches. The large intestine differs from the small intestine in its greater size, its more fixed position, its sacculated form (Figs. 923 and 924), and in possessing certain appendages to its external coat, the appendices epiploicae (Fig. 924). The appendices epiploicae are peritoneal pouches containing fat, unless the subject is greatly wasted; they protrude here and there from the peritoneal coat of the entire large bowel, except the rectum, and are particularly frequent along the anterior longi-
tudinal band. Further, the longitudinal muscular fibres of the large intestine do not form a continuous layer around the gut, but are arranged in three longitudinal bands or taeniae (taeniae coli) (Fig. 924). The large intestine, in its course, describes an arch, which surrounds the convolutions of the small intestine. It commences in the right inguinal region, in a dilated part, the caecum. It ascends through the right lumbar and right hypochondriac regions to the under surface of the liver; it here takes a bend to the left, the hepatic flexure, and passes transversely across the abdomen on the confines of the epigastric and umbilical regions, to the left hypochondriac region; it then bends again, the splenic flexure, and descends through the left lumbar region to the left iliac fossa, where it becomes convoluted, and forms the sigmoid flexure; finally it enters the pelvis, and descends along its posterior wall to the anus. The large intestine is divided into the caecum, colon, and rectum.

The Caecum (Intestinum Caecum) (Figs. 925, 926).

The caecum, the commencement of the large intestine, is the large blind pouch, or cul-de-sac, situated below the ileo-caecal valve. Its name is derived from caecus, blind. Its blind end or fundus is directed downward, and its open end upward, communicating directly with the colon, of which this blind pouch appears to be the beginning or head, and hence the old name caput caecum coli was applied to it. An incomplete groove marks the upper limit of the caecum. This groove is at the level of the opening of the ileum. When the caecum is contracted it bends on this groove as on a hinge and forms an angle with the ascending colon. In the contracted caecum sacculations are but slightly evident; in the distended caecum they are definite. Its size is variously estimated by different authors, but on an average it may be said to be two and a half inches in length and three in breadth. In 435 careful autopsies, Robinson found the caecum and appendix congenitally absent in one case. Sometimes a very large, sometimes an exceedingly small, caecum is encountered. A large caecum may be four inches in width, entirely surrounded by peritoneum and usually is excessively mobile. An adult caecum may be only one inch in width and one-half an inch in length, and it is usually devoid of mobility. It is situated in the right iliac fossa, above the outer half of Poupart's ligament, usually rests on the Ilio-psoas muscle, the iliac fascia intervening, and lies immediately behind the abdominal wall. The right side of the caecum is in contact with the outer wall of the abdomen, and the outer aspect of the anterior wall of the caecum is in contact with the anterior abdominal wall (Spalteholz). When the caecum is full the small intestine lies in front of the left side and lower portion of the anterior caecal wall. If the caecum is empty the small intestine lies in front of its anterior wall, and the lower end is on a higher level than when this portion of the gut is full. In a small per cent. of cases the

1 St. Louis Courier of Medicine, October-December, 1902.
caecum is covered by the omentum. Robinson describes four positions of the caecum: 1. On the Psoas muscle. 2. To the right of the Psoas muscle. 3. In the pelvis. 4. The potential position, in which it lies free in the abdominal cavity. It may be found in various positions in the abdomen, because of elongation of the fixation apparatus. The commonest position is on the Psoas muscle, and this position is even more common in men than in women. It is twice as often in the pelvis in women as in men—20 per cent. of cases in the former; 10 per cent. in the latter. As a rule, it is entirely enveloped on all sides by peritoneum, but in a certain number of cases (6 per cent., according to Berry) the peritoneal covering is not complete, so that a small portion of the upper end of the posterior surface is uncovered and connected to the iliac fascia by connective tissue. As a matter of fact, there is no real mesocaecum—meaning by the term a peritoneal fold which holds the caecum to the dorsal wall of the abdomen—except when there is failure in development. Originally the caecum receives its blood along a single peritoneal fold, the ileo-caecal fold, which is a simple mesentery. As development advances, this simple mesentery becomes a double fold and practically bloodless, and is replaced by two vascular folds, the mesoappendix to the left and the mesenterico-colic to the right. The mobility of the caecum varies. Very small caeca are fixed. In most cases the caecum lies quite free in the abdominal cavity and enjoys a considerable amount of movement. Sometimes it is excessively mobile, and in such cases is usually also of large size. Such mobility is due to a stretched fixation apparatus. A very large and mobile caecum may be made to come in contact with any abdominal viscus and may enter any hernial sac on either side. It is to be remembered that a mobile caecum carrying with it the appendix may pass to almost any region of the abdomen. Sometimes the caecum fails to descend or only descends a part of the way during development, the axial rotation of the intestinal tract having been arrested. In such a case it may terminate at the level of the gall-bladder, and the ascending colon is absent. In 310 adult males Robinson found 8 per cent. with undescended caecum and appendix. Nondescent is found in less than 4 per cent. of adult females. A partly descended caecum usually lies upon the right kidney.

The caecum varies in shape, but, according to Treves, in man it may be classified under one of four types (Fig. 926). In early foetal life it is short, conical, and broad at the base, with its apex turned upward and inward toward the ileo-caecal junction. It then resembles the caecum of some of the monkey tribe, e.g., Mangabey monkey. As the foetus grows the caecum increases in length more than in breadth, so that it forms a longer tube than in the primitive form and without the broad base, but with the same inclination inward of the apex toward the ileo-caecal junction. This form is seen in others of the monkey tribe, e.g., the spider monkey. As development goes on, the lower part of the tube ceases to grow and the upper part becomes greatly increased, so that at birth there is a narrow tube, the vermiform appendix, hanging from a conical projection, the caecum. This is the infantile form, and as it persists throughout life, in about 2 per cent. of cases, it is regarded by Treves as the first of his four types of human caeca. The caecum is conical and the appendix rises from its apex. The three longitudinal bands start from the appendix and are equidistant from each other. In the second type, the conical caecum has become quadrate by the growing out of a saccule on either side of the anterior longitudinal band. These saccules are of equal size, and the appendix arises from between them, instead of from the apex of a cone. This type is found in about 3 per cent. of cases. The third type is the normal type of man. Here the two saccules, which in the second type were uniform, have grown at unequal rates: the right with greater rapidity than the left. In consequence of this an apparently new apex has been formed by the growing downward of the right saccule, and the original apex, with the appendix attached, is pushed
over to the left toward the ileo-caecal junction. The three longitudinal bands still start from the base of the appendix, but they are now no longer equidistant from each other, because the right saccule has grown between the anterior and posterolateral bands, pushing them over to the left. This type occurs in about 90 per cent. of cases. The fourth type is merely an exaggerated condition of the third;

the right saccule is still larger, and at the same time the left saccule has been atrophied, so that the original apex of the caecum, with the appendix, is close to the ileo-caecal junction, and the anterior band courses inward to the same situation. This type is present in about 4 per cent. of cases.

Supports of the Caecum.—According to Robinson,¹ the caecum is maintained in position by the mesocolon and a peritoneal fold, the right phrenico-colic ligament, which arises from the hepato-duodenal and hepato-renal ligaments. It receives support from the connective tissue about vessels and nerves, and inconstantly from folds which fixes it in the iliac fossa and in the region of the precava.

The Interior of the Caecum.—In the interior of the caecum are seen depressions which correspond to the surface hastrae, and semilunar folds (plicae semilunares coli) (Fig. 925), which correspond to the transverse surface constrictions. There are three openings in the caecum: that into the colon; that into the ileum, which is guarded by the ileo-caecal valve (p. 1315); and that into the appendix, which may be guarded by the valve of Gerlach.

¹ St. Louis Courier of Medicine, October-December, 1902.
Pericaecal Folds and Fossae.—See p. 1272, and Figs. 879, 880, and 881.

The Vermiform Appendix (processus vermiformis) (Figs. 879, 880, 881, 926, 927, 928, 929, and 931).—The vermiform appendix is found only in man, the higher apes, and the wombat, although in certain rodents a somewhat similar arrangement exists. In carnivorous animals the caecum is very slightly developed; in herbivorous animals (with a simple stomach) it is, as a rule, extremely large. It has been suggested that the vermiform process in man is the degenerated remains of the herbivorous caecum, which has been replaced by the carnivorous form. 1 The vermiform appendix is a long, narrow, worm-shaped, musculo-membranous tube, which starts from what was originally the apex of the caecum. After development has advanced the vermiform appendix comes off, as a rule, from the inner side of the posterior wall of the caecum that is below and behind the termination of the ileum. This origin usually corresponds to McBurney's point, which is in the abdominal wall, midway between the umbilicus and the anterior superior iliac spine, and which is the usual seat of the greatest tenderness in appendicitis. The origin of the appendix varies with the type of caecum present. These variations are shown in Fig. 926. In the foetal or infantile type of appendix it arises from the apex of the caecum; in the second type of caecum it arises between the two caecal sacculi; in the third type it arises between a large outer and a small inner sacculus; and on the posterior wall of the caecum, the excessive growth of the anterior wall having caused the appendix to originate posteriorly; in the fourth type there is no internal sacculus, and the appendix arises from the posterior caecal wall behind the ileo-caecal junction (p. 1310). The movable portion of the appendix may be met with in different situations. It may pass upward and in front of the caecum and colon, upward and behind the caecum, and even behind the colon between the two layers of the mesocolon; upward and to the inner side, or upward and to the outer side of the caecum and colon. It may pass to the left under the ileum and mesentery, upward and to the left or downward and to the left into the true pelvis. It may pass directly downward under the caecum. It may pass to the right in front of or back of the caecum. It may occupy any one of the caecal fossae (p. 1272), but most often enters the ileo-caecal fossa. In unusual cases the appendix is found in the inguinal canal as a portion of or the sole contents of a hernia; adherent to the parietal peritoneum in front of or to the side of the caecum, or "behind the peritoneum, below the caecum, adherent to the under surface of the caecum and in contact with its muscular wall and covered by its peritoneal coat." 2 When the caecum is mobile the appendix may be found almost anywhere within the abdomen. When the caecum is undescended, the appendix of course shares in the failure to descend, and may be below the gall-bladder or in front of the right kidney, and may pass in several directions: upward behind the caecum; to the left behind the ileum and mesentery; or downward and inward into the true pelvis. It varies from one-half an inch to nine inches in length, its average being about three inches. Its diameter is from one-eighth inch to one-quarter inch. The operating surgeon may occasionally fail to find an appendix buried in one of the caecal fossae, and may conclude that the diverticulum is absent. As a matter of fact, unless the colon is also absent, it seems doubtful if the appendix is ever absent, except as a result of disease. This view is maintained by Lockwood and Rolleston, 3 by Kelynack, 4 and others. It is asserted by some that the appendix is absent 5 times out of 10,000 autopsies. It is retained in position by a fold of peritoneum derived from the left leaf of the mesentery, which forms a mesentery for it, and is called the meso-appendix (p. 1269, and Figs. 879, 880, and 881). In color the healthy appendix is

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1 Cunningham's Text-book of Anatomy.
2 Deaver's Surgical Anatomy.
4 A Contribution to the Pathology of the Vermiform Appendix.
yellowish-pink, is soft and smooth to the touch, and the "subperitoneal vessels are barely visible." The canal of the appendix is small and extends throughout the whole length of the tube. The walls of the healthy diverticulum are thick, and the diameter of the lumen is usually trivial as compared with the diameter of the appendix itself. The lumen of the appendix communicates with the caecum by an orifice which is placed below and behind the ileo-caecal opening (Fig. 932). It is sometimes guarded above and to the left side by a semilunar fold of mucous membrane, the valve of Gerlach (valvula processus vermiformis). The valve is inconstant, and is never perfect. It is stated that the appendix tends to undergo obliteration as an involution change in a functionless organ. The lumen rarely contains foreign bodies after death, but often contains fecal concretions. Certain it is that in 25 per cent. of necropsies upon adults or elderly people the lumen is found to be partially or completely occluded.

Structure of the Appendix (Fig. 930).—The coats of the appendix correspond to the coats of the bowel: serous, muscular (the outer layer of longitudinal, the inner of circular fibres), submucous, and mucous. In the deepest portion of the mucous coat, against the submucous coat, are the unstriated fibres constituting the muscularis mucosae. The muscularis mucosae is often present in some regions and absent in others. It may not be present at all.

The Outer or Serous Coat usually completely covers the appendix and has a definite mesentery, the mesoappendix (p. 1269). Occasionally the base of the appendix is not surrounded by peritoneum, but is extraperitoneal, lying in the retroperitoneal tissue. The appendiculο-ovarian ligament of Clado is occasionally present in females. It is a prolongation of the mesoappendix which passes into the broad ligament, and is extremely thin, and its fine connective-tissue fibres send prolongations into the longitudinal muscle-fibres of the appendix. Lockwood points out that the subperitoneal tissue of the meso-appendix and "the blood-vessels, nerves, and lymphatics which it contains are very intimately connected with the submucosa. This union takes place at certain large gaps in the muscular coats. These gaps serve for the transmission of blood-vessels, nerves, and lymphatics from the mesoappendix to the mucous coat. They are situated at the junction of the mesoappendix with the appendix."2

The Longitudinal Muscular Layer is thin and irregularly distributed, and in certain regions may be excessively thin or actually absent, and between the fibres are the blood-vessels, nerves, and lymphatics passing from the subperitoneal tissue to the mucous coat.

1 Appendicitis, its Pathology and Surgery. By Charles Barrett Lockwood.
2 Ibid.
The **Circular Fibres** are much better developed than the longitudinal fibres, and, according to Lockwood, the layer is 1 mm. thick. Large gaps are found here and there for the passage of vessels, lymphatics, and nerves to and from the meso-appendix and the mucous membrane, and a few vessels pierce the fibres at other points (Lockwood).

The **Submucous Coat** varies greatly in thickness. It contains blood-vessels, nerves, and lymphatics, and some lymphoid follicles.

The **Mucous Membrane** (Fig. 928) is covered by columnar epithelial cells and contains numerous solitary lymph-follicles, some glands of Lieberkühn, surrounded by lymphoid tissue, blood-vessels, lymphatics, and nerves.

The muscularis mucosae may be absent, may be scanty, or may be distinct. The **lymphoid follicles** are visible to the naked eye (Fig. 928). Some of them are in the sub-mucosa, some of them chiefly in the mucosa, the bases of the latter, however, being in the submucosa. Lockwood estimates that an appendix three and a half inches in length contains from 150 to 200 follicles.

**Blood-vessels of the Caecum and Appendix** (Figs. 927, 929, 945, and 946).—The **ileo-colic artery** in the ileo-colic angle gives off the **anterior** and **posterior ileo-caecal arteries**. The anterior ileo-caecal runs down over the front of the ileum and supplies the ileum, and sends off a terminal branch, the **anterior caecal artery**, which supplies the anterior surface of the caecum and of a portion of the ascending colon, and to the upper and lower margins of the ileo-caecal valve. It sends no branch to the appendix. The arteries of the appendix come from the **posterior ileo-caecal artery**. This vessel, after arising from the ileo-colic artery, passes back of the termination of the ileum and gives branches to the lower end of the ileum back of a portion of the ascending colon and to the lower margin of the ileo-caecal valve, where they anastomose with the valvular branches from the anterior ileo-caecal (Lockwood). From the posterior ileo-caecal comes the posterior caecal branch, which passes over the posterior and inner portion of the caecum near the base of the appendix and sends one or two branches to the appendix. The chief blood-supply of the appendix is the **appendicular artery**, which comes off the beginning of the posterior ileo-caecal or, occasionally, from the termination of the ileo-colic. If there is a distinct mesoappendix the largest branch of the artery passes along its free edge. If the mesoappendix is absent or rudimentary the artery usually lies upon the appendix from base to tip beneath the peritoneum.

Lockwood points out that the appendicular artery as it enters the mesoappendix divides into three branches. The largest branch runs along the free edge, and from this the tip of the appendix obtains its blood-supply; "the other two reach the appendix at intervals of half an inch." When the branches reach the appendix they divide and pass around it in the subperitoneal coat and send branches through the muscular gaps to enter and pass through the submucous coat.

In females there is occasionally some additional blood-supply through a branch of the **ovarian artery** in the appendiculoso-ovarian ligament.

The **veins** of the appendix are numerous, thin walled, and large. Veins from the submucous plexus pass through the muscular gaps and enter the subperi-
toneal plexus. Veins from the subperitoneal plexus pass into veins in the meso-
appendix which correspond to but do not really accompany the arteries (Lock-
wood). Most of the veins of the mesoappendix pass to the posterior ileo-caecal
vein, though some pass directly to the caecal vein. These veins are radicles of
the portal system.

![Diagram of arteries and veins of the caecum and vermiform appendix]

**Lymphatic System of the Caecum and Appendix** (Fig. 930).—Surrounding the base
of each lymph-follicle in the submucous tissue of the appendix is a lymph-space,
which Lockwood calls the *follicular* or *basilar lymph-sinus*. This sinus communic-
ates with the lymphatics of the submucous coat, "which again communicate
freely through the hiatus muscularis with those of the peritoneum and of the
mesoappendix." The collecting trunks from the caecum and appendix follow the

![Diagram of transverse section of the vermiform appendix]

blood-vessels (Fig. 931). The anterior collecting trunks of the caecum pass
through several small glands in the anterior ileo-caecal fold, and terminate in
glands along the ileo-colic artery (Fig. 931). The posterior collecting trunks pass
through some small glands and terminate in glands along the ileo-colic
artery. The appendicular collecting trunks enter the mesoappendix. There are
usually four of them, sometimes five. Some of them traverse a gland constantly
present at the ileo-caecal angle (Clado). Another gland is constant. It is situated
beneath the ileo-colic fossa (Lockwood and Rolleston). The editor subscribes to

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1 Appendicitis, its Pathology and Surgery. By Charles Barrett Lockwood.
Lockwood's statement that in appendicitis there is often a chain of inflamed glands along the inner side of the ascending colon behind the ascending mesocolon. Hence this is one road taken by the lymphatics of the appendix. The others pass to the mesenteric glands.

The Ileo-caecal Valve or the Valve of Bauhin (*valvula coli*) (Figs. 932, 933, 934, and 935).—The lower end of the ileum terminates by opening into the inner and back part of the large intestine, at the point of junction of the caecum with the colon. The opening is guarded by a valve, consisting of two semilunar segments, an upper or colic segment (*labium superius*) and a lower or caecal segment (*labium inferius*), which project into the lumen of the large intestine. The upper one, nearly horizontal in direction, is attached by its convex border to
the point of junction of the ileum with the colon; the lower segment which is more concave and longer, is attached to the point of junction of the ileum with the caecum. At each end of the aperture the two segments of the valve coalesce, and are continued as a narrow membranous ridge around the canal for a short distance. Each ridge is known as the retinaculum or frenulum of the valve (frenulum valvulae coli). The left or anterior end of the aperture is rounded; the right or posterior is narrow and pointed. In the formation of the valve the termination of the small intestine invaginates for a short distance into the lumen of the large intestine (Fig. 933), the invaginated portion of the wall of the small intestine uniting with a corresponding portion of the wall of the large intestine.

Each segment of the valve is formed by a reduplication of the mucous membrane and of the circular muscular fibres of the intestine, the longitudinal fibres and peritoneum being continued uninterruptedly across from one portion of the intestine to the other. When the longitudinal fibres and peritoneum are divided or removed, the ileum may be drawn outward, and all traces of the valve will be lost, the ileum appearing to open into the large intestine by a funnel-shaped orifice of large size.

The surface of each segment of the valve directed toward the ileum possesses villi, and presents the characteristic structure of the mucous membrane of the small intestine; while that turned toward the large intestine is destitute of villi, and marked with the orifices of the numerous tubular glands peculiar to the mucous membrane of the large intestine. These differences in structure continue as far as the free margins of the valve. When the caecum is distended it is supposed that the margins of the opening are approximated so as to prevent reflux into the ileum. It is known, however, that a very large enema which distends the caecum and colon may in part enter the ileum, being driven there by waves of reversed peristalsis. The valve resists, but a certain amount of pressure overcomes it. Some believe that the so-called ileo-caecal valve is not a valve, but a distinct sphincter. This has been demonstrated to be true in cats and dogs, but lacks demonstration in man (p. 1331).
The Colon.

The colon is divided into four parts—the ascending, transverse and descending colon, and the sigmoid flexure.

The Ascending Colon (colon ascendens).—The ascending colon is smaller than the caecum, with which it is continuous. It passes upward, from its commencement at the frenula of the caecum, opposite the ileo-caecal valve, to the under surface of the right lobe of the liver, on the right of the gall-bladder, where it is lodged in a shallow depression on the liver, the impressio colica; here it bends abruptly inward to the left, forming the hepatic flexure (flexura coli dextra). It is retained in contact with the posterior wall of the abdomen by the peritoneum, which covers its anterior surface and sides, its posterior surface being connected by loose areolar tissue with the Quadratus lumborum and Transversalis muscles, and with the front of the lower and outer part of the right kidney (Fig. 936). Sometimes the peritoneum almost completely invests it, and forms a distinct but short mesocolon1 (p. 1269). It is in relation, in front, with the convolutions of the ileum and the abdominal parietes.

The Transverse Colon (colon transversum) (Fig. 871).—The transverse colon, the longest part of the large intestine, passes transversely from right to left across the abdomen, opposite the confines of the epigastric and umbilical zones, into the left hypochondriac region, where it curves downward beneath the lower end of the spleen, forming the splenic flexure (flexura coli sinistra). In its course the transverse colon describes an arch, the concavity of which is directed backward toward the vertebral column and a little upward; hence the name transverse arch of the colon. This is the most movable part of the colon, being almost completely invested by peritoneum, and connected to the spine behind by a large and wide duplication of that membrane, the transverse mesocolon (Fig. 876). The transverse colon is in relation, by its upper surface with the liver and gall-bladder, the great curvature of the stomach, and the lower end of the spleen; by its under surface, with the small intestines; by its anterior surface, with the anterior layers of the great omentum and the abdominal parietes; its posterior surface on the right side is in relation with the second portion of the duodenum, and on the left side is in contact with some of the convolutions of the jejunum and ileum.

The Descending Colon (colon descendens).—The descending colon passes downward through the left hypochondriac and lumbar regions along the outer border of the left kidney. At the lower end of the kidney it turns inward toward the outer border of the Psoas muscle, along which it descends to the crest of the ilium, where it terminates in the sigmoid flexure. At its commencement it is connected with the Diaphragm by a fold of peritoneum, the phreno-colic ligament (see p. 1268). It is retained in position by the peritoneum, which covers its anterior surface and sides, its posterior surface being connected by areolar tissue with the outer border of the left kidney, and the Quadratus lumborum and Transversalis muscles (Fig. 876). It is smaller in calibre and more deeply placed than the ascending colon, and is more frequently covered with peritoneum on its posterior surface than the ascending colon (Treves).

The Sigmoid Flexure, Pelvic Colon or Sigmoid Colon (colon sigmoideum) (Figs. 937, 938, 939, and 940) is the narrowest part of the colon; it is situated in the left iliac fossa, commencing from the termination of the descending colon, at the margin of the crest of the ilium, and then forming a loop, which varies in length

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1 Treves states that after a careful examination of one hundred subjects, he found that in fifty-two there was neither an ascending nor a descending mesocolon. In twenty-two there was a descending mesocolon, but no corresponding fold on the left side. In fourteen subjects there was a mesocolon to both the ascending and the descending segments of the bowel; while in the remaining twelve there was an ascending mesocolon, but no corresponding fold on the left side. It follows, therefore, that in performing lumbar colostomy a mesocolon may be expected on the left side in 36 per cent. of all cases, and on the right in 26 per cent. (The Anatomy of the Intestinal Canal and Peritoneum in Man, 1885, p. 55.)—En. of 15th English edition.
and position, and which terminates in the rectum at the level of the attachment of the mesentery upon the front of the third sacral vertebra. It passes downward about two inches parallel to the outer border of the Psoas muscle, then taking a transverse direction enters the cavity of the pelvis, crosses this cavity from left to right and a little upward to the lower margin of the right iliac fossa; "from this

Fig. 936.—Diagram of the relations of the large intestine and kidneys, from behind.
point it passes downward, backward, and inward along the anterior surface of the sacrum to its junction with the rectum." ^1 

It is surrounded with the peritoneum and is attached to the posterior abdominal wall by the *mesosigmoid*, a continuation of the mesocolon, but which greatly exceeds the latter in length, hence the sigmoid is the most mobile portion of the large intestine. Tuttle divides the sigmoid into four portions. The *first* or *vertical portion*; the *second* or *transverse portion*; the *third portion*, which is a loop and is concave upward if the sigmoid occupies the pelvis, and is concave downward if it occupies the abdomen; the *fourth portion*, which is curved irregularly in the hollow of the sacrum, and which joins the rectum as often from the right as from the left. When the sigmoid is lifted up and to the right and the mesosigmoid is put slightly upon the stretch, an opening is seen at the parietal border of the left

layer of the mesosigmoid. This opening leads into a *cul-de-sac*, the *intersigmoid fossa*. When the sigmoid is empty most of it falls into the recto-vesical or recto-

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^1 Tuttle, Diseases of the Anus, Rectum, and Pelvic Colon.
vaginal space (Fig. 938). When distended it mounts up into the abdomen, reaching to or even above the umbilicus. The sigmoid flexure is in relation in front with the small intestine and abdominal parietes. The sigmoid mesocolon is attached to a line running downward and inward from the crest of the ilium, across the Psoas muscle (Fig. 876).

The Rectum (Intestinum Rectum) (Figs. 937, 938, 939, 940, 941, 942).

The rectum is the terminal part of the large intestine, and extends from the termination of the sigmoid flexure to the level of the semilunar valves of Mor-

![Diagram of the pelvis showing the rectum and related structures.](image)

**Fig. 939.—Sagittal section in the median line of the pelvis. (Poirier and Charpy.)**

gagni. The sigmoid flexure terminates at the level of the attachment of the mesentery in front of the third sacral vertebra. This definition is practical and useful. It was suggested by Sir Frederick Treves. "It gives to the organ definite limits; it separates the mobile from the immobile portion of the gut; it marks the line where the course of the blood-supply changes; it indicates the point where the three longitudinal muscular bands of the colon spread out and become more or less equally distributed around the gut; and, finally, it marks a point at which there is always a decided narrowing in calibre, indicating the juncture of the rectum with the pelvic colon." The old division added to this the so-called first part of the rectum, which we consider as part of the sigmoid colon. The rectum is divided into two portions, a superior and an inferior. The superior or sacrococcygeal portion of the rectum (flexura sacralis) curves downward with the concavity forward and upward in front of the sacrum and coccyx, and

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1 A Treatise on Diseases of the Anus, Rectum, and Pelvic Colon. By James P. Tuttle.
is continued as far as the apex of the prostate gland, about an inch in front of the tip of the coccyx. The inferior or prostatic portion (flexura perinealis) begins at this point. The bowel is directed downward and backward, being convex in front, and terminates at the beginning of the anus at the level of the semilunar valves of Morgagni. The inferior or prostatic portion of the rectum is described by Symington as the anal canal.

Curves of the Rectum.—It will be seen, therefore, that the rectum presents two antero-posterior curves: the first, with its convexity backward, is due to the conformation of the sacro-coccygeal column, and represents the arc of a circle, the centre of which is opposite the third sacral vertebra. The lower one has its convexity forward, and is angular. Its centre corresponds to a line drawn between the anterior parts of the ischiāl tuberosities. Two lateral curves are also described: the one to the right, opposite the junction of the third and fourth sacral vertebrae; the other to the left, opposite the sacro-coccygeal articulation. They are of little importance.

The adult rectum as here described has a length of from four to six inches in men, and from three and five-eighths to five and one-eighth inches in women. According to Tuttle the length of the rectum depends to some degree on the size of the subject, and is somewhat greater in the old than in the young. The prostatic portion is the narrowest portion of the rectum. The widest part of the rectum is the ampulla recti just above the anal canal (Figs. 939 and 940). The prostatic portion has no peritoneal investment whatever and includes the lower two inches of the superior portion of the rectum. When the rectum is empty it is a mere slit, the anterior and posterior walls being in contact. When distended it is "irregularly cylindrical" (Tuttle). At and above the level of the third sacral vertebra the gut is entirely surrounded by peritoneum, and there is a mesosigmoid. This is the mesorectum of those who describe the lower pelvic colon as the first part of the rectum. At the level
of the third sacral vertebra the true rectum begins, and the true rectum has no meso-
rectum. The rectum is covered in front and laterally by peritoneum at its upper part; 
gradually the peritoneum leaves its sides, and about an inch above the prostate is re-
lected from the anterior surface of the bowel on to the posterior wall of the bladder in 
the male, and the upper fifth of the posterior wall of the vagina in the female, forming 
the recto-vesical or recto-vaginal pouch (ex-
cavatio rectovesicalis and excavatio rectoute-
rina), as the case may be (Fig. 866). The 
balance of the rectum has no peritoneal cov-
ering. The level at which the peritoneum 
leaves the anterior wall of the rectum to be 
reflected on to the viscus in front of it is of 
considerable importance from a surgical 
point of view, in connection with removal of the lower part of the rectum. It is 
higher in the male than in the female. In the former the height of the recto-
vesical pouch is about three inches; that is to say, the height to which an ordinary 
index finger can reach from the anus. In the female the height of the recto-
vaginal pouch is about two and a quarter inches from the anal orifice.

The upper or sacro-coccygeal portion of the rectum is in relation, in front, in 
the male, with the recto-vesical pouch, the triangular portion of the base of the 
bladder, the vesiculæ seminales, and vasa deferentia, and more anteriorly with 
the under surface of the prostate. In the female, with the posterior wall of 
the vagina below, and the recto-vaginal pouch above, in which are some convolutions 
of the small intestine (Fig. 940). To the sides below the peritoneal reflections, 
the rectum is surrounded by cellular tissue in which on each side lie the lateral 
sacral artery and the bifurcated hypogastric plexus. This portion of the rectum is 
separated from the sacrum and coccyx by an interval, the retro-rectal space, which 
is filled with cellular tissue. The superior portion of the distended rectum is in con-
tact posteriorly and on each side with the sacral plexus, ganglia of the sympathetic, 
and the fascial origin of the pyramidalis muscle (Tuttle). The lower or prostatic 
portion in men is in relation anteriorly with the prostate gland and the membranous 
urethra; in women with the posterior wall of the vagina. The lower end of the 
rectum takes a backward turn, and the uro-genital organs turn forward; the inter-
vening space is called the perineum. In the female, the fibro-fatty and muscular 
tissue which occupies this space is called the perineal body. The prostatic portion 
of the rectum is invested by the Internal sphincter, supported by the Levatores 
ani muscles, and surrounded at its termination by the External sphincter; in the 
empty condition it presents the appearance of a longitudinal slit. Posteriorly 
the lower part of the rectum is in contact with cellular tissue, which separates it 
from the coccygeal gland and the coccyx.

Supports of the Rectum.—The rectum as it has been described in these pages is a 
fixed tube. The upper portion of the rectum is supported by “the inferior mesen-
teric arteries and the fibrous sheaths which surround them” (Tuttle); by the per-
itoneal folds which attach it to the sacrum; and by the peritoneal folds which pass 
in front to the bladder (plicæ rectovesicales), or to the uterus (plicæ rectouterinae), 
and laterally to the pelvis. The middle of the rectum receives some support 
from the lateral sacral arteries and their fibrous sheaths. The lower portion of the 
rectum is supported by the Levator ani, External sphincter, and Recto-coccygeus 
muscles.
Blood-vessels and Lymphatics of Rectum.—See pp. 1328 and 1329.

Nerves of Rectum.—See p. 1329.

Structure of Rectum.—See p. 1324.

![Diagram of Rectal Valves](image1)

**Fig. 942.**—The anal canal and lower part of the rectum in the foetus. *A,* aged four to five months; *B,* six months; *C,* nine months. In each the anal canal is distinctly marked off from the rectum proper; the columns of Morgagni and the rectal valves are distinct. (Cunningham.)

The Common Anal Canal (*pars analis recti*) (Figs. 942 and 943).—The anal canal is the third portion of the rectum of the older descriptions. It begins where the true rectum ends. This canal is the portion of the intestinal tract which

![Diagram of Rectal Canal](image2)

is below the distribution of genuine mucous membrane, and is just posterior to the middle of a line drawn from one tuberosity to the other. It lies between the true skin and the upper borders of the semilunar valves of Morgagni. When at rest it is a mere slit placed antero-posteriorly. The external opening of the anal canal is the **anus**. The skin about the anus is pigmented, is thrown into radiating folds by the contraction of the External sphincter muscle, and contains hairs, sebaceous glands, and sudoriparous glands (*glandulae circumanales*). Ascending into the canal, it alters its character and becomes muco-cutaneous, and true mucous membrane appears at the rectum proper. Back of the anus is a median cutaneous fold passing posterior to the coccyx and called the **anal raphé**. In front of the anus is a median fold which, in the female, passes forward and merges with the labia major and in the male continues into the raphé of the serotum. This is called the **perineal raphé**. The length of the anal canal is three-quarters to one inch. "Its circumference varies from 3 cm. (one and three-sixteenths inches) in normal condition to 15 cm. (five and five-sixteenths inches) in disease, following injury or vicious practices. The average anus will admit a cylinder of 65 mm. in circumference without rupturing the mucous membrane."

Relations of the Anal Canal.—It is surrounded by the external and internal sphincter muscles, and above by the Levatores ani. To each side is the ischio-rectal fossa containing fat. Between the anal canal and the coccyx is a collection of muscular fibres and connective tissue, the ano-coccygeal body of Symington. In front, in the male, is the bulb of the urethra and the base of the triangular ligament; in the female, is the perineal body, which separates the anus from the vagina. There are three layers in the wall of the anal canal:

1. The muco-cutaneous layer, which contains glands, blood-vessels, and numerous nerve-endings. The lower portion is covered with pavement-epithelium, but gradually there is a transition, and at the beginning of the rectum proper the epithelium is entirely columnar. The valves of Morgagni, the anal valves or the semi-lunar valves (Figs. 943 and 944) are in the upper portion of the anal canal between the lower ends of the columns of Morgagni (Figs. 943 and 944). Above the valves the canal is lined by transitional mucous membrane, below them by modified skin.

The ano-rectal line is not straight, but is irregularly dentated by trivial elevations, each of which is papilliform at its summit. According to Tuttle, these elevations number from five to eight. About one-fifth of an inch below the ano-rectal line is the depression known as Hilton's white line (annulus haemorrhoidalis) (Fig. 944). This line is somewhat indistinct to sight, but can always be felt with the finger. It marks the junction of the External with the Internal sphincter. Above Hilton's line are some mucous crypts and also dilatations produced by the internal haemorrhoidal plexus of veins (Fig. 944).

2. The fibro-cellular layer is beneath the mucous membrane. Above Hilton's line it is composed of cellular tissue; below it is a thin fascia-like layer which joins the superficial fascia.

The anal canal is surrounded by longitudinal fibres from the rectum, fibres from the Levator ani, the lower portion of the Internal sphincter, and particularly by the External sphincter.

Blood-vessels, Lymphatics, and Nerves of Anus.—See pp. 1328 and 1329.

Structure of Large Intestine (including the Rectum and Anal Canal).—The large intestine has four coats—serous, muscular, areolar or submucous and mucous.

The Serous Coat (tunica serosa).—The serous coat is derived from the peritoneum, and invests the different portions of the large intestine to a variable extent. The caecum is completely covered by the serous membrane, except in a small percentage of cases (5 or 6 per cent.), where a small portion of the upper end of the posterior surface is uncovered. The ascending and descending colon are usually covered only in front and at the sides; a variable amount of the posterior surface is uncovered. The transverse colon is almost completely invested, the parts corresponding to the attachment of the great omentum and transverse mesocolon being alone excepted. The sigmoid flexure is completely surrounded, except along the line to which the sigmoid mesocolon is attached. The upper two-thirds of the rectum is covered in front and laterally by the peritoneum, but not posteriorly, between the two posterior folds of peritoneum, the so-called mesorectum; later it is covered only on its anterior surface; and the lower portion is entirely devoid of any serous covering. In the course of the colon the peritoneal coat is thrown into a number of small pouches filled with fat, called appendices epiploicae. They are chiefly appended to the transverse colon, and are particularly numerous along the anterior band.

The Muscular Coat (tunica muscularis).—The muscular coat consists of an external longitudinal and an internal circular layer of muscular fibres.

The Longitudinal Fibres, although found to a certain extent all around the intestine, do not form a uniform layer over the whole surface of the large intestine. In the caecum and colon they are especially collected into three flat longitudinal bands or taeniae (taeniae coli) (Figs. 923 and 924), each being about
half an inch in width. These bands commence at the base of the vermiform appendix, which structure is surrounded by a uniform layer of longitudinal muscular fibres. The bands pass from the base of the appendix to the rectum. At this point they broaden, fuse, and surround the rectum. On the ascending, descending, and sigmoid colon the mesocolic band (taenia mesocolica) is posterior and internal; the omental band (taenia omentalis) is posterior and external; the free band (taenia libera) is anterior. On the transverse colon the taenia libera is inferior; the taenia mesocolica is posterior; the taenia omentalis is anterior and superior. These bands are one-sixth shorter than the other coats of the intestine to which they are applied, and serve to produce the sacculi (Fig. 924), which are characteristic of the caecum and colon; accordingly, when they are dissected off, the tube can be lengthened, and its sacculated character becomes lost. The sacculations are called haustra coli. There are three rows of the sacculations separated from each other by the longitudinal bands. These pouches are also subdivided by transverse furrows which correspond to concave folds of mucous membrane, called semilunar folds (plecae semilunares coli). In the sigmoid flexure the longitudinal fibres become more scattered; but upon its lower part, and around the rectum, they spread out and form a layer which completely encircles this portion of the gut, but is thicker on the anterior and posterior surfaces, where two accentuations exist, than on the lateral surfaces. In the rectum the external fibres of the longitudinal layer descend and are inserted into the fascia covering the Levator ani muscle. The middle fibres are mingled with descending fibres of the Levator ani and terminate by attachment to the rectal wall. The internal fibres descend between the External and Internal sphincter muscles and are inserted into the superficial fascia around the anal margin. The lower part of the rectum is surrounded by the Levator ani muscle (p. 453). In addition to the muscular fibres of the bowels, two bands of plain muscular tissue are to be noted. They arise from the front of the second and third cecocygeal vertebræ, and pass downward and forward to blend with the longitudinal muscular fibres on the posterior wall of the rectum. Each is known as the rectococygeal muscle (m. rectococygeus).

The Circular Fibres form a thin layer over the caecum and colon, being especially accumulated in the intervals between the sacculi. In the rectum the circular fibres constitute a thick coat at some portions of the circumference and a thinner coat at others. The circular fibres are thickened at every flexure. The thickenings only partly surround the gut, and hence are not to be considered as additional sphincters. Tuttle calls them the semicircular muscles of the rectum. These semi-circular muscles are opposite the insertion of Houston’s valves. At the lower end of the rectum the circular fibres become very numerous and constitute the Internal sphincter muscle (m. sphincter ani internus) (Fig. 943). Tuttle describes it as follows: “This muscle, composed of an aggregation of circular fibres, begins about 4 cm. above the anal margin, and gradually increases in thickness until it reaches the ano-rectal line, after which it thins out again and disappears about the middle of the anal canal. Its width from above downward averages 1 to 3 cm. (three-fifths of an inch to one and one-fifth inches). Its thickness is so variable that no accurate measurement can be given. Its lower fibres are below and within the grasp of the External sphincter, from which it is separated by a narrow zone of connective tissue. A depressed zone, not always perceptible to the eye, but appreciable by digital touch, marks the line of division between these two muscles.”

The Internal sphincter is an involuntary muscle. The external sphincter muscle is not a portion of the wall of the bowel. It is described on pages 450 and 451.

The Areolar Coat or Submucous Coat (tela submucosa).—The areolar or submucous coat connects the muscular and mucous layers closely together. This coat

is thicker, looser, and more elastic in the rectum than elsewhere. In this coat are
the blood-vessels, nerves, and lymphatics.

The Mucous Membrane (tunica mucosa).—The mucous membrane, in the caecum
and colon, is pale, smooth, destitute of villi, and raised into numerous crescentic
folds which correspond to the intervals between the sacculi. In the rectum it is
thicker, of a darker color, more vascular, and connected loosely to the muscular
coat, as in the oesophagus.

The rectum contains certain horizontal folds. Most of them disappear when
the gut is distended, but some of them do not disappear, but remain as distinct
folds with free crescentic edges. These permanent folds were first described by
Houston, of Dublin, and are known as rectal valves or Houston's valves (plicae
transversales recti) (Figs. 941 and 942). Each fold surrounds more than one-
third of the gut, and is composed of mucous membrane, submucous tissue, and
a layer from the circular muscular layer of the gut. There may be three, four, or
five of these folds. Three of them are constant. One is on the right rectal wall,
about the point of peritoneal reflection; another is on the left side, about one
inch above the margin of the anal canal. A third is on the rectal wall, either
toward the right or left, at the point where the rectum joins the front of the
sigmoid. These shelf-like valves are not perfectly flat, for on the superior surface
of each is a depression.

The borders of a valve are thinner than its base and are very flexible. These
valves support the mass of feaces as it descends, and give to it a rotary motion
(Tuttle). In the lower end of the rectum the mucous membrane forms longi-
tudinal folds known as the columns of Morgagni or the rectal columns (columnae
rectales [Morgagni]) (Figs. 943 and 944). There are from five to ten of these
folds, each of which is about one-half an inch long, and they contain longitudinal
muscle-fibres. They are most prominent when the sphincter contracts. The base
of each column helps to form the upper margin of the anal canal. The outer angle
of each below passes into a similiar valve. The grooves between the columns are
shallow above and deeper below, and end in the semilunar valves. The semilunar
valves, valves of Morgagni or anal valves (Figs. 943 and 944) are folds
which stretch from the base of one column to another, and form the anal pockets
or crypts of Morgagni (sinus rectales). These pockets are about 5 mm. in depth.
They are most marked pos'teriorly (Ball), but none exists in either the anterior

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**Fig. 944.—Inner wall of the lower end of the rectum and anus. On the right the mucous membrane has
been removed to show the dilatation of the veins and how they pass through the muscular wall to anastomose
with the external haemorrhoidal plexus. (Luschka.)**
or posterior commissure (Tuttle). Below the sinuses is the white line of Hilton (Fig. 944), which reaches to the region where hair and sebaceous glands appear.

As in the small intestine, the mucous membrane consists of a muscular layer, the muscularis mucosae (Fig. 948); of a quantity of retiform tissue in which the vessels ramify; of a basement-membrane and epithelium, which is of the columnar variety, and exactly resembles the epithelium found in the small intestine. In the rectum the epithelial cells are columnar; at the lower end of the tube, however, they begin to change into stratified polyhedrons and prisms. The mucous membrane of the large intestine presents for examination simple follicles and solitary glands.

The Simple Follicles, Intestinal Glands, Crypts or Glands of Lieberkühn (glandulae intestinales [Lieberkuhni]) (Fig. 948) are minute tubular prolongations of the mucous membrane arranged perpendicularly, side by side, over its entire surface; they are longer, more numerous, and are placed in much closer apposition than those of the small intestine; and they open by minute rounded orifices upon the surface, giving it a cribriform appearance.

The Solitary Glands (noduli lymphatici solitarii) (Fig. 948) in the large intestine are most abundant in the caecum and vermiform appendix, but are irregularly scattered also over the rest of the intestine. They are similar to those of the small intestine.

Vessels of the Large Intestine.—The arteries supplying the large intestine give off large branches, which ramify between the muscular coats supplying them, and, after dividing into small vessels in the submucous tissue, pass to the mucous membrane. The caecum, the appendix, and the ileo-caecal valve are supplied by the branches from the anastomotic loops between the right colic and ileo-colic branches of the superior mesenteric artery (Figs. 945 and 946). In males the sole blood-supply of the appendix is by the appendicular artery from the posterior ilio-caecal branch of the ileo-caecal artery (Fig. 946). In the female the appendix occasionally receives an additional vessel along the appendiculoo-ovarian ligament.
from the ovarian artery. The ascending colon is supplied by the right colic, and the transverse colon by the middle colic branch of the superior mesenteric. The descending colon is supplied by the left colic branch of the inferior mesenteric, and the sigmoid flexure by the sigmoid branches of the inferior mesenteric. The rectum (Fig. 947) is supplied mainly by the superior haemorrhoidal branch of the inferior mesenteric, but also at its lower end by the middle haemorrhoidal from the internal iliac, and the inferior haemorrhoidal from the pudic artery. The supe-

Fig. 946.—The arterial blood-supply of the anterior (ventral) surface of the caecum and appendix. A, ileocolic artery; B, caecal-appendicular artery; D, anterior caecal artery; F and G, appendicular artery. Note that the caecal and appendicular arteries anastomose by fine capillaries, both ventrally and dorsally; C, Iliac artery; 1, right colon; 2, external sacculus of caecum (to right of taeniae coli); 3, appendix; 4, Iliac, and 5, Psoas muscles. (Robinson.)
STRUCTURE OF THE LARGE INTESTINE AND RECTUM 1329

trunk, the superior haemorrhoidal vein, which empties into the inferior mesenteric branch of the portal vein. This arrangement is termed the haemorrhoidal plexus (Fig. 473); it communicates with the tributaries of the middle and inferior haemorrhoidal veins at its commencement, and thus a communication is established between the systemic and portal circulations. The inferior haemorrhoidal veins empty into the internal pudic veins, and the middle haemorrhoidal veins empty into the internal iliac veins.

The Lymphatics of the Large Intestine.—The lymphatics of the large intestine begin in the mucous membrane and form an extensive plexus in the submucosa. There are also lymphatics more deeply seated, beneath the simple follicles. Those from the ascending colon and transverse colon open into the glands within the mesocolon and behind the colon (mesocolic glands), from which glands trunks pass to the superior mesenteric glands. The lymphatics from the transverse colon join with lymph-vessels of the great omentum, and hence communicate with the lymphatics of the greater curvature of the stomach. The lymph from the descending colon, from the sigmoid and from the pelvic colon passes to the glands along the inferior mesenteric artery. The lymphatics of the rectum pass first to the rectal glands, which lie on the muscular coat of the rectum, next to the glands which lie back of the rectum along the superior haemorrhoidal artery, and finally to the sacral glands. Lymphatics from the skin of the anus pass with the lymphatics of the skin to the superficial inguinal glands. Lymphatics from the anus between the skin margin and Hilton's white line pass to the hypogastric glands.

The Nerves of the Anus and Rectum.—The nerves of the anus and rectum are derived from both the sympathetic and cerebro-spinal system. The chief supply of the rectum is from the mesenteric, sacral, and hypogastric plexuses of the sympathetic. It also obtains small branches from the third, fourth, and fifth sacral nerves. The lower part of the rectum is much more sensitive than the upper part. The muscles of the anus and rectum are supplied "from the intricate plexuses formed by the second, third, fourth, and fifth sacral nerves" (Tuttle).
External sphincter is supplied by nerves which contain motor, sensor, and sympathetic fibres. These nerves come from three sources. "Two filaments from the branches formed by the third, fourth, and fifth sacral nerves extend transversely across the ischio-rectal fossa and distribute themselves to the middle portion of the muscle and to the peri-anal cutaneous surface; a filament which comes off from the internal pudic just before its division into terminal branches supplies the anterior portion of the muscle, and is called the anterior sphincterian nerve; while a filament coming off from the fifth and sixth sacral nerves passes down into the hollow of the sacrum, between the Levator ani muscle and the rectococcygeus ligament, and finally reaches the posterior superficial surface of the External sphincter."1 The spinal centre for the nerves of the anus and rectum is opposite the first lumbar vertebra, and is in practically the same region as the centre for the genito-urinary organs.

**Fig. 948.—Minute structure of large intestine.**

**Movements and Innervation of the Intestines.**

**Movements.**—As the small intestine is devoid of any sphincter arrangement peristalsis cannot mix the food as it does in the pyloric portion of the stomach. The process by which the food is mixed with the secretions and is brought against the intestinal wall for absorption is called by Cannon "rhythmic segmentation." Rhythmic motions "mix the food and expose it to the mucosa without advancing it appreciatively along the canal."2 In this process constrictions occur in the circular fibres, with the result that a collection of stationary food is divided into a number of segments. In the middle of each segment constrictions appear and the earlier constrictions relax. Then the latter constrictions relax and the earlier reappear and so on until the food is thoroughly mixed with digestive secretions. Finally the food is driven on by peristalsis coming again to rest and being again subjected to "rhythmic segmentation." Cannon says that in the duodenum "rhythmic segmentation" lasts for several minutes, but in other parts of the intestine it may continue for half an hour or more, the food which is being subjected to it scarcely moving along the canal. It is probable that in man there are from seven to eight segmentations per minute in a given area. It is also probable that there is a sphincter action at the ileo-caecal opening.

Cannon divides the large intestine into two parts: a distal part, in which the material is hard and lumpy and is "advanced by rings of tonic contraction," and a proximal part, in which the material is soft. In this part "the common movements are waves of constriction running backward toward the caecum." The resistance of the valve or sphincter enables reversed peristalsis or antiperistalsis to mix the food. When more food enters from the small intestine, antiperistalsis ceases, tonic contraction of the caecum and proximal portion of the colon occurs, some of the food is merged into the transverse colon, and antiperistalsis again begins to act on what remains. The above facts have been observed in animals and are probably true in man.

**Innervation.**—The vagus fibres of the small intestine seem to excite contraction of the circular fibres after a brief preliminary period of inhibition.3 Some observers maintain that the

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2 Medical News, May 20, 1905.
3 Bayliss and Starling, Journal of Physiology, 1899.
Surgical Anatomy of the Intestines

Splanchnic fibres are inhibitory, but others claim that they are also motor. The local reflex of the small intestine is in Auerbach's plexus. Cannon quotes Bayliss and Starling to the effect that the pelvic visceral nerves to the large intestine, "arising like the vagus from the central nerve system, are augmentary nerves, whereas the supply from the sympathetic system is purely inhibitory in its action."

It is further contended that the pelvic visceral nerves are distributed to the distal colon only. "The region of antiperistalsis does not, therefore, receive motor impulses from the pelvic nerves."

**Surface Form.**—The coils of the small intestine occupy the front of the abdomen below the transverse colon, and are covered more or less completely by the great omentum. For the most part the coils of the jejunum occupy the left side of the abdominal cavity—i.e., the left lumbar and inguinal regions and the left half of the umbilical region—whilst the coils of the ileum are situated to the right, in the right lumbar and inguinal regions, in the right half of the umbilical region, and also in the hypogastric region. The caecum is situated in the right inguinal region. Its position varies slightly, but the mid-point of a line drawn from the anterior superior spinous process of the ilium to the symphysis pubis will about mark the middle of its lower border. It is comparatively superficial. From it the ascending colon passes upward through the right lumbar and hypochondriac regions, and becomes more deeply situated as it ascends to the hepatic flexure, which is deeply placed under cover of the liver. The transverse colon crosses the belly transversely on the confines of the umbilical and epigastric regions, its lower border being on a level slightly above the umbilicus, its upper border just below the greater curvature of the stomach. The splenic flexure of the colon is situated behind the stomach in the left hypochondrium, and is on a higher level than the hepatic flexure. The descending colon is deeply seated, passing down through the left hypochondriac and lumbar regions to the sigmoid flexure, which is situated in the left inguinal region, and which can be felt in thin persons, with relaxed abdominal walls, rolling under the fingers when empty, and when distended forming a distinct bulge. The usual position of the base of the vermiform appendix is indicated by a point on the cutaneous surface two inches from the anterior superior spinous process of the ilium, on a line drawn from this process to the umbilicus. This is known as *McBurney's point.* Another mode of defining the position of the base of the appendix is to draw a line between the anterior superior spines of the ilia and marking the point where this line intersects the right seminal line.

Upon introducing the finger into the rectum, the membranous portion of the urethra can be felt, if an instrument has been introduced into the bladder, exactly in the middle line; behind this the prostate gland can be recognized by its shape and hardness and any enlargement detected; behind the prostate the fluctuating wall of the bladder when full can be felt, and if thought desirable it can be tapped in this situation; on either side and behind the prostate the vesical seminales can be readily felt, especially if enlarged by tuberculous disease. Behind, the coccyx is to be felt, and on the mucous membrane one or two of Houston's folds. The ischiorectal fossae can be explored on either side, with a view to ascertaining the presence of deep-seated collections of pus. Finally, it will be noted that the finger is firmly gripped by the sphincter for about an inch up the bowel. By gradual dilatation of the sphincter, the whole hand can be introduced into the rectum so as to reach the descending colon. This method of exploration is not at the present day employed for diagnostic purposes.

**Surgical Anatomy.**—The small intestine is much exposed to injury, but, in consequence of its elasticity and the ease with which one fold glides over another, it is not so frequently ruptured as would otherwise be the case. Any part of the small intestine may be ruptured, but probably the most common situation is the transverse duodenum, on account of its being more fixed than other portions of the bowel, and because it is situated in front of the bodies of the vertebrae, so that if this portion of the intestine is struck a sharp blow, as from the kick of a horse, it is unable to glide out of the way, but is compressed against the bone and lacerated. Wounds of the intestine sometimes occur. If the wound is a small puncture, under, it is said, three lines in length, there may be no extravasation of the contents of the bowel. The mucous membrane becomes everted and perhaps plugs the little opening. The bowels, therefore, may be punctured with a fine capillary trocar, in cases of excessive distention of the intestine with gas, without much danger of extravasation. A longitudinal wound gaping more than a transverse wound, owing to the greater thickness of the circular muscular coat. In closing a wound of the intestine, use Lambert's inversion sutures, which bring the peritoneal surfaces in contact. Halsted showed us that these sutures must include the tough submucous coat. The portions of intestine which lie in the pelvis are inflamed in pelvic peritonitis and become embedded in adhesions. The portions of intestine which may be present are the termination of the ileum, the portion of small intestine with the largest mesentery (Treves), the rectum, and the pelvic colon. The small intestine, and most frequently the ileum, may become strangulated by internal bands, or through apertures, normal or abnormal. The bands may be formed in several different ways: they may be old peritoneal adhesions from previous attacks of peritonitis; or adherent omentum from the same cause; or the band may be formed by Meckel's diverticulum, which has contracted adhesions at its distal extremity; or the band may be the result of the abnormal attachment of some normal structure, as the adhesion of two appendices epiploicae, or an adherent vermiform appendix or...
Fallopian tube. Intussusception or invagination of the small intestine may take place in any part of the jejunum and ileum, but the most frequent situation is at the ileo-caecal valve, the valve forming the apex of the entering tube. This form may attain great size, and it is not uncommon in these cases to find the valve projecting from the anus. Stricture, the impaction of foreign bodies, and twisting of the gut (volvulus) may lead to intestinal obstruction. Volvulus is most common in the sigmoid flexure. Meckel's diverticulum may itself become twisted and strangulated.

Resection of a portion of the intestine may be required in cases of gangrenous gut; in cases of intussusception; for the removal of new growth in the bowel; in dealing with artificial anus; and in the treatment of cases of rupture. The operation is termed enterectomy, and is performed as follows: the abdomen having been opened and the amount of bowel requiring removal having been determined upon, the gut must be clamped on either side of this portion in order to prevent the escape of any of the contents of the bowel during the operation. The portion of bowel is then separated above and below by means of scissors. If the portion removed is small, it may be simply removed from the mesentery at its attachment and the bleeding vessels tied; but if it is large, it will be necessary to remove also a triangular piece of the mesentery, and having secured the vessels, suture the cut edges of this structure together. The surgeon then proceeds to unite the cut ends of the bowel together. He may do it by the operation termed end-to-end anastomosis. There are many ways of doing this, which may be divided into two classes: one, where the anastomosis is made by means of some mechanical appliance, such as Murphy's button, or one of the forms of decalcified bone bobbins; and the other, where the operation is performed by simply suturing the ends of the bowel in such a manner that the peritoneum covering the free divided ends of the bowel is brought into contact, so that speedy union may ensue.

In some cases after resection each open end of the gut is closed, the side of the terminal portion is sutured to the side of the initial portion, a fistula is made in each, and the suturing is completed so as to cause the two fistulae to correspond. A permanent side-to-side opening is thus made. Lateral anastomosis without resection may be practised between two pieces of intestine, in order to side-track an intervening portion, which is the seat of malignant disease or of an artificial anus. Complete exclusion of a portion of intestine is performed for irreremovable tumors or persistent fistulae of the large intestine. The intestine is cut through above and below the diseased area and the ends of the healthy gut are united to each other, or the larger end is closed, an opening is made into the side of the larger end and the smaller end is implanted in it (lateral implantation). The two ends of the excluded portion are fastened to the skin and are left open.

In ascites resulting from cirrhosis of the liver benefit occasionally follows the performance of Talma's operation (epiplenectomy). The abdomen is opened and the omentum is sutured to the anterior abdominal wall or in the abdominal wound in the hope of establishing a more free communication between the portal and systemic circulations, thus lowering portal pressure.

External hernia is considered on page 1333.

By the term internal hernia, we mean hernia into the foramen of Winslow, into the retro-duodenal fossa, into the retro-caecal fossa, or into the intersigmoid fossa. Such a hernia produces the symptoms of acute strangulation of the intestine.

In typhoid fever there is ulceration of Peyer's patches. One of these ulcers may perforate. The only chance for life is immediate laparotomy and closure of the perforation. This saves one-fifth, or possibly one-third, of the cases. The incision is made to expose the lower ileum, as in the vast majority of cases the perforation is in this portion of the gut.

Ulcer of the duodenum is more common than used to be thought. The portion of the duodenum between the pylorus and the bile papilla is about four inches in length, and is called by the Mayo brothers the vestibule of the duodenum. Here the acid gastric juice enters and may produce an ulcer. The portion of the duodenum below the vestibule is not liable to ulcer, because it is protected by the alkaline bile and pancreatic juice.

A duodenal ulcer may perforate a large duodenal vessel and cause death from hemorrhage, or may perforate the intestine and produce septic peritonitis. A perforated ulcer is treated by laparotomy and closure of the perforation. Occasionally ulceration of the duodenal glands (Curling's ulcer) may occur in cases of burns, but is not a very common complication.

The veriform appendix is very liable to become inflamed, the condition being known as appendicitis. This condition may be set up by a catarrhal inflammation arising in the appendix, or derived from the colon. It may remain catarrhal and then subside. It may become purulent or may be purulent from the beginning. Anything which lessens vital resistance makes the appendix a ready prey to bacteria. Among causes which lessen resistance are febrile concretions, twists of the mesoappendix cutting off the blood-supply, bruises inflicted by the Psoas muscle (Byron Robinson), blocking of the outlet of the appendix by catarrhal exudate, concretions, proliferated lymphoid tissue, or adhesions. Appendicitis may arise by the appendix becoming twisted, owing to the shortness of its mesentery, in consequence of distention of the caecum. As the result of inflammation, its blood-supply, which is mainly through one large artery running in the mesoappendix, becomes interfered with. Again, in rarer cases, the inflammation is set up by the impaction of a solid mass of feces or a foreign body in the appendix. The inflammation
Surgical Anatomy of the Intestines

may result in ulceration and perforation, or in gangrene of the appendix the appendix may be blocked and full of pus, or abscess may form outside of it (appendicular abscess). These conditions require prompt operative interference, and in cases of recurrent attacks of appendicitis it is advisable to remove this diverticulum between the attacks. In external hernia the ilium is the portion of the bowel most frequently herniated. When a part of the large intestine is involved, it is usually the cæcum, and this may occur even on the left side. In some few cases the vermiform appendix has been the part implicated in cases of strangulated hernia, and has given rise to serious symptoms of obstruction. The diameter of the large intestine gradually diminishes from the cæcum, which has the greatest diameter of any part of the bowel, to the point of junction of the sigmoid flexure with the rectum, at or a little below which point stricture most commonly occurs and diminishes in frequency as one proceeds upward to the cæcum. When distended by some obstruction low down, the outline of the large intestine can be defined throughout nearly the whole of its course—all, in fact, except the hepatic and splenic flexures, which are more deeply placed; the distention is most obvious in the two flanks and on the front of the abdomen just above the umbilicus. The cæcum, however, is that portion of the bowel which is, of all, most distended. It sometimes assumes enormous dimensions, and has been known to give way from the distention, causing fatal peritonitis. The hepatic flexure and the right extremity of the transverse colon are in close relationship with the liver, and abscess of this viscus sometimes bursts into the gut in this situation. The gall-bladder may become adherent to the colon, and gall-stones may find their way through into the gut, where they may become impacted or may be discharged per anum. The mobility of the sigmoid flexure renders it more liable to become the seat of a volvulus or twist than any other part of the intestine. It generally occurs in patients who have been the subjects of habitual constipation, and in whom, therefore, the mesosigmoid is elongated. The gut at this part being loaded with faeces, from its weight falls over the gut below, and so gives rise to the twist.

The surgical anatomy of the rectum is of considerable importance. There may be congenital malformation due to arrest or imperfect development. Thus, there may be no invagination of the epiblast, and consequently a complete absence of the anus; or the hind-gut may be imperfectly developed, and there may be an absence of the rectum, though the anus is developed; or the invagination of the epiblast may not communicate with the termination of the hind-gut from want of solution of continuity in the septum which in early fetal life exists between the two. The mucous membrane is thick and but loosely connected to the muscular coat beneath and thus favors prolapse, especially in children. The vessels of the rectum are arranged as mentioned above, longitudinally, and are contained in the loose cellular tissue between the mucous and muscular coats, and receive no support from surrounding tissues; and this favors varicosity. Moreover, the veins, after running upward in a longitudinal direction for about five inches in the submucous tissue, pierce the muscular coats, and are liable to become constricted at this point by the contraction of the muscular wall of the gut. In addition to this there are no valves in the superior hemorrhoidal veins, and the vessels of the rectum are placed in a dependent position, and are liable to be pressed upon and obstructed by hardened faeces. The anatomical arrangement, therefore, of the hemorrhoidal vessels explains the great tendency to the occurrence of piles. The presence of the Sphincter ani is of surgical importance, since it is the constant contraction of this muscle which prevents an ischio-rectal abscess from healing and tends to cause a fistula. Also, the reflex contraction of this muscle is the cause of the severe pain complained of in fissure of the anus. The relations of the peritoneum to the rectum are of importance in connection with the operation of removal of the lower end of the rectum for malignant disease. The membrane gradually leaves the rectum as it descends into the pelvis; first leaving its posterior surface, then the sides, and then the anterior surface to become reflected in the male on to the posterior wall of the bladder, forming the recto-vesical pouch, and in the female on to the posterior wall of the vagina, forming Douglas's pouch. The recto-vesical pouch of peritoneum extends to within three inches from the anus, so that it is not desirable to remove more than two and a half inches of the entire circumference of the bowel, for fear of the risk of opening the peritoneum. When, however, the disease is confined to the posterior surface of the rectum, or extends farther in this direction, a greater amount of the posterior wall of the gut may be removed, as the peritoneum does not extend on this surface to a lower level than five inches from the margin of the anus. The recto-vaginal or Douglas's pouch in the female extends somewhat lower than the recto-vesical pouch of the male, and therefore it is advisable to remove a less length of the tube in this sex. Of recent years, however, much more extensive operations have been done for the removal of cancer of the rectum, and in these the peritoneal cavity has necessarily been opened. If, in these cases, the opening is plugged with iodoform gauze until the operation is completed and then the edges of the wound in the peritoneum is accurately brought together with sutures, no evil result appears to follow. For cases of cancer of the rectum which are too low to be reached by abdominal section, and too high to be removed by the ordinary operation from below, Kraske has devised an operation which goes by his name. The patient is placed on his right side and an incision is made from the second sacral spine to the anus. The soft parts are now separated from the back of the left side of the sacrum as far as its left margin, and the greater and lesser sacro-sciatic liga-
ments are divided. A portion of the lateral mass of the sacrum, commencing on the left border at the level of the third posterior sacral foramen, and running downward and inward through the fourth foramen to the cornu, is now cut away with a chisel. The left side of the wound being now forcibly drawn outward, the whole of the rectum is brought into view, and the diseased portion can be removed, leaving the anal portions of the gut, if healthy. The two divided ends of the gut can perhaps then be approximated and sutured together. Kraske's operation is in many cases preceded by the performance of iliac colostomy. In cancer high up in the rectum removal of the growth through the abdomen is sometimes practised, the divided lower end of the rectum being sutured to the divided upper end (Weir's operation).

The colon frequently requires opening in cases of intestinal obstruction, and by some surgeons this operation is performed in cases of cancer of the rectum, as soon as the disease is recognized, in the hope that the rate of growth may be retarded by removing the irritation produced by the passage of fecal matter over the diseased surface. The operation of colostomy may be performed either in the inguinal or lumbar region; but inguinal colostomy (Maydl's operation) has at the present day superseded the lumbar operation. The main reason for preferring this operation is that a spur-shaped process can be formed which prevents any fecal matter finding its way past the artificial anus and becoming lodged on the diseased structures below. The sigmoid flexure being surrounded by peritoneum, a coil can be drawn out of the wound, and when it is opened transversely a spur is formed, and this prevents any fecal matter finding its way from the gut above the opening into that below. The operation is performed by making an incision two or three inches in length from a point one inch internal to the anterior superior spinous process of the ilium, parallel to Poupart's ligament. The various layers of abdominal muscles are cut through, and the peritoneum opened and sewed to the external skin. The sigmoid flexure is now sought for, and pulled out of the wound and fixed by pushing a glass bar through a slit in the mesocolon. The two parts of the loop are sutured together. The intestine is now sutured to the parietal peritoneum. The wound is dressed, and either immediately or between the second to the fourth day, according to the requirements of the case, the protruded coil of intestine is opened. It is opened transversely with the Paquelin cautery.

THE LIVER (HEPAR) (Figs. 949, 950, 951, 952).

The liver is the largest gland in the body, and is situated in the upper and right part of the abdominal cavity, occupying almost the whole of the right hypochondrium, the greater part of the epigastrium, and extending into the left hypochondrium as far as the mammary line. In the male it weighs from fifty to sixty ounces; in the female, from forty to fifty. It is relatively much larger in the foetus than in the adult, constituting, in the former, about one-eighteenth, and in the latter, about one-thirty-sixth of the entire body-weight. Its greatest transverse-
measurement is from eight to nine inches. Vertically, near its lateral or right surface, it measures about six or seven inches, while its greatest antero-posterior diameter is on a level with the upper end of the right kidney and is from four to five inches. Opposite the vertebral column its measurement from before backward is reduced to about three inches. Its consistence is that of a soft solid; it is,
however, friable and easily lacerated; its color is a dark reddish-brown, and its specific gravity is 1.05.

To obtain a correct idea of its shape, it must be hardened in situ, and it will then be seen to present the appearance of a wedge, the base of which is directed to the right and the thin edge toward the left. Symington describes its shape as that “of a right-angled triangular prism with the right angles rounded off.” It possesses five surfaces, viz., a superior, inferior, anterior, posterior, and a right lateral surface.

The superior and anterior surfaces are separated from each other by a thick rounded border, and are attached to the Diaphragm and anterior abdominal wall by a triangular or falciform fold of peritoneum, the suspensory or falciform ligament, which divides the liver into two unequal parts, termed the right and left lobes (Figs. 949, 953, and 954). Except along the line of attachment of this ligament to the liver, the superior and anterior surfaces are covered by peritoneum.

The Superior Area or Surface (facies superior) (Fig. 949).—The superior area or surface comprises a part of both lobes. Spalteholz considers as parts of the superior surface the right surface and the anterior surface. The superior surface is convex, and fits under the vault of the Diaphragm; its central part, however, presents a shallow depression, the cardiac depression (impressio cardiaca), which corresponds with the position of the heart on the upper surface of the Diaphragm. It is separated from the anterior, posterior, and lateral surfaces by thick, rounded borders. Its left extremity is continued into the under surface by a prominent sharp margin.

The Anterior Area or Surface.—The anterior area or surface is large and triangular in shape, comprising also a part of both lobes. It is directed forward, and the greater part of it is in contact with the Diaphragm, which separates it from the right lower ribs and their cartilages. In the middle line it lies behind the ensiform cartilage, to the left of which it is protected by the seventh and eighth left costal cartilages. In the angle between the diverging rib cartilages of opposite sides the anterior surface is in contact with the abdominal wall. It is continuous with the inferior surface by a sharp margin, and with the superior and lateral surfaces by thick rounded borders.

The Lateral Right Area or Surface (Figs. 949 and 951).—The lateral or right area or surface is convex from before backward and slightly so from above downward. It is directed toward the right side, forming the base of the wedge, and lies against the lateral portion of the Diaphragm, which separates it from the lower part of the left pleura and lung, outside which are the right costal arches from the seventh to the eleventh inclusive.

The Under or Visceral Area or Surface (facies inferior) (Figs. 951 and 952).—The under or visceral area or surface is uneven, concave, directed downward and backward and to the left, and is in relation with the stomach and duodenum, the hepatic flexure of the colon, and the right kidney. The surface is divided by a longitudinal fissure into a right and a left lobe, and is almost completely invested by peritoneum; the only parts where this covering is absent are where the gall-bladder is attached to the liver and at the transverse fissure, where the two layers of the lesser omentum are separated from each other by the blood-vessels and duct of the vices. The under surface of the left lobe presents to the right and near the centre a rounded eminence, the omental tuberosity (tuber omentale) (Fig. 951), which is in contact with the lesser omentum. It is surrounded by a broad depression, the gastric surface or impression (impressio gastrica), with which the stomach is in contact. Between the gall-bladder and the left lobe is the quadrate lobe. The quadrate lobe is bounded to the left by the umbilical fissure or the fissure of the umbilical vein (fossa venae umbilicus), which is the anterior portion of the longitudinal fissure and lodges the round ligament. The under surface of the right lobe is divided into two unequal portions by a fossa, which lodges the
gall-bladder and is called the fossa vesicalis (fossa-vesicae felleae); the portion to the left, the smaller of the two, is somewhat oblong in shape, its antero-posterior diameter being greater than its transverse. It is known as the quadrate lobe, and is in relation with the pyloric end of the stomach (impressio pylorica) and the first portion of the duodenum. The portion of the under surface of the right lobe to the right of the fossa vesicalis presents two shallow concave impressions, one situated behind the other, the two being separated by a ridge. The anterior of these two impressions, the colic impression (impressio colica), is produced by the hepatic flexure of the colon; the posterior, the renal impression (impressio renalis), is occupied by the upper end of the right kidney (Fig. 951). To the inner side of the latter impression is a third and slightly marked impression, lying between it and the neck of the gall-bladder. This is caused by the second portion of the duodenum, and is known as the duodenal impression (impressio duodenalis). Just in front of the postcava is a narrow strip of liver tissue, the caudate lobe, which connects the right inferior angle of the Spigelian lobe to the under surface of the right lobe. Immediately below it is the fornmen of Winslow.

The Posterior Area or Surface (facies posterior) (Figs. 950 and 952).—The posterior area or surface is rounded and broad behind the right lobe, but narrow on the left. Over a large part of its extent it is not covered by peritoneum; this uncovered area (Fig. 951) is about three inches broad, and is in direct contact with the Diaphragm, being united to it by areolar tissue. In this tissue are numerous small veins which join the portal circulation to the systemic circulation. The uncovered area is marked off from the upper surface by the line of reflection of the upper or anterior layer of the coronary ligament. It is in the same way marked off from the under surface of the liver by the line of reflection of the lower layer of the coronary ligament (Fig. 953). In its centre the posterior surface is deeply notched for the vertebral column and crura of the Diaphragm, and to the right of this is indented for the postcava, which is often partly embedded in its substance. Close to the right of this indentation and immediately above the renal impression is a small triangular depressed area, the suprarenal impression (impressio suprarenalis) (Fig. 951), the greater part of which is devoid of peritoneum; it lodges the right suprarenal capsule, which is inserted between the liver and Diaphragm. To the left of the fossa for the postcava is the Spigelian lobe, which lies between the fissure for the postcava and the fissure for the ductus venosus. Below and in front it projects and forms part of the posterior boundary of the transverse fissure. Here, to the right, it is connected with the under surface of the right lobe of the liver by the caudate lobe, and to the left it presents a tubercle, the tuberculum papillare (Fig. 951). It is opposite the tenth and eleventh thoracic vertebrae, and rests upon the aorta and crura of the Diaphragm, being covered by the peritoneum of the lesser sac. The lobe is nearly vertical in position, and is directed backward; it is longer from above downward than from side to side, and is somewhat concave in the transverse direction. On the posterior surface to the left of the Spigelian lobe is a groove, the oesophageal groove (impressio oesophagea), indicating the position of the abdominal portion of the oesophagus (Fig. 951).

Prof. Cunningham divides the liver into two surfaces, a visceral and a parietal, and subdivides the parietal surface into a posterior area and superior area, an anterior area and a right area. The parietal surface is separated from the visceral surface by the inferior border or margin.

The inferior border or margin (margo inferioris), posteriorly, is rather ill defined. It is the lower margin of the posterior surface; it follows the line of rib and is in contact with the right kidney. At the right side the lower margin is thick and distinct, and, as a rule, projects slightly below the thorax. The front of the inferior margin is called the anterior margin (margo anterior). It is a sharp edge which, on inspiration, corresponds to an oblique line on the abdominal wall.
THE ORGANS OF DIGESTION

drawn from “a point half an inch below the margin of the ribs (tip of tenth costal cartilage), on the right side, to a point an inch below the nipple on the left, and extending down in the middle line to a point half-way between the gladiolus and the umbilicus.”

In men the anterior margin of the liver often corresponds to the lower margin of the ribs, but in women and children it is usually below the ribs in the line indicated above. Opposite the attachment of the falciform ligament the anterior border often exhibits a deep notch, the umbilical notch (incisura umbilicalis), which is the anterior end of the fossa venae umbilicalis. Another notch, sometimes present, corresponds to the fundus of the gall-bladder, and is known as the notch of the gall-bladder (incisura vesicae felleae).

The left extremity of the inferior margin of the liver is thin and flattened from above downward. The margin passes posteriorly around the free end of the left lobe and terminates posteriorly at the oesophageal groove.

Fissures.—Five fissures are seen upon the under and posterior surfaces of the liver, which serve to divide it into five lobes. They are: the umbilical fissure, the fissure of the ductus venosus, the transverse fissure, the fissure for the gall-bladder, and the fissure for the postcava. They are arranged in the form of the letter H. The left limb of the H is known as the longitudinal fissure. The right limb is formed in front by the fissure for the gall-bladder, and behind by the fissure for the postcava; these two fissures are separated from each other by the caudate lobe. The connecting bar of the H is the transverse or portal fissure. It separates the quadrato lobe in front from the caudate and Spigelian lobes behind.

The Longitudinal Fossa or Fissure (fossa longitudinalis sinistra).—The longitudinal fissure is a deep groove, which extends from the notch on the anterior margin of the liver to the upper border of the posterior surface of the organ. It separates the right and left lobes; the transverse fissure (Fig. 951) joins it, at right angles, and divides it into two parts. The anterior part is called the umbilical fossa or fissure (fossa venae umbilicalis) (Fig. 951); it is deeper than the posterior, and lodges the umbilical vein in the foetus, and its remains (the round ligament) in the adult; the posterior part contains the ductus venosus, and is known as the fissure of the ductus venosus. This fissure lies between the quadrate lobe and the left lobe of the liver, and is often partially bridged over by prolongation of the hepatic substance, the pons hepatis.

1 Ambrose Birmingham, in Cunningham’s Text-book of Anatomy.
The Fissure or Fossa of the Ductus Venosus (fossa ductus venosi) (Fig. 951) is the back part of the longitudinal fissure, and is situated mainly on the posterior surface of the liver. It lies between the left lobe and the lobe of Spigelius. It lodges in the foetus the ductus venosus, and in the adult a slender fibrous cord, the obliterated remains of that vessel.

The Transverse or Portal Fissure (porta hepatis) (Fig. 951).—The transverse or portal fissure is a short but deep fissure, about two inches in length, extending transversely across the under surface of the left portion of the right lobe, nearer to its posterior surface than its anterior border. It joins, nearly at right angles, with the longitudinal fissure, and separates the quadrate lobe in front from the caudate and Spigelian lobes behind. By the older anatomists this fissure was considered the gateway (porta) of the liver; hence the large vein which enters at this fissure was called the portal vein (Fig. 952). Besides this vein, the fissure transmits the hepatic artery and nerves, and the hepatic duct and lymphatics. At their entrance into the fissure, the hepatic duct lies in front and to the right, the hepatic artery to the left, and the portal vein behind and between the duct and artery.

The Fossa or Fissure for the Gall-bladder (fossa vesicae felleae).—The fossa or fissure for the gall-bladder is a shallow, oblong fossa, placed on the under surface of the right lobe, parallel with the longitudinal fissure. It extends from the anterior free margin of the liver, which is notched for its reception, to the right extremity of the transverse fissure.

The Fissure or Fossa for the Postcava (fossa venae cavae) (Fig. 951).—The fissure or fossa for the postcava is a short, deep fissure, in some cases a complete canal, in consequence of the substance of the liver occasionally surrounding the postcava. It extends obliquely upward from the lobus caudatus, which separates it from the transverse fissure, on the posterior surface of the liver, and separates the Spigelian from the right lobe. On slitting open the postcava the orifices of the hepatic veins will be seen opening into this vessel at its upper part, after perforating the floor of this fissure.

Lobes.—The lobes of the liver, like the ligaments and fissures, are five in number—the right lobe, the left lobe, the lobus quadratus, the lobus Spigelli, and the lobus caudatus, the last three being merely parts of the right lobe.
The Right Lobe (lobus hepatis dexter) (Figs. 949 and 951).—The right lobe is much larger than the left; the proportion between them being as six to one. It occupies the right hypochondrium, and is separated from the left lobe, on its upper and anterior surfaces by the falciform ligament; on its under and posterior surfaces by the longitudinal fissure; and in front by the umbilical notch. It is of a somewhat quadrilateral form, its under and posterior surfaces being marked by three fissures—the transverse fissure, the fissure for the gall-bladder, and the fissure for the postcava, which separate its left part into three smaller lobes—the lobus Spigelii, lobus quadratus, and lobus caudatus. On it are seen four shallow impressions: one in front, for the hepatic flexure of the colon; a second behind, for the right kidney; a third internal, between the last-named and the gall-bladder, for the second part of the duodenum; and a fourth on its posterior surface, for the suprarenal capsule.

The Lobus Quadratus or Square Lobe (Figs. 951 and 952) is situated on the under surface of the right lobe, is bounded in front by the inferior margin of the liver; behind, by the transverse fissure; on the right, by the fissure of the gall-bladder; on the left, by the umbilical fissure.

The Lobus Spigelii (lobus caudatus [Spigelii]) (Figs. 951 and 952) is situated upon the posterior surface of the right lobe of the liver. It looks directly backward, and is nearly vertical in direction. It is bounded, above, by the upper layer of the coronary ligament; below, by the transverse fissure; on the right, by the fissure for the postcava; and on the left, by the fissure for the ductus venosus. Its left upper angle forms part of the groove for the oesophagus. What is here called the lobus Spigelii, Spalteholz calls the lobus caudatus of Spigelius.

The Lobus Caudatus or Tuberculum Caudatum (processus caudatus) (Fig. 951), or tailed lobe, is a small elevation of the hepatic substance extending obliquely outward, from the lower extremity of the Spigelian lobe to the under surface of the right lobe. It is situated behind the transverse fissure, and separates the fissure for the gall-bladder from the commencement of the fissure for the postcava. What is here called the lobus caudatus, Spalteholz calls the processus caudatus of the lobus caudatus of Spigelius.

The Left Lobe (lobus hepatis sinister) (Figs. 949 and 951).—The left lobe is smaller and more flattened than the right. It is situated in the epigastric and left hypochondriac regions. Its upper surface is slightly convex; its under surface is concave, and presents a shallow depression for the stomach, the gastric impression. This is situated in front of the groove for the oesophagus, and is separated from the longitudinal fissure by the omental tuberosity, which lies against the small omentum and lesser curvature of the stomach. The posterior end of the left lobe frequently exhibits a flat projection, composed of connective tissue, and called the appendix fibrosus hepatitis. In the adult, portions only of bile-duets are present in it. In the newborn it is a definite portion of secreting liver substance, which later undergoes connective-tissue transformation.

Ligaments.—The liver is connected to the under surface of the Diaphragm and the anterior walls of the abdomen and the postcava by six ligaments, four of which are peritoneal folds; the other two, which are the round ligament and the ligament of the ductus venosus, are fibrous cords, resulting from the obliteration of foetal vessels. These ligaments are the falciform, two lateral, coronary, round, and the ligament of the ductus venosus. It is also attached to the lesser curvature of the stomach by the gastro-hepatic or small omentum.

The Falciform, Broad or Suspensory Ligament (ligamentum falciforme hepatitis) (Figs. 949, 953, and 954).—The falciform or suspensory ligament is a broad and thin antero-posterior peritoneal fold, falciform in shape, its base being directed downward and backward, its apex upward and backward. It is attached by one margin to the under surface of the Diaphragm, and the posterior surface of the
sheath of the right Rectus muscle to within one inch of the umbilicus; by its hepatic margin it extends from the notch on the anterior margin of the liver, as far back as its posterior surface.

The free edge or base of the falciform ligament reaches from a little above and to the right of the umbilicus to the umbilical fissure on the anterior margin of the liver. This free edge contains between its folds the round ligament of the liver. On the posterior surface of the liver the two peritoneal folds which constitute the falciform ligament separate, the right fold passing into the upper fold of the coronary ligament, the left fold passing into the upper fold of the left lateral ligament.

The Lateral Ligaments (Figs. 949 and 953).—The lateral ligaments are two in number, and are called the right and left lateral ligaments.

The Right Lateral Ligament (ligamentum triangulare dextrum) (Figs. 949 and 953) is in reality the right extremity of the coronary ligament. This ligament is triangular in form, runs from the liver to the Diaphragm, and is formed by the apposition of the upper and lower layers of the coronary ligament. It is attached to the liver between its lateral and inferior surfaces.

The Left Lateral Ligament (ligamentum triangulare sinistrum) (Figs. 949 and 953) is also formed by apposition of the upper and lower layers of the coronary ligament. It is triangular in form, runs from the liver to the Diaphragm, and is longer than the right lateral ligament. It is attached to the upper surface of the left lobe, where it lies, in front of the oesophageal opening in the Diaphragm.

The Coronary Ligament (ligamentum coronarium hepatitis) (Figs. 949 and 953).—The coronary ligament connects the posterior surface of the liver to the Diaphragm. It is formed by the reflection of the peritoneum from the Diaphragm on to the upper and lower margins of the posterior surface of the liver. The coronary ligament consists of two layers, which are continuous on each side with the lateral ligaments, and, in front, with the falciform ligament. Between the layers a large triangular area is left uncovered by peritoneum, and is connected to the Diaphragm by firm areolar tissue.
The Round Ligament (ligamentum teres hepatis) (Figs. 952 and 954).—The round ligament is a fibrous cord resulting from the obliteration of the foetal umbilical vein. It ascends from the umbilicus, in the free margin of the falciform ligament, to the notch in the anterior border of the liver, from which it may be traced along the umbilical fissure on the under surface of the liver, to the left branch of the portal vein.

The Ligament of the Ductus Venosus (ligamentum venosum [Arantii]) is composed of slender bundles of fibrous tissue, and results from the obliteration of the ductus venosus of the foetus. It arises from the left branch of the portal vein, almost opposite the insertion of the round ligament, passes backward in the fissure of the ductus venosus, and, as it emerges from the liver, is attached to the postcava.

Support and Movability of the Liver.—The liver is movable within certain narrow limits. It moves with respiration. On inspiration it moves down with the Diaphragm to distinctly below the costal arch in the right nipple line. Much discussion has taken place as to what supports the liver in place. Symington asserted that the ligaments do not give support, because they lie relaxed. Other observers (Graham, Steele) apparently demonstrate that the peritoneal ligaments do give some support to the liver. The connective tissue which unites the uncovered area of the right lobe of the liver to the Diaphragm and the hepatic veins which join the postcava (Faure) do give distinct support. The chief factor in the support of the liver is the intra-abdominal pressure resulting from the tonic contraction of the abdominal muscles. When abdominal tension is normal the intestines are driven up and become a bed for the liver. Intrahepatic vascular tension aids in supporting the liver (Glénard).

Abnormalities of the Liver.—The liver may be divided into many lobules, and such lobulation is most evident on the parietal surface of the right lobe. Lobulation is probably a pathological change. Occasionally the right lobe is small and the left large.

The editor, in performing an abdominal operation, encountered a liver the left lobe of which was so large and the right so small as to suggest transposition or rotation of the organ. Such a change may result from abnormality of the foetal circulation or from syphilitic disease of the right lobe, producing cicatricial contraction. The left lobe may be very small; sometimes it is rudimentary. When the left lobe is very small an unusual amount of stomach is visible, and the entire gall-bladder can be seen from the front. In such a case the gall-bladder is usually displaced and it may actually "lie with its long axis in the transverse axis of the body."

Atrophy of the left lobe is usually a congenital defect, but may result from syphilis. Small accessory lobes, about one inch in length, are not uncommon, and they are most often met with on the visceral surface of the right lobe. "When markedly pedunculated, they may form accessory livers. The Spigelian lobe is sometimes curiously pedunculated."

Accessory livers are fragments of hepatic tissue or rests, which are entirely separated from the liver. They are seldom met with. When they do exist their most common situation is in the suspensory ligament, but they have been found in the great omentum, in the peritoneum, wall of the gall-bladder, and in other situations. They may be congenital or may be due to atrophy of the pedicle of an accessory lobe or of a pedunculated lobe. Tight lacing alters the shape and position of the liver (Fig. 955). It may flatten the dome and increase the length of the anterior surface, this change being especially obvious in the right lobe, and a costal groove may be formed by the pressure of a rib. "When the elongated right lobe passes over the right kidney, there is atrophy of the hepatic substance.

1 H. D. Rolleston on Diseases of the Liver.
2 Ibid.
3 Ibid.
and thickening of the capsule, which is opaque and forms a hinge-like ligament between the main part of the right lobe above and the constricted lower portion. This lobe is variously termed partial hepatoptosis, constriction lobe, or the sustentacular formation of the right lobe (Hertz). The constriction furrow is produced by the pressure of the corset in front and the resistance of the kidney behind. The constriction lobe tapers to a point, so that the shape of the liver, as seen from the front, is that of a right-angled triangle, with the apex downward.  

The condition resembles Riedel's lobe. The left lobe may also project down, but not so markedly. Tight lacing may cause the entire organ to occupy a level higher than normal. Such a liver is thick and excessively convex above and thin below, and reaches to or laps over the spleen. In severe cases the superior surface is thrown into antero-posterior creases or folds. Linguiform or tongue-like lobe, Riedel's lobe or floating lobe (Fig. 955), may be congenital, may be due to tight lacing, or may arise in cholelithiasis or cholecystitis from the traction of adhesions. Such a lobe comes off from the right lobe. It may be a tapering mass of liver tissue, it may have a thin pedicle of liver tissue, or its pedicle may be merely a double fold of peritoneum. The gall-bladder may lie upon its under surface, or may be placed to the left of it.

**Vessels.**—The blood-vessels connected with the liver are the hepatic artery, the portal vein and the hepatic veins.

The Hepatic Artery and Portal Vein (Figs. 421, 422, 488, and 957), accompanied by numerous lymphatics and nerves, ascend to the transverse fissure between the layers of the gastro-hepatic omentum, and in front of the foramen of Winslow. The hepatic duct, lying in company with them, descends from the transverse fissure between the layers of the same omentum. The relative position of the three structures in the lesser omentum (Fig. 872) is as follows: the hepatic duct lies to the right, the hepatic artery to the left, and the portal vein behind and between the other two. They enter the transverse fissure in the above-described order, but in that fissure undergo rearrangement, the duct being in front, the artery in the

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1 Rolleston, on Diseases of the Liver.
middle, and the vein behind. The artery, the vein, and the duct divide into a right and left branch and several smaller branches, and within the organ the vessels from the three sources accompany each other and divide at the same points; so each branch of the portal vein is accompanied by a branch of the hepatic artery and of the duct. They are enveloped in a loose areolar tissue, the capsule of Glisson (Fig. 956), which accompanies the vessels in their course through the portal canals in the interior of the organ.

The Hepatic Veins (Fig. 424).—The hepatic veins convey the blood from the liver. They commence in the substance of the liver, in the capillary terminations of the portal vein and hepatic artery; these tributaries, gradually uniting, usually form three veins, which converge toward the posterior surface of the liver and open into the portion of the postcava situated in the groove at the back part of this organ. Of these three veins, one from the right and another from the left lobe open obliquely into the postcava; that from the middle of the organ and lobus Spigeli having a straight course.

The hepatic veins have very little cellular investment; what there is binds their parietes closely to the walls of the canals through which they run; so that, on section of the organ, these veins remain widely open and solitary (Fig. 959), and may be easily distinguished from the branches of the portal vein (Fig. 960),
which are more or less collapsed, and always accompanied by an artery and duct, the hepatic veins are destitute of valves.

**Structure.**—The substance of the liver is composed of lobules held together by extremely fine areolar tissue, and of the ramifications of the portal vein, hepatic duct, hepatic artery, hepatic veins, lymphatics, and nerves, the whole being invested by a serous and a fibrous coat.

**The Serous Coat (tunica serosa).**—The serous coat is derived from the peritoneum, and invests the greater part of the surface of the organ. It is intimately adherent to the fibrous coat.

**The Areolar or Fibrous Coat (capsula fibrosa [Glissoni]).**—The areolar or fibrous coat lies beneath the serous investment and covers the entire surface of the organ. It is difficult of demonstration, excepting where the serous coat is deficient. At the transverse fissure it is thick and evident, is known as the capsule of Glisson, and envelops the vessels which enter the liver and passes with them along the portal canals. The areolar tissue which surrounds and binds together the liver lobules is continuous with the areolar coat.

**The Lobules (lobuli hepatitis) (Fig. 962).**—The lobules form the chief mass of the hepatic substance; they may be seen either on the surface of the organ or by making a section through the gland. They are small granular bodies about the size of a millet-seed, measuring from one-twentieth to one-tenth of an inch in diameter. In the human subject their outline is very irregular, but in some of the lower animals (for example, the pig) they are well defined, and when divided transversely have a polygonal outline. If divided longitudinally they are more or less foliated or oblong. The bases of the lobules are clustered around the smallest radicles of the hepatic veins (sublobular veins), to which each is connected by means of a small branch which issues from the centre of the lobule (intralobular vein). The remaining part of the surface of each lobule is imperfectly isolated from the surrounding lobules by a thin stratum of areolar tissue in which are ducts and a plexus of vessels, the interlobular plexus (Figs. 961 and 962). In some animals, as the pig, the lobules are completely isolated one from another by this interlobular areolar tissue.

If one of the sublobular veins be laid open, the bases of the lobules may be seen through the thin wall of the vein on which they rest, arranged in the form of a tessellated pavement, the centre of each polygonal space presenting a minute aperture, the mouth of an intralobular vein (Fig. 959).

**Microscopic Appearance.**—Each lobule is composed of a mass of cells, hepatic cells (Fig. 958), surrounded by a dense capillary plexus, composed of vessels which penetrate from the circumference to the centre of the lobule, and terminate in a single straight central vein, which runs through its centre, to open at its base into one of the radicles of the hepatic vein. Between the cells are also the minute commencements of the bile-ducts. Therefore in the lobule we have all the essentials of a secreting gland; that is to say: (1) cells, by which the secretion is formed; (2) blood-vessels, in close relation with the cells, containing the blood from which the secretion is derived; and (3) ducts, by which the secretion, when formed, is carried away. Each of these structures will have to be further considered.
(1) The \textbf{Hepatic Cells} are epithelial in nature and of more or less spheroidal form, but may be rounded, flattened, or many-sided from mutual compression. They vary in size from the \(\frac{1}{1000}\) to the \(\frac{1}{2000}\) of an inch in diameter. They consist of a honeycomb network (Klein) without any cell-wall, and contain one or sometimes two distinct nuclei. In the nucleus is a highly refracting nucleolus with granules. Embedded in the honeycomb network are numerous yellow particles, the coloring matter of the bile, and oil-globules. The cells adhere together by their surfaces so as to form rows, which radiate from the centre to the circumference of the lobules.\(^1\) As stated above, they are the chief agents in the secretion of the bile.

(2) \textbf{The Blood-vessels}.—The blood in the capillary plexus around the liver-cells is brought to the liver principally by the portal vein, but also to a certain extent by the hepatic artery. For the sake of clearness the distribution of the blood derived from the hepatic artery may be considered first.

The \textbf{Hepatic Artery}, entering the liver at the transverse fissure with the portal vein and hepatic duct, ramifies with these vessels through the portal canals. It gives off \textit{vaginal branches} which ramify in the capsule of Glisson, and appear to be destined chiefly for the nutrition of the coats of the large vessels, the ducts, and the investing membranes of the liver. It also gives off \textit{capsular branches} which reach the surface of the organ, terminating in the fibrous coat in stellate plexuses. Finally it gives off \textit{interlobular branches} (\textit{rami arteriosi interlobulares}) which form a plexus on the outer side of each lobule, to supply its wall and the accompanying bile-ducts. From this plexus lobular branches enter the lobule and end in the capillary network between the cells. Some anatomists, however, doubt whether it transmits any blood directly to the capillary network.

The \textbf{Portal Vein} also enters at the transverse fissure and runs through the portal canals, enclosed in Glisson’s capsule, dividing into branches in its course, which finally break up into a plexus, the \textit{interlobular plexus}, in the interlobular spaces. In their course these branches receive the vaginal and capsular veins, corresponding to the vaginal and capsular branches of the hepatic artery (Fig. 959).

\[\text{FIG. 959.—Longitudinal section of an hepatic vein. (After Kiernan.)}\]

\[\text{FIG. 960.—Longitudinal section of a small portal vein and canal. (After Kiernan.)}\]

\(^1\) Delpeigne states that there are evidences of the arrangement of these cells in the form of columns, which form tubes with narrow lumina branching from terminal bile-ducts. This branching is evidenced by a diversification of the columns from lines extending between adjacent portal vessels. The columns of cells group around terminal bile-ducts, and not around the so-called intralobular veins. (\textit{Lancet}, 1896, vol. i., p. 1254.)—En. of 15th English edition.
Thus it will be seen that all the blood carried to the liver by the portal vein and hepatic artery, except perhaps that derived from the interlobular branches of the hepatic artery, directly or indirectly finds its way into the interlobular plexus. From this plexus the blood is carried into the lobule by fine branches which pierce its wall and then converge from the circumference to the centre of the lobule, form-

![Diagram of liver structures](image)

**Fig. 961.—Horizontal section of liver (dog.)**

ing a number of converging vessels which are connected by transverse branches (Figs. 961 and 962). In the interstices of the network of vessels thus formed are situated, as before said, the liver-cells; and here it is that the blood is brought into intimate connection with the liver-cells and the bile is secreted. Arrived at the centre of a lobule, all these minute vessels empty themselves into one vein, of considerable size, which runs down the centre of the lobule from apex to base and is called the **intralobular or central vein** (*vein interlobularis*) (Fig. 962). At the base of the lobule this vein opens directly into the **sublobular vein**, with which the lobule is connected, and which, as before mentioned, is a radicle of the hepatic vein. The sublobular veins, uniting into larger and larger trunks, end at last in the hepatic veins, which do not receive any intralobular veins. Finally, the hepatic veins, as mentioned on page 767, converge to form three large trunks which open into the postcava, while that vessel is situated in the fissure appropriated to it at the back of the liver.
(3) The Ducts.—Having shown how the blood is brought into intimate relation with the hepatic cells in order that the bile may be secreted, it remains now only to consider the way in which the secretion, having been formed, is carried away.

Several views have prevailed as to the mode of origin of the hepatic ducts; it seems, however, to be clear that they commence by little passages which are formed between the cells, and which have been termed *intercellular biliary passages*, *bile-capillaries* or *bile-canaliculi* (*ductus biliferi*). These passages are merely little channels or spaces left between the contiguous surfaces of two cells or in the angle where three or more liver-cells meet (Fig. 964), and it seems doubtful whether there is any delicate membrane forming the wall of the channel. Heidenhain, however, thinks they have coats. The channels thus formed radiate to the circumference of the lobule, and, piercing its wall, form a plexus...
(interlobular) between the lobules. From this plexus interlobular ducts (ductus interlobulares) are derived which pass into the portal canals, become enclosed in Glisson's capsule, and, accompanying the portal vein and hepatic artery (Fig. 952), join with other ducts to form two main trunks, the right and left branches of the hepatic duct, which leave the liver at the transverse fissure, and by their union form the hepatic duct.

Structure.—The coats of the smallest biliary ducts, which lie in the interlobular spaces, are a connective-tissue coat, in which are muscle-cells, arranged both circularly and longitudinally, and an epithelial layer, consisting of short columnar cells. In the larger ducts, which lie in the portal canals, there are a number of orifices disposed in two longitudinal rows, which were formerly regarded as the openings of mucous glands, but which are merely the orifices of tubular recesses. They occasionally anastomose, and from the sides of them saccular dilatations are given off.

Lymphatics of the Liver (Fig. 504).—The lymphatics in the substance of the liver commence in lymphatic spaces around the capillaries of the lobules; they accompany the vessels of the interlobular plexus, often enclosing and surrounding them. These unite and form larger vessels, which run in the portal canals, enclosed in Glisson's capsule, and emerge at the portal fissure to be distributed in the manner described. Other superficial lymphatics arise from the superficial lobules, pass under the peritoneum, and form a close plexus, where this membrane covers the liver. The first-named group of lymphatics give origin to the deep collecting trunks, the second to the superficial collecting trunks. According to Poirier, Cunéo and Delamare,¹ one group of deep collecting trunks accompanies the portal vein, there being fifteen to eighteen of them emerging from the transverse fissure. They empty into the glands of the hilum. Another group accompanies the hepatic veins. There are five or six trunks which pass through the Diaphragm and terminate in the glands about the postcava (intrathoracic glands). According to the above-cited authorities, the superficial trunks of the superior surface are divided into posterior, anterior, and superior trunks. Some of the posterior trunks terminate in the glands about the coeliac axis, others in the glands about the lower portion of the postcava in the thorax; others in the glands about the abdominal portion of the oesophagus. The anterior trunks which are limited to the right lobe pass to the glands of the hilum. The superior trunks ascend in the suspensory ligament. Some pass to the glands about the postcava, just above the Diaphragm; others to the hepatic glands. The balance unite to form a very large trunk, which passes through the Diaphragm and divides into branches which enter the glands back of the base of the ensiform cartilage.

Nerves of the Liver.—The nerves of the liver are derived from the left vagus and the solar plexus of the sympathetic. The branches of the vagus ascend from in front of the stomach within the lesser omentum. The sympathetic nerves pass along the hepatic artery from the coeliac plexus. The nerves enter the liver at the transverse fissure and accompany the vessels and ducts to the interlobular spaces. Here, according to Korolkow, the myelinic fibres are distributed almost exclusively to the coats of the blood-vessels; while the amyelinic fibres enter the lobules and ramify between the cells.

The Excretory Apparatus of the Liver.

The excretory apparatus of the liver consists of (1) the hepatic duct, which, as we have seen, is formed by the junction of the two main ducts, which pass out of the liver at the transverse fissure, and are formed by the union of the bile-capillaries; (2) the gall-bladder, which serves as a reservoir for the bile; (3) the

¹ The Lymphatics. Translated and edited by Cecil H. Leaf.
cystic duct, which is the duct of the gall-bladder; and (4) the common bile-duct, formed by the junction of the hepatic and cystic ducts.

The Hepatic Duct (ductus hepaticus) (Figs. 961, 967, and 969).—Two main trunks of nearly equal size issue from the liver at the transverse fissure, one from the right, the other from the left lobe; these unite to form the hepatic duct, which then passes downward and to the right for about an inch and a half or two inches, between the layers of the lesser omentum, where it is joined at an acute angle by the cystic duct, and so forms the ductus communis choledochus. The hepatic duct, as it descends from the transverse fissure of the liver, between the two layers of the lesser omentum, lies in company with the hepatic artery and portal vein (Fig. 957).

The Gall-bladder (vesica fellea) (Figs. 872, 874, 951, 957, and 966).—The gall-bladder is the reservoir for the bile; it is a conical or pear-shaped musculo-membranous sac, lodged in a fossa on the under surface of the right lobe of the liver, and fixed in it by connective tissue, and extending from near the right extremity of the transverse fissure to the anterior border of the organ. It is about four inches in length, one inch in breadth at its widest part, and holds from eight to ten drachms. It is divided into a fundus, body, and neck. The fundus (fundus vesicae felleae), or broad extremity, is directed downward, forward, and to the right, and projects beyond the anterior border of the liver; the body (corpus vesicae felleae) and neck (collum vesicae felleae) are directed upward and backward to the left. The neck of the gall-bladder is on a slightly higher level than the lowest point of the gall-bladder; thus the weight of the bile is away from rather than toward the outlet. The upper surface of the gall-bladder is attached to the liver by connective tissue and vessels. The under surface is covered by peritoneum, which is reflected on to it from the surface of the liver. Occasionally the whole of the organ is invested by the serous membrane, and is then connected to the liver by a kind of mesentery.

Relations.—The body of the gall-bladder is in relation, by its upper surface, with the liver, to which it is connected by areolar tissue and vessels; by its under surface, with the commencement of the transverse colon; and farther back, with the upper end of the descending portion of the duodenum or sometimes with the pyloric end of the stomach or the first portion of the duodenum. The fundus is completely invested by peritoneum; it is in relation, in front, with the abdominal parietes, immediately below the ninth costal cartilage; behind, with the transverse arch of the colon.

The neck is narrow, and curves upon itself like the letter S; at its point of connection with the cystic duct it presents a well-marked constriction.

When the gall-bladder is distended with bile or filled with calculi, the fundus may be felt through the abdominal parietes, especially in an emaciated subject; the relations of this sac will also serve to explain the occasional occurrence of abdominal biliary fistulae, through which biliary calculi may pass out, and of the passage of calculi from the gall-bladder into the stomach, duodenum, or colon, which occasionally happens.
Structure.—The gall-bladder consists of three coats—serous, fibrous and muscular, and mucous.

The External or Serous Coat (tunica serosa vesicae felleae) is derived from the peritoneum; it completely invests the fundus, but covers the body and neck only on their under surfaces.

The Fibro-muscular Coat (tunica muscularis vesicae felleae) is a thin but strong layer which forms the framework of the sac, consisting of dense fibrous tissue which interlaces in all directions and is mixed with plain muscular fibres which are disposed chiefly in a longitudinal direction, a few running transversely.

The Internal or Mucous Coat (tunica mucosa vesicae felleae) is loosely connected with the fibrous layer. It is generally tinged with a yellowish-brown color, and is everywhere elevated into minute rugae, by the union of which numerous meshes are formed, the depressed intervening spaces having a polygonal outline. The meshes are smaller at the fundus and neck, being most developed about the centre of the sac. Opposite the neck of the gall-bladder the mucous membrane projects inward in the form of oblique ridges or folds, forming a sort of screw-like or spiral valve (Fig. 966).

The mucous membrane is covered with columnar epithelium, and secretes an abundance of thick viscid mucus; it is continuous through the hepatic duct with the mucous membrane lining the ducts of the liver, and through the ductus communis choledochus with the mucous membrane of the duodenum.

The Cystic Duct (ductus cysticus).—The cystic duct, the smallest of the three biliary ducts, is about an inch and a half in length. It passes obliquely downward and to the left from the neck of the gall-bladder, and joins the hepatic duct to form the common bile-duct. It lies in the gastro-hepatic omentum in front of the portal vein, the hepatic artery lying to its left side. The mucous membrane lining its interior is thrown into a series of crescentic folds, from five to twelve in number, similar to those found in the neck of the gall-bladder. They project into the duct in regular succession, and are directed obliquely round the tube, presenting much the appearance of a continuous spiral valve (valvula spiralis [Heisteri]) (Fig. 966). When the duct is distended, the spaces between the folds are dilated, so as to give to its exterior a succulated appearance.

The Ductus Communis Choledochus or Common Bile-duct (ductus choledochus) Figs. 966 and 967), the largest of the three,
is the common excretory duct of the liver and gall-bladder. It is about three inches in length, is of the diameter of a goose-quill, and is formed by the junction of the cystic and hepatic ducts.

It descends within the two layers and along the right border of the lesser omentum behind the first portion of the duodenum, in front of the portal vein, and to the right of the hepatic artery (Fig. 872); then passes either between the pancreas and descending portion of the duodenum, or through the head of the pancreas. In fifty-eight dissections Prof. Büngner found that it passed through the pancreas fifty-five times and over the head only three times. Even when it passes through the pancreas it almost always joins the pancreatic duct outside of the gland. It descends by the right side of the pancreatic duct and passes with it obliquely through the wall of the descending portion of the duodenum between the mucous and muscular coats in the submucous tissue for one-half to three-quarters of an inch. The two ducts usually unite just before opening into the duodenum (Figs. 967, 968, and 970), but may remain independent throughout (in about 10 per cent. of individuals). The diverticulum ampulla of Vater (Fig. 967) is the conical cavity formed by the fusion of the two ducts, and is much larger than the opening on the bile-papilla. It averages 3.9 mm. in length. The average diameter of the orifice is 2.5 mm. (Opie). The two ducts open by a common orifice if there is an ampulla, or by two separate orifices if there is no ampulla, upon the summit of a papilla, situated at the inner side of the descending portion of the duodenum, a little below its middle and about three or four inches below the pylorus. Circular muscular fibres, continuous with the longitudinal fibres of the ducts, surround the termination of the two ducts in the ampulla. These fibres constitute the so-called sphincter of Oddi (Fig. 968).

Structure.—The coats of the large biliary ducts are an external or fibrous and an internal or mucous. The fibrous coat is composed of strong fibro-areolar tissues, with a certain amount of muscular tissue arranged, for the most part, in a circular manner around the duct. The mucous coat is continuous with the lining mem-

Fig. 969.—Part of the bile-duct and the pancreatic ducts. C and B, calculi; Sa, Santorini’s duct; P, pancreatic duct; H and I, ducts from the right and left lobes of the liver; H, cystic duct; C, gall-bladder; A, common duct. (Robinson.)

Fig. 970.—Diagram showing the bile and pancreatic ducts piercing the wall of the duodenum obliquely. (Cunningham.)
brane of the hepatic ducts and gall-bladder, and also with that of the duode-
num; and, like the mucous membrane of these structures, its epithelium is of the
columnar variety. It is provided with numerous mucous glands, which are lobu-
lated and open by minute orifices scattered irregularly in the larger ducts. It is
questionable if the smallest biliary ducts, which lie in the interlobular spaces, have
any coats. Heidenhain thinks they have a connective-tissue coat, in which are
muscle-cells arranged both circularly and longitudinally, and an epithelial layer,
consisting of short columnar cells.

Dimensions of the Bile-ducts.—The hepatic duct is about two inches in length,
and its lumen is one-sixth of an inch in diameter. The cystic duct is about one
and one-half inches in length, and its lumen is one-twelfth of an inch in diameter.
The common duct is about three inches in length, and its lumen is one-quarter of
an inch in diameter. The duodenal opening is smaller than the common duct.
The ducts are capable of considerable distention, but the duodenal opening can-
not be dilated (Hyrtl).

Blood-vessels, Lymphatics, and Nerves of the Gall-bladder and Bile-ducts.—The
cystic artery (Fig. 421), a branch from the right division of the hepatic, supplies the
gall-bladder and cystic duct with blood. It passes along the cystic duct, and on
reaching the gall-bladder divides into an upper branch and a lower branch. The
upper branch lies between the gall-bladder and the liver and sends branches to each.
The lower branch is between the peritoneum and the wall of the gall-bladder.
The cystic veins empty into the portal vein. The common duct receives branches
from the superior pancreatico-duodenal artery. There is a submucous lymphatic net-
work and a muscular lymphatic network. The lymphatics are much less numer-
ous at the fundus of the gall-bladder than at the neck or in the extra-hepatic ducts.
The collecting trunks (Fig. 504) end in glands along the cystic and common ducts
and these glands are in communication with the duodenal lymphatics and the
lymphatics from the head of the pancreas. The nerves of the gall-bladder and
bile-ducts come from the coeliac plexus of the sympathetic. The adjacent peri-
toneum is plentifully supplied with nerves (Robinson).

The Bile (fcl).—The bile is a reddish-brown or greenish fluid. It contains pig-
ments (bilirubin and biliverdin), fats and soaps, cholesterol, sodium salts of glyco-
choleic and taurocholic acid, lecithin, and nucleo-albumin furnished by the mucous
membrane. There are also present CO2; chlorides, carbonates, phosphates, and
sulphates of the alkalies and of calcium, and iron. The amount normally secreted is from one pint to one and one-half pints in the twenty-four hours.

Surface Relations.—The liver is situated in the right hypochondriac and the epigastric
regions, and is moulded to the arch of the Diaphragm. In the greater part of its extent it lies
under cover of the lower ribs and their cartilages, but in the epigastric region it comes in con-
tact with the abdominal wall, in the subcostal angle. The upper limit of the right lobe of the
liver may be defined in the middle line by the junction of the mesosternum with the ensiform
cartilage; on the right side the line must be carried upward as far as the fifth rib cartilage
in the line of the nipple and then downward to reach the seventh rib at the side of the chest.
The upper limit of the left lobe may be defined by continuing this line to the left with an inclina-
tion downward to a point about two inches to the left of the sternum on a level with the sixth
left costal cartilage. The lower limit of the liver may be indicated by a line drawn half an inch
below the lower border of the thorax on the right side as far as the ninth right costal cartilage,
and thence obliquely upward across the subcostal angle to the eighth left costal cartilage. A
slight curved line with its convexity to the left from this point—i.e., the eighth left costal
cartilage—to the termination of the line indicating the upper limit will denote the left margin of
the liver. The fundus of the gall-bladder approaches the surface behind the anterior extremity
of the ninth costal cartilage, close to the outer margin of the Right rectus muscle.

It must be remembered that the liver is subject to considerable alterations in position, and
the student should make himself acquainted with the different circumstances under which this
occurs, as they are of importance in determining the existence of enlargement or other diseases
of the organ.
Its position varies according to the posture of the body. In the erect position in the adult male the edge of the liver projects about half an inch below the lower edge of the right costal cartilages, and its anterior border can be often felt in this situation if the abdominal wall is thin. In the supine position the liver gravitates backward and recedes above the lower margin of the ribs, and cannot then be detected by the finger. In the prone position it falls forward, and can then generally be felt in a patient with loose and lax abdominal walls. Its position varies also with the ascent or descent of the Diaphragm. In a deep inspiration the liver descends below the ribs; in expiration it is raised behind them. Again, in emphysemata, where the lungs are distended and the Diaphragm descends very low, the liver is pushed down; in some other diseases, as phthisis, where the Diaphragm is much arched, the liver rises very high up. Pressure from without, as in tight lacing, by compressing the lower part of the chest, displaces the liver considerably, its anterior edge often extending as low as the crest of the ilium; and its convex surface is often at the same time deeply indented from the pressure of the ribs. Again, its position varies greatly according to the greater or less distortion of the stomach and intestines. When the intestines are empty the liver descends in the abdomen, but when they are distended it is pushed upward. Its relations to surrounding organs may also be changed by the growth of tumors or by collections of fluid in the thoracic or abdominal cavities.

**Surgical Anatomy.**—Movable liver or hepatoptosis is a rare condition, in which the liver moves or can be moved from its normal position. It is due to lessened tone of the abdominal muscles and relaxation of the liver supports. In movable liver the organ may be rotated on its vertical axis or on its transverse axis. Tongue-like lobes have been referred to. On account of its large size, its fixed position, and its friability, the liver is more frequently ruptured than any of the abdominal viscera. The rupture may vary considerably in extent, from a slight scratch to an extensive laceration completely through its substance, dividing it into two parts. Sometimes an internal rupture without laceration of the peritoneal covering takes place, and such injuries are most susceptible of repair; but small tears of the surface may also heal; when, however, the laceration is extensive, death usually takes place from hemorrhage, on account of the fact that the hepatic veins are contained in rigid canals in the liver-substance and are unable to contract, and are moreover unprovided with valves. The liver may also be torn by the end of a broken rib perforating the Diaphragm. The liver may be injured by stabs or other punctured wounds, and when these are inflicted through the chest-wall both pleural and peritoneal cavities may be opened up and both lung and liver be wounded. In cases of wound of the liver from the front, protrusion of a part of this viscus may take place, but can generally easily be replaced. In cases of laceration of the liver, when there is evidence that bleeding is going on, the abdomen must be opened, the laceration sought for, and the bleeding arrested. This may be done temporarily by introducing the forefinger into the foramen of Winslow and placing the thumb on the gastro-hepatic omentum and compressing the hepatic artery and portal vein between the two. Any bleeding points can then be seen. Bleeding is, if possible, arrested by suture ligatures. The edges of a small laceration are simply brought together and sutured by means of a blunt, curved, round needle passed from one side of the wound to the other. All sutures must be passed before any are tied, and this must be done with the greatest gentleness, as the liver substance is very friable. If suture fails the actual cautery may succeed. When the laceration is extensive, the liver is sutured to the abdominal wall to hold it firm when pressure is applied, and then the laceration is packed with a piece of iodine gauze, the gauze of which is allowed to hang out of the external wound. **Abscess of the liver** is of not infrequent occurrence, and may open in many different ways on account of the relations of this viscus to other organs. Thus it may burst into the lung, the pus being coughed up, or into the stomach; the pus perhaps being vomited, it may burst into the colon or into the duodenum, or, by perforating the Diaphragm, it may empty itself into the pleural cavity. Frequently it makes its way forward, and points on the anterior abdominal wall, and finally it may burst into the peritoneal or pericardiac cavity. Abscesses of the liver require opening, and this must be done by an incision in the abdominal wall, in the thoracic wall, or in the lumbar region, according to the direction in which the abscess is tracking. The incision through the abdominal wall is to be preferred when possible. The abdominal wall is incised over the swelling, and unless the peritoneum is adherent, gauze is packed all around the exposed liver surface and the abscess opened, if deeply seated, preferably by the thermocautery. **Hydatid cysts** are more often found in the liver than in any other of the viscera. The reason of this is not far to seek. The embryo of the egg of the tapeworm ischococcus being liberated in the stomach by the disintegration of its shell, bores its way through the gastric walls and usually enters a blood-vessel, and is carried by the blood-stream to the hepatic capillaries, where its onward course is arrested, and where it undergoes development into the fully formed hydatid. **Tumors of the liver** have recently been subjected to surgical treatment by removal of a portion of the organ. The abdomen is opened and the diseased portion of liver exposed; the circulation is controlled by compressing the portal vein and the hepatic artery in the gastro-hepatic omentum and a wedge-shaped portion of liver containing the tumor removed; the divided vessels are ligated and the cut surfaces brought together and sutured in the manner directed above.

When the gall-bladder or one of its main ducts is ruptured, which may occur independently of laceration of the liver, death usually occurs from peritonitis. If the symptoms have led to
THE PANCREAS 1355

the performance of a laparotomy and a small rent is found, it should be sutured; if an extensive opening is found the gall-bladder should be removed. If the cystic duct is torn, its intestinal end must be closed and the gall-bladder removed. In rupture of either of the other ducts, simply provide for free drainage.

The gall-bladder may become distended with bile in cases of obstruction of its duct or of the common bile-duct, or it may become distended from a collection of gall-stones within its interior, thus forming a large tumor. The swelling due to distention with bile is pear-shaped, and projects downward and forward to the umbilicus. It moves with respiration, since it is attached to the liver. To relieve a patient of gall-stones, the gall-bladder must be opened and the gall-stones removed. The operation is performed by an incision two or three inches long in the right semilunar line, commencing at the costal margin. The peritoneal cavity is opened, and the tumor having been found, gauze pads are packed around it to protect the peritoneal cavity, and it is aspirated. When the contained fluid has been evacuated the flaccid bladder is drawn out of the abdominal wound and its wall incised to the extent of an inch; any gall-stones in the bladder are now removed and the interior of the sac sponged dry. If the case is one of obstruction of the duct, an attempt must be made to dislodge the stone by manipulation through the wall of the duct; or it may be crushed from without by the fingers or carefully padded forceps. If this does not succeed, the safest plan is to incise the duct, extract the stone, close the incision in the duct by fine sutures in two layers and employ drainage. After all obstruction has been removed, four courses are open to the surgeon: 1. The wound in the gall-bladder may be at once sewed up, the organ returned into the abdominal cavity, and the external incision closed. 2. The edges of the incision in the gall-bladder may be sutured to the fascia of the external wound, and a fistulous communication established between the gall-bladder and the exterior; this fistulous opening usually closes in the course of a few weeks. 3. The gall-bladder may be connected with the intestinal canal, preferably the duodenum, by means of a lateral anastomosis; this is known as cholecystenterostomy. 4. The gall-bladder may be completely removed (cholecystectomy). Plan 2 is usually followed. Plan 4 is employed when the coats of the gall-bladder are seriously diseased. Plan 2 is employed in obstruction of the common duct by malignant disease.

If a stone blocks the diverticulum of Vater and if the common bile-duct and the pancreatic duct empty into the diverticulum, it is evident that both ducts will be blocked. It has been demonstrated that in such a case the pressure urging the bile onward is sufficient to overcome the pressure in the pancreatic duct and drive bile into the ducts of the pancreas, the result, perhaps, being disastrous inflammation of the pancreas.

Septic trouble arises more rapidly when a stone is blocked in the duct than when stones merely block the gall-bladder, because the first-named part is richer in lymphatics (Murphy).

THE PANCREAS (Figs. 971, 972, 973, 974).

Dissection.—The pancreas may be exposed for dissection in three different ways: 1. By raising the liver, drawing down the stomach, and tearing through the gastro-hepatic omentum and the ascending layer of the transverse mesocolon. 2. By raising the stomach, the arch of the colon, and great omentum, and then dividing the inferior layer of the transverse mesocolon and raising its ascending layer. 3. By dividing the two layers of peritoneum, which descend from the great curvature of the stomach to form the great omentum; turning the stomach upward, and then cutting through the ascending layer of the transverse mesocolon (see Fig. 860).

The Pancreas (παν-κρέας, all flesh) is a compound racemose gland, analogous in its structure to the salivary glands, though softer and less compactly arranged than those organs. It is long and irregularly prismatic in shape, and has been compared to a human or a dog's tongue; it is of reddish-white color. Its right extremity being broad, is called the head. The right half of the head above is continuous with the neck, which connects the head to the main portion of the organ, the body. The neck is a slight constriction or thin part of the gland, placed in front of the portal vein, and connecting the head to the body. The left half of the head is separated from the neck by a notch, the incisura pancreaticus. The body of the gland gradually tapers into an extremity directed to the left, and called the tail. The pancreas is placed transversely across the posterior wall of the abdomen, at the back of the epigastric and left hypochondriac regions. Its length varies from five to six inches, its breadth is an inch and a half, and its thickness from half an inch to an inch, being greater at its right extremity and along
its upper border. Its weight varies from two to three and a half ounces, but it may reach six ounces.

**FIG. 971.**—Position and relations of pancreas.

**FIG. 972.**—The duodenum and pancreas. The liver has been lifted up and the greater part of the stomach removed: a, portal vein; b, hepatic duct; c, cystic duct; d, hepatic artery; e, right suprarenal capsule; f, pyloric orifice; g, right gastro-epiploic artery; h, superior mesenteric vein; i, left crus of diaphragm; j, left suprarenal capsule; k, splenic vein; l, splenic artery; m, duodeno-jejunal junction; A, B, C, D, the four portions of the duodenum. (Testut.)
The Right Extremity or Head of the Pancreas (caput pancreatis) (Fig. 971) is shaped like the head of a hammer, being elongated both above and below; it is flattened from before backward, and conforms to the whole concavity of the duodenum, which is slightly overlapped by it. The anterior surface near its left border exhibits a notch, the incisura pancreatis, which contains the superior mesenteric vessels. The notch marks the separation of the inferior portion of the head, which is known as the uncinate process of Winslow (processus uncinatus [Winslow]), which rests, below, upon the inferior portion of the duodenum, and, above, is pushed up back of the upper portion. The lower end of the head is crossed by the transverse colon and its mesocolon. Behind, the head of the pancreas is in relation with the postcava, the left renal vein, the right crus of the Diaphragm, and the aorta. The common bile-duct descends behind, between the duodenum and pancreas, or in the substance of the gland; and the pancreatico-duodenal artery descends in front between the same parts. The head of the pancreas is closely adherent to the duodenum.

**Fig. 973.—Duodenal orifice of the pancreatic duct and of the canal of Santorini.**

The Neck of the Pancreas is about an inch long, and passes upward and forward to the left, having the first part of the duodenum above it, and the termination of the fourth portion below. It lies in front of the commencement of the portal vein, and is grooved on the right by the gastro-duodenal and superior pancreatico-duodenal arteries. The pylorus lies just above it.

The Body (corpus pancreatis) and Tail (cauda pancreatis) of the Pancreas are somewhat prismatic in shape, and have three surfaces: anterior, posterior, and inferior.

**The Anterior Surface (facies anterior).—**The anterior surface is somewhat concave, and is covered by the posterior surface of the stomach which rests upon it, the two organs being separated by the lesser sac of the peritoneum. At its right extremity there is a well-marked prominence, called by His the omental tuberosity (tuber omentale).

**The Posterior Surface (facies posterior).—**The posterior surface is separated from the vertebral column by the aorta, the splenic vein, the left kidney and its vessels, the left suprarenal capsule, the pillars of the Diaphragm, and the origin of the superior mesenteric artery.

**The Inferior Surface (facies inferior) (Fig. 972).—**The inferior surface is narrow, and lies upon the duodeno-jejunal flexure and on some coils of the jejunum; its left extremity rests on the splenic flexure of the colon.

**The Superior Border (margo superior) (Fig. 972).—**The superior border of the body is blunt and flat to the right; narrow and sharp to the left, near the tail. It commences to the right in the omental tuberosity, and is in relation with the coeliac axis, from which the hepatic artery courses to the right just above the gland, while the splenic branch runs in a groove along this border to the left.
The Anterior Border (margo anterior).—The anterior border is the position where the two layers of the transverse mesocolon separate; the one passing upward in front of the anterior surface, the other backward below the inferior surface (Fig. 866). The lesser end or tail of the pancreas is narrow; it extends to the left as far as the lower part of the inner aspect of the spleen, and its end is directed upward and to the left (Fig. 972).

Birmingham describes the body of the pancreas as projecting forward as a prominent ridge into the abdominal cavity and forming a sort of shelf on which the stomach lies. He says: "The portion of the pancreas to the left of the middle line has a very considerable antero-posterior thickness; as a result the anterior surface is of considerable extent, it looks strongly upward, and forms a large and important part of the shelf. As the pancreas extends to the left toward the spleen it crosses the upper part of the kidney, and is so moulded on to it that the top of the kidney forms an extension inward and backward of the upper surface of the pancreas and extends the bed in this direction. On the other hand, the extremity of the pancreas comes in contact with the spleen in such a way that the plane of its upper surface runs with little interruption upward and backward into the concave gastric surface of the spleen, which completes the bed behind and to the left, and, running upward, forms a partial cap for the wide end of the stomach." An occasional anomaly is a pancreas prolonged in front of the duodenum or actually embracing it (annular pancreas).

Fig. 974.—Transverse section through the middle of the first lumbar vertebra, showing the relations of the pancreas. (Braune.)

Peritoneal Relations (Fig. 866).—The transverse mesocolon is attached to the anterior border of the pancreas, from the tail to the neck of the gland, and the two layers of the mesocolon separate. The anterior layer which comes from the lesser peritoneum covers part of the anterior surface and the superior surface; the posterior layer, which comes from the greater omentum, covers the rest of the anterior surface and the inferior surface. The posterior surface is devoid of peritoneum.

There is in front of the head and at the anterior margin a narrow strip of pancreas, which remains uncovered by peritoneum and which corresponds to the cellular tissue of the mesocolon.

The principal excretory duct of the pancreas, called the **pancreatic duct** or **canal of Wirsung** (ductus pancreaticus [Wirsungii]) (Figs. 969, 971, and 973), from its discoverer, extends transversely from left to right through the substance of the pancreas. In order to expose it, the superficial portion of the gland must be removed. It commences by the junction of the small ducts of the lobules situated in the tail of the pancreas, and, running from left to right through the body, it constantly receives the ducts of the various lobules composing the gland. Considerably augmented in size, it reaches the neck, and turning obliquely downward, backward, and to the right, it comes into relation with the common bile-duct, lying to its left side; leaving the head of the gland, it passes very obliquely through the mucous and muscular coats of the duodenum, and usually terminates by an orifice common to it and the ductus communis choledochus upon the summit of an elevated papilla, situated at the inner side of the descending portion of the duodenum, three or four inches below the pylorus (Figs. 967, 968, and 970).

Sometimes the pancreatic duct and ductus communis choledochus open separately into the duodenum (Fig. 906). In about one-fifth of the subjects there is an accessory duct, which is given off from the canal of Wirsung in the neck of the pancreas and passes horizontally to the right to open into the duodenum about an inch above the orifice of the main duct. This is known as the **duct of Santorini** (ductus pancreaticus accessorius [Santorini]) (Figs. 969, 970, and 973).

The pancreatic duct, near the duodenum, is about the size of an ordinary quill; its walls are thin, consisting of two coats, an external fibrous and an internal mucous; the latter is smooth, and furnished near its termination with a few scattered follicles.

**Structure.**—In structure, the pancreas resembles the salivary glands. It differs from them, however, in certain particulars, and is looser and softer in its texture. It is not enclosed in a distinct capsule, but is surrounded by areolar tissue, which dips into its interior, and connects together the various lobules of which it is composed. Each lobule, like the lobules of the salivary glands, consists of one of the ultimate ramifications of the main duct, terminating in a number of caecal pouches or alveoli, which are tubular and somewhat convoluted. The minute ducts connected with the alveoli are narrow and lined with flattened cells. They are the secreting end tubules. The narrow ducts which come from the end tubules are lined with flat epithelial cells. The alveoli are almost completely filled with secreting cells, so that scarcely any lumen is visible. In the centre of the end tubules flat cells are frequently found. They are continuations into the tubules of the duct epithelium. These cells are known as the **centro-acinar cells of Langerhans**. The true secreting cells which line the wall of the alveolus are very characteristic. They are columnar or rounded in shape and present two zones: an outer one clear and finely striated next the basement-membrane, and an inner granular one next the lumen. The highly refracting granules are known as **zymogen granules**. During digestion the granules gradually disappear and the cells become clear. During fasting the granular zone occupies more than one-half of the cell (Szymonowicz). In some secreting cells of the pancreas is a spherical mass, staining more easily than the rest of the cells; this is termed the **paranucleus**, and is believed to be an extension from the nucleus. The connective tissue among the gland tubules and alveoli presents in certain parts collections of cells, which are termed **inter-alveolar cell-islets, intertubular cell-masses** or **islands of Langerhans**. Opie points out that they are most common in the splenic end of the pancreas. The cells of the islands are smaller than the secreting cells of the alveoli, and are arranged in layers with intervening spaces. The islands are surrounded by
fine connective tissue. The spaces in the islands contain capillaries. There are no ducts in the islands of Langerhans. Their function is to furnish the internal secretion of the pancreas.

Blood-vessels, Lymphatics, and Nerves.—The arteries of the pancreas come from the superior pancreatico-duodenal branch of the gastro-duodenal; the inferior pancreatico-duodenal branch of the superior mesenteric; the inferior pancreatic branch of the superior mesenteric; pancreatic branches of the hepatic and pancreatic branches of the splenic. In a few cases a large artery, the \textit{pancreatica magna}, accompanies the pancreatic duct. In most cases there is no such vessel. The veins are the anterior pancreatico-duodenal branch of the superior mesenteric; the posterior pancreatico-duodenal branch and other pancreatic branches of the portal; and pancreatic branches of the splenic. The lymphatics arise in a network about the lobules. Numerous collecting trunks pass to the surface of the pancreas, anastomose with each other, and enter into glands about the pancreas. The \textit{splenic glands} receive most of the trunks. Others are received by glands along the aorta (Sappey), glands at the origin of the superior mesenteric artery, and glands along the pancreatico-duodenal vessels.\(^1\) The \textit{nerves} come from the coeliac, superior mesenteric, and splenic plexuses.

The Pancreatic Juice.—The pancreatic juice is a clear, somewhat viscid alkaline liquid. Its specific gravity is about 1030. The solid matter consists chiefly of proteids, and amounts to about 10 per cent. of a sample of the juice.\(^2\) The juice contains a ferment which breaks up fat, a ferment which converts starch into sugar, a ferment which curdles milk, and a ferment which digests protein material.

Surface Form.—The pancreas lies in front of the second lumbar vertebra, and can sometimes be felt, in emaciated subjects, when the stomach and colon are empty, by making deep pressure in the middle line about three inches above the umbilicus.

Surgical Anatomy.—Of late years our knowledge of the structure, functions, and diseases of the pancreas has been notably increased, and surgeons have begun to operate for certain pancreatic diseases. It is occasionally the seat of cancer, which usually affects the head or duodenal end, and therefore often speedily involves the common bile-duct, leading to persistent jaundice. Cancer of the pancreas may be primary or secondary. \textit{Primary sarcoma} is very unusual; secondary sarcoma is more common, but cancer is far commoner than either form of sarcoma. \textit{Adenoma} may also occur. Cases are on record of the successful removal of tumors of the pancreas, but the operations are very dangerous, are extremely difficult, and are seldom attempted. The pancreas may be the seat of \textit{syphilitic or tuberculous disease}. As a result of pancreatic injury, there may be \textit{effusion into the lesser peritoneal cavity}. The lesser cavity becomes distended, and the fluid of this \textit{pseudo-cyst} may contain pancreatic juice (Jordan Lloyd). True \textit{cysts} of the pancreas are occasionally found. Pancreatic cysts may result from blocking of the duct, from epithelial proliferation, from traumatism and hemorrhage, or from hydatid disease. \textit{Congenital cysts} may occur, and \textit{cystic carcinoma} is sometimes encountered. Cysts of the pancreas may present in the epigastric region above and to the right of the umbilicus. The fluid in these cysts contains some of the pancreatic secretion. A pancreatic cyst is best treated by opening the abdomen, suturing the cyst to the skin, opening the cyst and providing for drainage. Complete extirpation of the cyst is invariably difficult and is usually impossible. It has been said that the pancreas is the only abdominal viscus which has never been found in a hernial protrusion; but even this organ has been found, in company with other viscera, in rare cases of \textit{diaphragmatic hernia}. The pancreas has been known to become invaginated into the intestine, and portions of the organ have sloughed off. In cases of \textit{excision of the pylorus} great care must be exercised to avoid wounding the pancreas, as the escape of the pancreatic fluid may be attended with serious and even with fatal results, peritonitis and \textit{fat necrosis}, and gangrene being caused.

\textit{Rupture of the pancreas} as a solitary result of traumatism is very unusual, but is more common in violent injuries which rupture the liver and spleen as well. An injury which lacerates the pancreas and permits blood and pancreatic juice to flow into the lesser peritoneal cavity is usually rapidly fatal, but may not be. The foramen of Winslow may be occluded by inflammation, and a pseudo-cyst may form. In severe laceration of the pancreas alone, it would be proper to open the abdomen, ligature bleeding vessels, suture the pancreas, and drain the lesser peritoneal cavity posteriorly. A \textit{gunshot wound of the pancreas} requires posterior drainage. Every effort must

\(^1\) Poirier, Cunéo, and Delamare on the \textit{Lymphatics}. Edited and translated by Cecil H. Leaf.

\(^2\) Robson and Moynihan on Diseases of the Pancreas.
be made in a pancreatic wound to rapidly get rid of pancreatic fluid by drainage from the
wound area, as this fluid is extremely irritant and may cause gangrene.

Inflammation of the pancreas is due to infection. Occasionally it seems to follow the entrance
of bile into the pancreatic duct, because of plugging of the ampulla with a calculus (Halsted,
Opie). Hemorrhage into the pancreas is frequent in acute pancreatitis, and fat necrosis is common
in the fat of the mesentery, subperitoneal tissue, omentum, and other parts. Acute pancreatitis
may be recovered from if the abdomen is opened, the pancreas incised, and drainage employed.
In chronic interstitial pancreatitis of the head of the pancreas the gall-duct is apt to become
blocked, and the disease is frequently mistaken for cancer. Cure may follow opening and drain-
age of the gall-bladder.

THE SPLEEN (LIEN) (Figs. 971, 972, 974).

The spleen belongs to that class of bodies which are known as ductless glands. It
is probably related to the blood-vascular system, but in consequence of its
anatomical relationship to the stomach and its physiological relationship to the
liver it is convenient to describe it in this section. It is situated principally in the
posterior portion of the left hypochondriac region, its upper and inner extremity
extending into the epigastric region; lying between the fundus of the stomach
and the Diaphragm. If the abdomen is opened a spleen of ordinary size is not
visible from the front, as it is placed between the left kidney, Diaphragm, and
stomach. It moves with the respiratory movements and with the movements of
the stomach. It is the largest of the so-called ductless glands, and varies greatly
in size. Usually it measures some five inches in length. It is of an oblong,
flattened form, soft, of very brittle consistence, highly vascular, and of a dark-
purpleish color.

Surfaces. The External or Phrenic Surface (facies diaphragmatica).—The external
or phrenic surface is convex, smooth, and is directed upward, backward, and
to the left, except at its upper end, where it is directed slightly inward. It is in
relation with the under surface of the Diaphragm, which separates it from the
eighth, ninth, tenth, and eleventh ribs of the left side, and in part from the lower
border of the left lung and pleura. It is
to be remembered that not only are the
peritoneum and the Diaphragm between
the spleen and the ribs, but also the cavity
of the left pleura and a portion of the left
lung.

The Internal Surface.—The internal sur-
face is concave, and divided by a ridge into an anterior or larger, and a posterior or
smaller portion.

The Anterior Portion of the internal sur-
face or the gastric surface (facies gastrica), which is directed forward and inward, is
broad and concave, and is in contact with the posterior wall of the great end of the
stomach; and below this with the tail of the pancreas. It presents near its inner
border a long fissure, termed the hilum
(hilus lienis). This is pierced by several
irregular apertures, for the entrance and
exit of vessels and nerves.

The Posterior Portion of the internal sur-
face or the renal surface (facies renalis)
is directed inward and downward. It is
somewhat flattened, does not reach as high

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Fig. 975.—The spleen, showing its gastric and
renal surfaces. (Testut.)
as the gastric surface, is considerably narrower than the latter, and is in relation with the upper part of the outer surface of the left kidney and occasionally with the left suprarenal capsule.

The upper end of the spleen (extremitas superior) is directed inward, toward the vertebral column, where it lies on a level with the eleventh thoracic vertebra. The lower end (extremitas inferior), sometimes termed the basal surface, is flat, triangular in shape, and rests upon the splenic flexure of the colon and the phreno-colic ligament, and is generally in contact with the tail of the pancreas. The anterior border (margo anterior) is free, sharp, and thin, and is often notched, especially below. It separates the phrenic surface from the gastric surface. The posterior border (margo posterior) is more rounded and blunter than the anterior. It separates the renal portion of the internal surface from the phrenic surface. It corresponds to the lower border of the eleventh rib and lies between the Diaphragm and left kidney. The internal border is the name sometimes given to the ridge which separates the renal and gastric portions of the internal surface.

The spleen is surrounded by peritoneum, except at the hilum and the serous membrane, is firmly adherent to its capsule, and is held in position by two folds of this membrane: one, the lienorenal ligament (ligamentum phrenicolienale) (Figs. 870 and 873), is derived from the layers of peritoneum forming the greater and lesser sacs, where they come into contact between the left kidney and the spleen. Between its two layers the splenic vessels pass; the second, the gastro-splenic omentum (ligamentum gastrolienale), also formed of two layers, derived from the greater and lesser sacs, respectively, where they meet between the spleen and stomach (Fig. 873). Between these two layers run the vasa brevia of the splenic artery and vein. The spleen is also supported by the phrenocolic ligament (ligamentum phrenicocolicum), upon which its lower end rests.

The size and weight of the spleen are liable to very extreme variations at different periods of life, in different individuals, and in the same individual under different conditions. In the adult, in whom it attains its greatest size, it is usually about five inches in length, three inches in breadth, and an inch or an inch and a half in thickness, and weighs about seven ounces. At birth, its weight, in proportion to the entire body, is almost equal to what is observed in the adult, being as
1 to 350; while in the adult it varies from 1 to 320 to 1 to 400. In old age, the organ not only decreases in weight, but decreases considerably in proportion to the entire body, being as 1 to 700. The size of the spleen is increased during and after digestion, and varies considerably according to the state of nutrition of the body, being large in highly fed, and small in starved animals. In intermittent and other fevers it becomes much enlarged, weighing occasionally from eighteen to twenty pounds.

Frequently in the neighborhood of the spleen, and especially in the gastro-splenic and great omenta, small nodules of splenic tissue may be found, either isolated, or connected to the spleen by thin bands of splenic tissue. Every such nodule is known as a *supernumerary* or *accessory spleen* (*lien accessorius*). Accessory spleens vary in size from that of a pea to that of a plum.

**Support and Movability of the Spleen.**—The spleen is normally movable within certain narrow limits. It moves with respiration and with stomach movements. It is supported by ligaments (p. 1362). An unduly movable spleen is called a *movable spleen*. In order that a spleen shall become unduly movable, the ligaments must stretch, and this stretching is often effected when the organ is greatly enlarged, but even an apparently normal spleen may become movable. Movable spleen is usually associated with movable left kidney.

**Structure.**—The spleen is invested by two coats—an *external serous* and an *internal fibro-elastic coat*.

The **External or Serous Coat** (*tunica serosa*).—The external or serous coat is derived from the peritoneum; it is thin, smooth, and in the human subject is intimately adherent to the fibro-elastic coat. It invests the entire organ, except at the places of its reflection on to the stomach and Diaphragm and at the hilum.

The **Fibro-elastic Coat** (*tunica albuginea*).—The fibro-elastic coat forms the framework of the spleen. It is composed of connective tissue containing muscle-cells and elastic fibres, and it invests the organ as a *capsule*, and at the hilum is reflected inward upon the vessels in the form of sheaths. From these sheaths, as well as from the inner surface of the fibro-elastic coat, numerous small fibrous bands, *trabeculae* (*trabeculae lienis*) (Figs. 976 and 977), are given off in all directions; these uniting, constitute the framework of the spleen. This framework resembles a sponge-like material, consisting of a number of small spaces or areolae formed by the trabeculae, which are given off from the inner surface of the capsule, or from the sheaths prolonged inwardly on the blood-vessels. The spaces or areolae contain the adenoid material known as *splenic pulp* (*pulpa lienis*).

The proper coat, the sheaths of the vessels and the trabeculae, consist of a dense mesh of white and yellow elastic fibrous tissues, the latter decidedly predominating. It is owing to the presence of this tissue that the spleen possesses a considerable amount of elasticity, which allows of the very great variations in size that it presents under certain circumstances. In addition to these constituents of this tunic, there is found in man a small amount of non-stripped muscular fibre, and in some mammalia (e. g., dog, pig, and cat) a very considerable amount, so that the trabeculae appear to consist chiefly of muscular tissue. It is probably because of this muscular structure that the spleen exhibits, when acted upon by the galvanic current, faint traces of contractility.

The proper substance of the spleen or splenic-pulp is a soft mass of a dark reddish-brown color, resembling grumous blood. When a thin section is examined under a microscope, it is found to consist of a number of branching cells and an intercellular substance. The cells are connective-tissue corpuscles, and have been named the *sustentacular* or *supporting cells of the pulp*. The processes of these branching cells communicate with each other, thus forming a delicate reticulated tissue in the interior of the areolae formed by the trabeculae of the capsule; so that each primary space may be considered to be divided into a
number of smaller spaces by the junction of these processes of the branching corpuscles. These secondary spaces contain blood, in which, however, the white corpuscles are found to be in larger proportions than in ordinary blood. The sustentacular cells are either small uni-nucleated or larger multi-nucleated cells; they do not stain deeply with carmine, like the cells of the Malpighian bodies, presently to be described (W. Müller), but like them they possess amoeboid movements (Cohnheim). In many of them may be seen deep red or reddish-yellow granules of various sizes which present the characters of the hematin of the blood. Sometimes, also, unchanged blood-disks are seen included in these cells, but more frequently blood-disks are found which are altered both in form and color. In fact, blood-corpuscles in all stages of disintegration may be noticed to occur within them. Klein has recently pointed out that sometimes these cells in the young spleen contain a proliferating nucleus; that is to say, the nucleus is of large size, and presents a number of knob-like projections, as if small nuclei were budding from it by a process of gemmation. This observation is of importance, as it may explain one possible source of the colorless blood-corpuscles.

The interspaces or areolae formed by the framework of the spleen are thus filled by a delicate reticulum of branched connective-tissue corpuscles, the interstices of which are occupied by blood, and in which the blood-vessels terminate in the manner now to be described.

**Blood-vessels of the Spleen.**—The splenic artery (Fig. 974) is remarkable for its large size in proportion to the size of the organs, and also for its tortuous course. It divides into six or more branches, which enter the hilum of the spleen and ramify throughout its substance, receiving sheaths from the involution of the external fibrous tissue. Similar sheaths also invest the nerves and veins.

Each branch runs in the transverse axis of the organ from within outward, diminishing in size during its transit, and giving off in its passage smaller branches, some of which pass to the anterior, others to the posterior part. These ultimately leave the trabecular sheaths, and terminate in the proper substance of the spleen in small tufts or pencils of minute arterioles, which open into the interstices of the reticulum formed by the branched sustentacular cells (Figs. 977, 978, and 979). Each of the larger branches of the artery supplies chiefly that region of the organ in which the branch ramifies, having no anastomosis with the majority of the other branches.
The arterioles (Fig. 979), supported by the minute trabeculae, traverse the pulp in all directions in bundles or pencilli of straight vessels. Their external coat, on leaving the trabecular sheaths, consists of ordinary connective tissue, but it gradually undergoes a transformation, becomes much thickened, and is converted into a lymphoid material. This change is effected by the conversion of the connective tissue into a lymphoid tissue, the bundles of connective tissue becoming looser and laxer, their fibrils more delicate, and containing in their interstices an abundance of lymph-corpuscles (W. Müller). This lymphoid material is supplied with blood by minute vessels derived from the artery with which they are in contact, and which terminates by breaking up into a network of capillary vessels.

The altered coat of the arterioles, consisting of lymphoid tissue (Fig. 979), presents here and there thickenings of a spheroidal shape, the Malpighian bodies of the spleen (noduli lymphatici lienales [Malpighii]) (Fig. 978). These bodies vary in size from about the $\frac{1}{10}$ of an inch to the $\frac{1}{25}$ of an inch in diameter. They are merely local expansions or hyperplasias of the lymphoid tissue of which the external coat of the smaller arteries of the spleen is formed. They are most frequently found surrounding the arteriole, which thus seems to tunnel them, but occasionally they grow from one side of the vessel only, and present the appearance of a sessile bud growing from the arterial wall. Klein, however, denies this, and says it is incorrect to describe the Malpighian bodies as isolated masses of adenoid tissue, but that they are always formed around an artery, though there is generally a greater amount on one side than on the other, and that, therefore, in transverse sections the artery in the majority of cases is found in an eccentric position. These bodies are visible to the naked eye on the surface of a fresh section of the organ, appearing as minute dots of semi-opaque whitish color in the dark substance of the pulp. In minute structure they resemble the adenoid tissue of lymphatic glands, consisting of a delicate reticulum in the meshes of which lie ordinary lymphoid cells.

The reticulum of the tissue is made up of extremely delicate fibrils, and is comparatively open in the centre of the corpuscle, becoming closer at the periphery of the body. The cells which it encloses, like the supporting cells of the pulp, are possessed of amoeboid movements, but when treated with carmine become deeply stained, and can thus easily be recognized from those of the pulp.

The arterioles terminate in capillaries, which traverse the pulp in all directions; their walls become much attenuated, lose their tubular character, and the cells of the lymphoid tissue of which they are composed become altered; presenting a branched appearance and acquiring processes which are directly connected with the processes of the sustentacular cells of the pulp (Fig. 979). In this manner the capillary vessels terminate, and the blood flowing through them finds its way into the interstices of the reticulated tissue formed by the branched connective-tissue corpuscles of the splenic pulp. Thus the blood passing through the spleen is brought into intimate relation with the elements of the pulp, and no doubt undergoes important changes.

After these changes have taken place the blood is collected from the interstices of the tissue by the rootlets of the veins (Fig. 976), which commence much in the

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1 According to Klein, it is the sheath of the small vessel which undergoes this transformation, and forms a solid mass of adenoid tissue which surrounds the vessel like a cylindrical sheath. (Atlas of Histology, p. 424.)
same way as the arteries terminate. Where a vein is about to originate the connective-tissue corpuscles of the pulp arrange themselves in rows in such a way as to form an elongated space or sinus. They become changed in shape, being elongated and spindle-shaped, and overlap each other at their extremities. They thus form a sort of endothelial lining of the path or sinus, which is the radicle of a vein. On the outer surface of these cells are seen delicate transverse lines or markings which are due to minute elastic fibrillae arranged in a circular manner around the sinus. Thus the channel obtains a continuous external investment, and gradually becomes converted into a small vein, which after a time presents a coat of ordinary connective tissue, lined by a layer of fusiform endothelial cells which are continuous with the supporting cells of the pulp. The smaller veins unite to form larger ones which do not accompany the arteries, but soon enter the trabecular sheaths of the capsule, and by their junction form from six or more branches which emerge from the hilum and, uniting, form the splenic vein, the largest radicle of the portal vein (Figs. 971 and 975).

The veins are remarkable for their numerous anastomoses, while the arteries hardly Anastomose at all.

The lymphatics originate in two ways—i.e., from the sheaths of the arteries and in the trabecule. The former trunks are the deep collecting trunks, and accompany the blood-vessels; the latter pass to the superficial lymphatic plexus, which may be seen on the surface of the organ. The two sets communicate in the interior of the organ. The deep trunks at the hilum number from five to ten, and terminate in the splenic glands. The superficial trunks also pass to the hilum and terminate in the splenic glands.

The nerves are derived from the splenic plexus, which is part of or connected with the solar plexus. The nerves enter the spleen with the vessels.

**Surface Form.**—The spleen is situated under cover of the ribs of the left side, being separated from them by the Diaphragm, and above by a small portion of the lower margin of the left lung and pleura. Its position corresponds to the eighth, ninth, tenth, and eleventh ribs. It is placed very obliquely. “It is oblique in two directions—viz., from above downward and outward, and also from above downward and forward” (Cunningham). “Its highest and lowest points are on a level respectively with the ninth dorsal and first lumbar spines; its inner end is distant about an inch and a half from the median plane of the body, and its outer end about reaches the mid-axillary line” (Quain).

**Surgical Anatomy.**—Injury of the spleen is less common than that of the liver, on account of its protected situation and connections. It may be ruptured by direct or indirect violence, torn by a broken rib, or injured by a punctured or gunshot wound. When the organ is enlarged the chance of rupture is increased. The great risk is hemorrhage, owing to the extreme vascularity of the organ, and the absence of a proper system of capillaries. The injury is not, how-
ever, necessarily fatal, and this would appear to be due in a great measure to the contractile power of its capsule, which narrows the wound and thus antagonizes the escape of blood. In cases in which the symptoms suggest such an injury and indicate danger to life, laparotomy must be performed; and if the hemorrhage cannot be arrested by ordinary surgical methods the spleen must be removed. The spleen may become displaced, producing great pain from stretching of the vessels and nerves, and this dislocation may render necessary removal of the organ. The spleen may become enormously enlarged in certain diseased conditions, such as ague, leukemia, syphilis, valvular disease of the heart, or without any obtainable history of previous disease. It may also become enlarged in lymphadenoma as a part of a general blood disease. In these cases the mass may fill the abdomen and extend into the pelvis, and may be mistaken for ovarian or uterine disease.

The spleen is sometimes the seat of cystic tumors, especially hydatids, and of abscess. These cases require treatment by incision and drainage; and in abscess great care must be taken if there are no adhesions between the spleen and abdominal cavity, to prevent the escape of any of the pus into the peritoneal cavity. If possible, the operation should be performed in two stages. Sarcoma and carcinoma are occasionally found in the spleen, but very rarely as a primary disease. In movable spleen, if the organ is normal, follow the advice of Rydygier and loosen the parietal peritoneum to make a pocket, place the spleen in the pocket, and pass sutures through the parietal peritoneum and the splenic ligaments. A movable diseased spleen should be removed.

Extrirpation of the spleen has been performed for wounds or injuries, floating spleen, simple hypertrophy, and leukæmic enlargement; but in the latter case the operation is now regarded as unjustifiable, as it is practically certain to terminate fatally. The incision is best made in the left semilunar line: the spleen is isolated from its surroundings, and the pedicle transfixed and ligatured in two portions, before the tumor is turned out of the abdominal cavity, if this is possible, so as to avoid any traction on the pedicle, which may cause tearing of the splenic vein and which inevitably induces grave shock. In applying the ligatures the surgeon must not include the tail of the pancreas, and in lifting out the organ care must be taken to avoid rupturing the capsule.
THE ORGANS OF VOICE AND RESPIRATION.

THE LARYNX.

The larynx is the organ of voice, placed at the upper part of the air-passage. It is situated between the trachea and base of the tongue, at the upper and forepart of the neck, where it forms a considerable projection in the middle line. On either side of it lie the great vessels of the neck; behind, it forms part of the boundary of the pharynx, and is covered by the mucous membrane lining that cavity. Its vertical extent corresponds to the fourth, fifth, and sixth cervical vertebrae, but it is placed somewhat higher in the female and also during childhood. In infants between six and twelve months of age Symington found that the tip of the epiglottis was a little above the level of the cartilage between the odontoid process and body of the axis, and that between infancy and adult life the larynx descends for a distance equal to two vertebral bodies and two intervertebral disks. The movements of the head affect the position of the larynx. When the head is drawn back, the larynx is lifted, and when the chin approaches the chest the larynx is depressed. During swallowing the larynx moves distinctly; during singing it moves slightly. The larynx is suspended by the stylo-hyoid ligament, the
muscles of the upper border of the hyoid bone, the Stylo-pharyngeus and Palato-pharyngeus muscles. According to Sappey, the average measurements of the adult larynx are as follows:

<table>
<thead>
<tr>
<th></th>
<th>In males</th>
<th>In females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical diameter</td>
<td>44 mm.</td>
<td>36 mm.</td>
</tr>
<tr>
<td>Transverse diameter</td>
<td>43 &quot;</td>
<td>41 &quot;</td>
</tr>
<tr>
<td>Antero-posterior diameter</td>
<td>36 &quot;</td>
<td>26 &quot;</td>
</tr>
<tr>
<td>Circumference</td>
<td>136 &quot;</td>
<td>112 &quot;</td>
</tr>
</tbody>
</table>

Until puberty there is no marked difference between the larynx of the male and that of the female. In the latter its further increase in size is only slight, whereas in the former it is great; all the cartilages are enlarged, and the thyroid becomes prominent as the pomum Adami in the middle line of the neck, while the length of the glottis is nearly doubled.

The larynx is broad above, where it presents the form of a triangular box, flattened behind and at the sides, and bounded in front by a prominent vertical ridge. Below, it is narrow and cylindrical. It is composed of cartilages, which are connected together by ligaments and moved by numerous muscles. It is lined by mucous membrane, which is continuous above with that lining the pharynx and below with that of the trachea.

In the median line of the neck the larynx has in front of it the skin and cervical fascia. There is often a bursa between the skin and fascia over the most prominent part of the larynx. It is called the bursa subcutanea prominentiae laryngae. It is present particularly in men, and is seldom found in the young or in women. The larynx is covered on each side by the thyroid gland, and the Sterno-hyoid, Sterno-thyroid, Thyro-hyoid, and Omo-hyoid muscles, and the Inferior constrictors of the pharynx. Posterior is the laryngeal portion of the pharynx.

**The Cartilages of the Larynx (cartilagines laryngis).**—The cartilages of the larynx are nine in number, three single, and three pairs:

- Thyroid.
- Cricoid.
- Epiglottis.
- Two Arytenoid.
- Two Cornicula Laryngis.
- Two Cuneiform.

**The Thyroid Cartilage (cartilago thyroidea)** (Figs. 981 and 982).—The thyroid cartilage (from thyros, a shield) is hyaline cartilage and is the largest cartilage of the larynx. It is at the anterior and upper portion of the larynx. It consists of two lateral lamellae or alae, united at an acute angle in front, forming a vertical projection in the middle line, which is prominent above and called the pomum Adami (prominentia laryngae). This projection is subcutaneous, is more distinct in the male than in the female, and is often separated from the integument by a bursa, the bursa subcutanea prominentiae laryngae.

Each lamella is quadrilateral in form. Its outer surface (Fig. 981) presents an oblique ridge (linea obliqua), which passes downward and forward from a tubercle situated near the root of the superior cornu, the superior tubercle (tuberculum thyroideum superius), to a small tubercle near the anterior part of the lower border, the inferior tubercle (tuberculum thyroideum inferius). This ridge gives attachment to the Sterno-thyroid and Thyro-hyoid muscles, and the portion of cartilage included between it and the posterior border gives attachment to part of the Inferior constrictor muscle. Just below each superior tubercle there is often an opening, the thyroid foramen (foramen thyroideum).

The anterior borders of the alae of the thyroid cartilage which are continuous below are separated above by a V-shaped notch, the thyroid notch (incisura thyroidea [superior]).
The Inner Surface (Fig. 982) of each ala is smooth, slightly concave, and covered by mucous membrane above and behind; but in front, in the receding angle formed by their junction, are attached the epiglottis, the true and false vocal cords, the Thyro-arytenoid and Thyro-epiglottidean muscles, and the thyro-epiglottidean ligament.

The Upper Border or Margin of the Thyroid Cartilage (Fig. 982) is sinuously curved, being concave at its posterior part, just in front of the superior cornu, then rising into a convex outline, which dips in front to form the sides of the thyroid notch, in the middle line, immediately above the pomum Adami. This border gives attachment throughout its whole extent to the thyro-hyoid or hyothyroid membrane.

The Lower Border or Margin (Fig. 982) is nearly straight in front, but behind, close to the cornu, it is concave. It is connected to the cricoid cartilage, in and near the median line, by the middle portion of the crico-thyroid membrane (membrana cricothyreoidea); and, on either side, by the Crico-thyroid muscle.

The Posterior Borders (Fig. 982) are thick and rounded, and each terminates above, in a superior cornu (cornu superius), and below, in an inferior cornu (cornu inferius). The two superior cornua are long and narrow, directed upward, backward, and inward, and terminate in conical extremities, which give attachment to the lateral thyro-hyoid ligaments. The two inferior cornua are short and thick; they pass downward, with a slight inclination forward and inward, and each presents on its inner surface a small oval articular facet for articulation with the side of the cricoid cartilage (Fig. 981). The posterior border receives the insertion of the Stylo-pharyngeus and Palato-pharyngeus muscles on each side.

During infancy the alae of the thyroid cartilage are joined to each other by a narrow, lozenge-shaped strip, named the intrathyroid cartilage. This strip extends from the upper to the lower border of the thyroid cartilage in the middle line, and is distinguished from the alae by being more transparent and more flexible.

The Cricoid Cartilage (cartilago cricoidea) (Figs. 981, 982, and 984).—The cricoid cartilage is so called from its resemblance to a signet ring (στιγμή, a ring). It is smaller, but thicker and stronger than the thyroid cartilage, and forms the lower and back part of the cavity of the larynx. It is hyaline cartilage and consists of two parts: a quadratus portion, situated behind, and a narrow ring or arch, one-fourth or one-fifth the depth of the posterior part, situated in front. The posterior square portion rapidly narrows at the sides of the cartilage, at the expense of the upper border, into the anterior portion.

Its Posterior Portion or Lamina (lamina cartilaginis cricoidea) is very deep and broad, and measures from above downward about an inch (2 to 3 cm.); it presents, on its posterior surface, in the middle line, a vertical ridge for the attachment of the longitudinal fibres of the oesophagus; and on either side a broad depression for the Crico-arytenoides posticus muscle.

Its Anterior Portion or Arcus (arcus cartilaginis cricoidea) is narrow and convex, and measures vertically about one-fourth or one-fifth of an inch (5 to 7 cm.); it affords attachment externally in front and at the sides to the Crico-thyroid muscles, and, behind, to part of the Inferior constrictor.
At the point of junction of the posterior quadrate portion with the rest of the cartilage is a small round elevation, for articulation with the inferior cornu of the thyroid cartilage.

The **Lower Border** of the cricoid cartilage is horizontal, and connected to the upper ring of the trachea by fibrous membrane (Figs. 981 and 983).

Its **Upper Border** is directed obliquely upward and backward, owing to the great depth of the posterior surface. It gives attachment, in front, to the middle portion of the crico-thyroid membrane; at the sides, to the lateral portion of the same membrane and to the lateral Crico-arytenoid muscle; behind, it presents, in the middle, a shallow notch, and on each side of this is a smooth, oval surface, directed upward and outward, for articulation with the arytenoid cartilage.

The **Inner Surface** of the cricoid cartilage is smooth, and lined with mucous membrane.

The **Arytenoid Cartilages** (cartilagines arytaenoidae) (Figs. 982, 983, and 989).—The arytenoid cartilages are so called from the resemblance they bear, when approximated, to the mouth of a pitcher (*ὁρτάζων*, a pitcher). They are two in number, and situated at the upper border of the cricoid cartilage, at the back of the larynx in the interval between the posterior borders of the alae of the thyroid cartilages. Each cartilage is in form a three-sided pyramid, and presents for examination three surfaces, a base, and an apex.

The **Posterior Surface** is triangular, smooth, concave, and gives attachment to the transverse portion of the Arytenoid muscle.

The **Anterior or External Surface** is somewhat convex and rough. It presents, near its apex, a small elevation, the **colliculus**; from this a **ridge** (crista arcuata) passes backward and then forward and downward into a sharp-pointed process, the **vocal process**. This ridge separates a deep depression above, the **fovea triangularis**, from a broader and shallower depression below, the **fovea oblonga**. A short distance above the base a small tubercle gives origin to the ligament of the false vocal cord, the superior thyro-arytenoid ligament. To the outer part of the ridge, as well as the surface above and below, is attached the Thyro-arytenoid muscle.

The **Internal Surface** is narrow, smooth, and flattened, covered by mucous membrane, and forms the lateral boundary of the respiratory part of the glottis.
The **Base (basis)** of each cartilage is broad, and presents a concave smooth surface, for articulation with the cricoid cartilage. Two of its angles require special mention: the **external angle**, which is short, rounded, and prominent, projects backward and outward, and is termed the **muscular process (processus muscularis)**, from receiving the insertion of the Posterior and Lateral crico-arytenoid muscles. The **anterior angle**, also prominent, but more pointed, projects horizontally forward, and gives attachment to the inferior thyro-arytenoid ligament, the supporting ligament of the true vocal cord. This angle is called the **vocal process (processus vocalis)**.

The **Apex** of each cartilage is pointed, curved backward and inward, and surmounted by a small conical, cartilaginous-nodule, the **corniculum laryngis**, articulated with or united to the arytenoid cartilage.

The **Cuneiform Cartilages or Cartilages of Santorini** (cartilagines cuneilatae) (Figs. 982 and 988).—The cuneiform cartilages are two small conical nodules, consisting of white fibro-cartilage, which articulate with the summit of the arytenoid cartilages and serve to prolong them backward and inward. To them are attached the aryteno-epiglottidean folds. They are sometimes united to the arytenoid cartilages.

The **Cuneiform Cartilages or Cartilages of Wrisberg** (cartilagines cuneiformes) (Figs. 982 and 984).—The cuneiform cartilages are two small, elongated, cartilaginous bodies, placed one on each side, in the fold of mucous membrane which extends from the apex of the arytenoid cartilage to the side of the epiglottis, and is called the aryteno-epiglottidean fold (pleca arypepiglottica) (Fig. 984); they give rise to small whitish elevations on the inner surface of the mucous membrane, just in front of the arytenoid cartilages.

The **Epiglottis or the Cartilage of the Epiglottis** (cartilago epiglottica) (Figs. 980, 982, 983, 984, 985, and 988).—The epiglottis is a thin, flexible lamella of fibro-cartilage, of a yellowish color, shaped like a leaf, and placed behind the tongue in front of the superior opening of the larynx. Its free extremity, which is directed upward, is broad and rounded, and often notched; its attached part (petiolus epiglottidis) is long, narrow, and connected to the receding angle between the alee of the thyroid cartilage, just below the median notch, by a long, narrow ligamentous band, the **thyro-epiglottic ligament (Fig. 985)**. It is also connected to the posterior surface of the body of the hyoid bone by an elastic ligamentous band, the **hyo-epiglottic ligament**.

Its **Anterior or Lingual Surface** is curved forward, toward the tongue, and covered at its upper, free part by mucous membrane, which is reflected on to the sides and base of the organ, forming a median and two lateral folds, the **glosso-epiglottidean folds** (Fig. 984). The **median glosso-epiglottidean fold** contains the elastic **glosso-epiglottidean ligament (ligamentum glossopiglotticum)**. Each lateral glosso-epiglottidean fold runs from the front and side of the base of the epiglottis to the side of the tongue. The depression between the epiglottis and the base of the tongue on each side of the median fold is named the **vallecula epiglottica**. The lower part of the anterior surface of the epiglottis lies behind the hyoid bone, the thyro-hyoid membrane, and upper part of the thyroid cartilage, but is separated from these structures by a mass of fatty tissue.

Its **Posterior or Laryngeal Surface** is smooth, concave from side to side, concavo-convex from above downward; its lower part projects backward as an elevation, the **tubercle or cushion (tuberculum epiglotticum)(Fig. 983)**; when the mucous membrane is removed, the surface of the cartilage is seen to be studded with a number of small mucous glands, which are lodged in little pits upon its surface. To its sides the **aryteno-epiglottidean folds** are attached (Fig. 984).

**Structure.**—The cuneiform cartilages, the epiglottis, and the apices of the arytenoids are composed of yellow elastic cartilage, which shows little tendency to calcification; on the other hand, the thyroid, cricoid, and the greater part of the
arytenoids consist of hyaline cartilage, and become more or less ossified as age advances. Ossification commences about the twenty-fifth year in the thyroid cartilage, somewhat later in the cricoid and arytenoids; by the sixty-fifth year these cartilages may be completely converted into bone. The cornicula laryngis consist of white fibro-cartilage, which becomes osseous about the seventieth year.

**Ligaments, Joints, and Membranes of the Larynx.**—The ligaments of the larynx are extrinsic—i.e., those connecting the thyroid cartilage and epiglottis with the hyoid bone, and the cricoid cartilage with the trachea; and intrinsic, those which connect the several cartilages of the larynx to each other.

The ligaments connecting the thyroid cartilage with the hyoid bone are three in number—the thyro-hyoid membrane, and the two lateral thyro-hyoid ligaments. The Thyro-hyoid or Hyo-thyroid Membrane or Ligament (membrana hyothyreoidea) (Fig. 985) is a broad, fibro-elastic, membranous layer, attached below to the upper border of the thyroid cartilage, and above to the posterior border of the body and greater cornua of the hyoid bone, passing behind the postero-inferior surface of the hyoid, and being separated from this surface by a synovial bursa (bursa m. sternohyoiden), which facilitates the upward movement of the larynx during deglutition. The membrane is thicker in the middle line than at either side. This thickening is due to elastic fibres, and constitutes the middle thyro-hyoid ligament (ligamentum hyothyreoideum medium). On each side the posterior extremity of the membrane is thickened by elastic fibres, constituting the lateral thyro-hyoid ligament (ligamentum hyothyreoideum laterale). The thyro-hyoid membrane is pierced on each side by the superior laryngeal vessels and the internal laryngeal nerve. The anterior surface of the thyro-hyoid membrane is in relation with the Thyro-hyoid, Sterno-hyoid, and Omo-hyoid muscles and with the body of the hyoid bone. The two lateral ligaments are rounded, elastic cords, which pass between the superior cornua of the thyroid cartilage and the extremities of the greater cornua of the hyoid bone. A small cartilaginous nodule (cartilago triticia), sometimes bony, is frequently found in each.

The Membrana Quadrangularis is an elastic membrane containing numerous glands. The fibres of the membrane run in part downward and in part downward and backward. The membrane on each side arises in front and above at the lateral margin of the cartilage of the epiglottis, below at the posterior surface of the angle of the thyroid cartilage and becomes attached behind to the cornicula laryngis and to the inner margins of the arytenoid cartilages. The membranes converge below and medianward. The ligamentum ventriculare is the superior end of the membrane (Spalteholz). The fibres constituting the ligamentum ventriculare are given off at the thyroid cartilage above the ligamentum vocale and pass horizontally backward to the medial margin of the fovea triangularis of the arytenoid cartilage. The epiglottis is connected to the tongue by the three glosso-epiglottidean folds of mucous membrane, which may also be considered as extrinsic ligaments of the epiglottis.

The Glosso-epiglottidean Folds or Ligaments (plicae epiglotticae) (Fig. 984) number three. The middle glosso-epiglottidean fold (plica glossoepiglottica mediana) passes from the middle of the anterior free surface of the epiglottis to the base of the tongue. It contains the glosso-epiglottic ligament. The lateral glosso-epiglottidean or the pharyngo-epiglottidean fold (plica glossoepiglottica lateralis) on each side passes from the side of the epiglottis to the side of the base of the tongue and to the pharyngeal wall. On each side between the median and lateral folds is a depression, the vallecula epiglottica.

The Hyo-epiglottic Ligament (ligamentum hyoepiglotticum) is an elastic band, which extends from the anterior surface of the epiglottis, near its apex, to the

2 Ibid.
upper border of the body of the hyoid bone. The epiglottis is attached to the thyroid cartilage, below and behind the superior thyroid notch, by the strong and elastic *thyro-epiglottic ligament* (ligamentum thyreoepiglotticum) (Fig. 985). Between the epiglottis, the hyo-epiglottic ligament, and the thyro-hyoid membrane is a triangular space containing fat on each side of the median line.

The ligaments connecting the thyroid cartilage to the cricoid are also three in number—the *crico-thyroid membrane* and the *capsular ligaments*.

The **Crico-thyroid Membrane** (cornu elasticum) (Figs. 971 and 988) is an elastic membrane which passes radially from the posterior surface of the angle of the thyroid cartilage to the upper margin of the arch of the cricoid cartilage and to the vocal processes of the arytenoid cartilages. It is composed mainly of yellow elastic tissue. It consists of three parts, a central triangular portion and two lateral portions. The central part (ligamentum cricothyreoideum medium) is thick and strong, narrow above and broadening out below. It connects together the contiguous margins of the thyroid and cricoid cartilages. It is convex, concealed on each side by the Crico-thyroid muscle, but subcutaneous in the middle line; it is crossed horizontally by a small anastomotic arterial arch, formed by the junction of the two *crico-thyroid arteries*. The lateral portions are thinner and lie close under the mucous membrane of the larynx. They extend from the superior border of the cricoid cartilage to the inferior margin of the true vocal cords with which they are continuous. On each side are the uppermost fibres from the inferior thyro-arytenoid ligament (ligamentum vocale).

The lateral portions are lined internally by mucous membrane, and are separated from the thyroid cartilage by the lateral Crico-arytenoid and Thyr-o-arytenoid muscles. This membrane and the muscles just mentioned reduce greatly the interior of the larynx. The crico-thyroid membrane with the membrana quadrangularis constitute the *membrana elastica laryngis*.

The **Crico-arytenoid Articulation** (articulatio cricoarytaenoidea) (Fig. 981), on each side of the inferior cornu of the thyroid, with the cricoid cartilage on each side. A loose *synovial membrane* (capsula articularis cricoarytaenoidea) encloses the articulation.

The synovial capsule is strengthened by the ligamenta ceratocricoida, which pass from the lesser cornu of the thyroid to the lamina of the cricoid cartilage.

The **Crico-arytenoid Articulation** (articulatio cricoarytaenoidea) (Fig. 982) on each side is between the articular surface of the arytenoid cartilage and the arytenoid articular surface of the cricoid cartilage.

The ligaments connecting the arytenoid cartilages to the cricoid are on each side a *capsular ligament* (capsula articularis cricoarytaenoidea) and a *posterior crico-arytenoid ligament* (ligamentum cricoarytaenoideum posterius). The capsular ligaments are thin and loose capsules attached to the margin of the articular
surfaces; they are lined internally by synovial membrane. The posterior crico-arytenoid ligaments extend from the cricoid to the inner and back part of the base of the arytenoid cartilage.

The **Crico-tracheal Ligament** (*ligamentum cricotracheale*) connects the cricoid cartilage with the first ring of the trachea. It resembles the fibrous membrane which connects the cartilaginous rings of the trachea to each side.

There is on each side an articulation between the arytenoid cartilage and the **cartilage of Santorini** (*synchondrosis aryconiculata*). The cartilage of Santorini is somewhat movable and is fixed to the arytenoid by lax connective tissue. From each cartilage of Santorini a band of connective tissue runs down to the lamina of the cricoid cartilage and to the pharyngeal mucous membrane. Beneath the arytenoid muscles the ligaments from the two sides join and pass down together. Thus is formed a Y-shaped ligament called the **ligamentum corniculopharyngeum**. The portion between the cricoid cartilage and the mucous membrane of the pharynx is sometimes called the **ligamentum cricopharyngeum**.

**Interior of the Larynx** (Figs. 983, 984, and 985).—The **cavity of the larynx** (*cavum laryngis*) extends from the superior aperture of the larynx to the lower border of the cricoid cartilage. It is divided into two parts by the projection inward of the true vocal cords, between which is a narrow triangular fissure or chink, the **rima glottidis**. It is further subdivided by the false vocal cords. So we consider the larynx as divided into a portion above the false cords, a portion between the false and true vocal cords, and a portion below the true cords. The entrance of the first compartment is the superior aperture of the larynx.

**The Superior Aperture of the Larynx** (*adiitus laryngis*).—The superior aperture of the larynx (Figs. 983 and 984) is a triangular or cordiform opening, wide in front, narrow behind, and sloping obliquely downward and backward. It is bounded, in front, by the epiglottis; behind, by the apices of the arytenoid cartilages and the cornicula laryngis; and laterally, by a fold of mucous membrane, enclosing ligamentous and muscular fibres, stretched between the sides of the epiglottis and the apices of the arytenoid cartilages; these are the **aryteneo-epiglottidean folds** (Figs. 984 and 985), on the margins of which the cuneiform cartilages form more or less distinct whitish prominences.

The small gap between the cartilages of Santorini is called the **incisura interarytanoidea**. On the pharynx, on either side of the posterior portion of the superior aperture of the larynx, is a recess, called the **sinus pyriformis**.

**Upper Compartment or Vestibule of the Laryngeal Cavity** (*vestibulum laryngis*) (Figs. 983 and 985).—The vestibule is the portion between the superior opening and the false vocal cords. It is much narrower below than above. It is bounded anteriorly by the mucous membrane-covered epiglottis. The lower part of the epiglottis exhibits a prominence called the **cushion or tubercle** (Fig. 983). The lateral wall of the vestibule on each side is the **aryteneo-epiglottidean fold** (Fig. 985), which extends from the summit of the arytenoid cartilage forward, upward, and outward to the margin of the epiglottis, and which contains fibres of the Thyro-epiglottideus and Arytenoideus muscles (*musculus arytenoepiglottidean*). Near the posterior end of the fold are two trivial elevations: the anterior elevation is caused by the prominence of the cuneiform cartilage, and is called the **cuneiform tubercle of Wrisberg** (*tuberculum cuneiforme [Wrisbergi]*); the posterior elevation is caused by the anterior margin of the arytenoid cartilage and the cartilage of Santorini, and is called the **cornical tubercle of Santorini** (*tuberculum corniculatum [Santorini]*). Between these elevations is a groove, the **filtrum ventriculi of Merkel**, which passes into the space between the false and true vocal cords. The anterior elevation passes into the false vocal cord, the posterior elevation into the true vocal cord. The posterior portion of the laryngeal vestibule is the narrow space between the upper portions of the arytenoid cartilages.
The Middle Compartment of the Larynx (Figs. 983 and 985).—This lies between the false vocal cords above and the true vocal cords below. It is the smallest of the laryngeal compartments. It opens into the vestibule by way of the gap between the false vocal cords, which is called the false glottis; it opens into the lower compartment of the larynx by way of the space between the true vocal cords, the true glottis.

The True Glottis.—The true glottis is the apparatus for producing tone and is formed by the true vocal cords.

The Chink of the Glottis (rima glottidis) (Figs. 983 and 984).—The chink of the glottis is the elongated fissure or chink between the inferior or true vocal cords in front, and between the bases and vocal processes of the arytenoid cartilages behind. It is therefore frequently subdivided into an anterior, interligamentous or vocal portion, the glottis vocalis (pars intermembranacea), and a posterior, intercartilaginous or respiratory portion, the glottis respiratoria (pars intercartilaginea). Posteriorly it is limited by the mucous membrane passing between the arytenoid cartilages. The vocal portion averages about three-fifths of the length of the entire aperture. It is the narrowest part of the cavity of the larynx, and its level corresponds to the bases of the arytenoid cartilages. Its length, in the male, measures rather less than an inch (20 to 25 mm.); in the female it is shorter by 5 or 6 mm., or three lines. The width and shape of the rima glottidis vary with the movements of the vocal cords and arytenoid cartilages during respiration and phonation. In the condition of rest—i.e., when these structures are uninfluenced by muscular action, as in quiet respiration, the glottis vocalis is triangular, with its apex in front and its base behind, the latter being represented by a line about 8 mm. long, connecting the anterior extremities of the vocal processes, while the inner surfaces of the arytenoids are parallel to each other, and hence the glottis respiratoria is rectangular. During extreme adduction of the cords, as in the emission of a high note, the glottis vocalis is reduced to a linear slit by the apposition of the cords, while the glottis respiratoria is triangular, its apex corresponding to the anterior extremities of the vocal processes of the arytenoids, which are approximated by the inward rotation of the cartilages. Conversely in extreme abduction of the cords, as in forced inspiration, the arytenoids and their vocal processes are rotated outward, and the glottis respiratoria is triangular in shape, but with its apex directed backward. In this condition the entire glottis is somewhat lozenge-shaped, the sides of the glottis vocalis diverging from before backward, those of the glottis
respiratoria diverging from behind forward, the widest part of the aperture corresponding with the attachment of the cords to the vocal processes. 1

The Superior or False Vocal Cords (plicae ventriculares) (Figs. 983, 984, and 985), so called because they are not directly concerned in the production of the voice. Each is a thick fold of mucous membrane, enclosing a narrow band of fibrous tissue, the superior thyro-arytenoid ligament, which is attached in front to the angle of the thyroid cartilage immediately below the attachment of the epiglottis, and behind to the anterior surface of the arytenoid cartilage. The lower border of this ligament, enclosed in mucous membrane, forms a free crescentic margin, which constitutes the upper boundary of the ventricle of the larynx. The false vocal cord contains the lower part of the membrana quadrangularis with the ligamentum ventriculare, the muscle ventricularis, and laryngeal glands.

The Inferior or True Vocal Cords (plicae vocales) (Figs. 983, 984, 985, and 989), so called from their being concerned in the production of sound. Each is a strong band, the inferior thyro-arytenoid ligament (ligamentum vocale), covered on its surface by a thin layer of mucous membrane. Each ligament consists of a band of yellow elastic tissue, attached in front to the depression between the alae of the thyroid cartilage, and behind to the anterior angle of the base of the arytenoid. This angle is called the vocal process. Its lower border is continuous with the thin lateral part of the crico-thyroid membrane. Its upper border forms the lower boundary of the ventricle of the larynx. Externally, the Thyro-arytenoideus muscle lies parallel with it. It is covered internally by mucous membrane, which is extremely pale, thin, and closely adherent to its surface. The upper margin of the true vocal cord is covered with mucous membrane, and is the lower boundary of the ventricle of the larynx. Over the vocal process it is yellowish (macula flava). The true vocal cord contains the upper part of the crico-thyroid membrane with the ligamentum vocale and the muscle vocalis.

1 On the shape of the rima glottidis, in the various conditions of breathing and speaking, see Czermak. On the Laryngoscope, translated for the New Sydenham Society.—Ed. of 15th English edition.
The Ventricile of the Larynx or Laryngeal Sinus (ventriculus laryngis [Morgagnii]) (Figs. 970 and 972) is an oblong fossa, situated between the superior and inferior vocal cords on each side, and extending nearly their entire length. This fossa is bounded, above, by the free crescentic edge of the superior vocal cord; below, by the straight margin of the inferior vocal cord; externally, by the mucous membrane covering the corresponding Thyro-arytenoideus muscle. The anterior part of the ventricle leads up by a narrow opening into a caecal pouch of mucous membrane of variable size, called the laryngeal pouch.

The Laryngeal Sacculæ or Pouch (appendix ventriculi) (Fig. 983), or laryngeal pouch, is a membranous sac, placed between the superior vocal cord and the inner surface of the thyroid cartilage, occasionally extending as far as its upper border or even higher; it is conical in form, and curved slightly backward. On the surface of its mucous membrane are the openings of sixty or seventy mucous glands, which are lodged in the submucous areolar tissue. This sac is enclosed in a fibrous capsule, continuous below with the superior thyro-arytenoid ligament; its laryngeal surface is covered by the Aryteno-epiglottideus inferior muscle (compressor sacculi laryngis of Hilton); while its exterior is covered by the Thyro-arytenoideus and Thyro-epiglottideus muscles. These muscles compress the sacculus laryngis, and discharge the secretion it contains upon the vocal cords, the surfaces of which it is intended to lubricate.

The Lower Compartment of the Larynx (Figs. 983 and 985).—This space is just beneath the true vocal cords and leads into the trachea. It is called the additus glottidis inferior. Above, on cross-section, it is oval; below, it is round. It is bounded by the inner surface of the crico-thyroid membrane and the cricoid cartilage.

Muscles of the Larynx (musculi laryngis).—We do not consider all muscles which are attached to laryngeal cartilages as laryngeal muscles. Some muscles so attached in reality belong to other regions, for instance, the Inferior constrictor, the Stylo-pharyngeus, the Sterno-thyroid, the Thyro-hyoid, and the Palatopharyngeus. The muscles which really belong to the larynx are called intrinsic.

Four muscles of the vocal cords and rima glottidis are paired and one is single.
The paired muscles are the crico-thyroid, the posterior crico-arytenoid, the lateral crico-arytenoid, and the thyro-arytenoid. The single muscle is the arytenoideus.

A Crico-thyroid (m. crico-thyreoides) (Figs. 981, 983, and 986) is placed on each side. It is triangular in form, and situated at the forepart and side of the cricoid cartilage. It arises from the front and lateral part of the cricoid cartilage; its fibres diverge, passing obliquely upward and outward to be inserted into the lower border of the thyroid cartilage and into the anterior border of the lower cornu.

The inner borders of these two muscles are separated in the middle line by a triangular interval occupied by the central part of the crico-thyroid membrane.

The Posterior Crico-arytenoid (m. cricoarytaenoideus posterior) (Figs. 987, 988, and 989), a paired muscle, arises from the broad depression occupying each lateral half of the posterior surface of the cricoid cartilage; its fibres pass upward and outward, converging to be inserted into the outer angle (museum process) of the base of the arytenoid cartilage. The upper fibres are nearly horizontal, the middle oblique, and the lower almost vertical.

The Arytenoideus (Figs. 985, 987, 988, and 989) is a single muscle filling up the posterior concave surface of the arytenoid cartilages. It arises from the posterior surface and outer border of one arytenoid cartilage, and is inserted into the corresponding parts of the opposite cartilage. It consists of three planes of fibres, two oblique and one transverse. The oblique fibres (m. arytaenoideus obliquus), the most superficial, form two fasciculi, which pass from the base of one cartilage to the apex of the opposite one. The transverse fibres (m. arytaenoideus transversus), the deepest and most numerous, pass transversely across between the two cartilages; hence the Arytenoideus was formerly considered as three muscles, the transverse.
verse and the two oblique. A few of the oblique fibres are around the outer margin of the cartilage, and blend with the Thyro-arytenoid in the aryteno-epiglottidean fold, and are called the Aryteno-epiglottideus muscles.

In order to expose the rest of the muscles of the larynx the thyroid cartilage of one side must be removed. Begin by taking away the crico-thyroid muscle, then dividing the lateral thyro-hyoid ligament; disarticulate the inferior cornu of the thyroid cartilage from the cricoid cartilage, then carefully cut through the thyroid cartilage a short distance from its union with its twin. The following muscles will then be exposed after a little cleaning: the Lateral crico-thyroid, the Thyro-arytenoid, the Thyro-epiglottideus.

The Lateral crico-arytenoid (m. cricoarytenoideus lateralis) (Figs. 988 and 989), a paired muscle, is smaller than the preceding, and of an oblong form. It arises from the upper border of the side of the cricoid cartilage, and, passing obliquely upward and backward, is inserted into the muscular process of the arytenoid cartilage in front of the posterior Crico-arytenoid muscle.

The Thyro-arytenoid (m. thyroarytenoideus) (Figs. 988 and 989), a paired muscle, is broad and flat. It lies parallel with the outer side of the true vocal cord. It arises in front from the lower half of the receding angle of the thyroid cartilage, and from the crico-thyroid membrane. Its fibres pass backward and outward, to be inserted into the base and anterior surface of the arytenoid cartilage. This muscle consists of two fasciculi. The inner or inferior fasciculus (m. vocalis), the thicker, is prismatic in shape and is inserted into the vocal process of the arytenoid cartilage, and into the adjacent portion of its anterior surface; it lies parallel with the true vocal cord, to which it is adherent. This fasciculus on its deeper surface gives off some fibres which are attached to the true vocal cord. These are called the ary-vocalis (Ludwig). The outer or superior fasciculus, the thinner, is inserted into the anterior surface and outer border of the arytenoid cartilage above the preceding fibres; it lies on the outer side of the sacculus laryngis, immediately beneath the mucous membrane.

The muscles of the epiglottis are the—

Thyro-epiglottideus. Aryteno-epiglottideus superior.

Aryteno-epiglottideus inferior.

The Thyro-epiglottideus (m. thyroepiglotticus) is a delicate fasciculus, which arises from the inner surface of the thyroid cartilage, just external to the origin of the Thyro-arytenoid muscle, of which it is sometimes described as a part, and spreads over the outer surface of the sacculus laryngis; some of its fibres are lost in the aryteno-epiglottidean fold, while the others are continued forward to the margin of the epiglottis.

The Aryteno-epiglottideus (Figs. 983 and 988) is properly divided into two muscles, a superior and an inferior.

The Aryteno-epiglottideus superior consists of a few delicate muscular fasciculi, which arise from the apex of the arytenoid cartilages, and become lost in the fold of mucous membrane, the aryteno-epiglottidean fold, extending between the arytenoid cartilage and the side of the epiglottis.

The Aryteno-epiglottideus inferior, the Compressor sacculi laryngis of Hilton, arises from the arytenoid cartilage, just above the attachment of the superior vocal cord; passing forward and upward, it spreads out upon the anterior surface of the epiglottis. This muscle is separated from the preceding by an indistinct areolar interval.

1 Henle describes these two portions as separate muscles, under the names of the External and Internal thyro-arytenoid.—Ed. of 15th English edition.
2 Luschka has described a small but fairly constant muscle as the Arytenoideus rectus. It is attached below to the posterior concave surface of the arytenoid cartilage, beneath the Arytenoideus muscle, and, passing upward, emerges at the upper border of this muscle, and is inserted into the posterior surface of the cartilage of Santorini (Anatomy, by Hyrtl, p. 718).—Ed. of 15th English edition.
3 Musculus triticeo-glossus. Bochdalek, Jr. (Prager Vierteljahrschrift, 1866, 2d part) describes a muscle hitherto entirely overlooked, except by Henle, who makes a brief statement in his Anatomy, which arises from the node of cartilage (corpus tritceum) in the posterior thyro-hyoid ligament, and passes forward and upward to enter the tongue along with the Hyo-glossus muscle. He met with this muscle eight times in twenty-two subjects. It occurred in both sexes, sometimes on both sides, at others on one only.—Ed. of 15th English edition.
Actions.—In considering the action of the muscles of the larynx, they may be conveniently divided into two groups, viz.: 1. Those which open and close the glottis. 2. Those which regulate the degree of tension of the vocal cords.

1. The muscles which open the glottis are the two Posterior crico-arytenoids; and those which close it are the Arytenoideus and the two Lateral crico-arytenoids.

2. The muscles which regulate the tension of the vocal cords are the two Cricothyroids, which tense and elongate them, and the two Thyro-arytenoids, which relax and shorten them. The Thyro-epiglottideus is a depressor of the epiglottis, and the Aryteno-epiglottideus, superior and inferior, constrict the superior aperture of the larynx.

The Posterior crico-arytenoids separate the chordae vocales, and consequently open the glottis, by rotating the arytenoid cartilages outward around a vertical axis passing through the crico-arytenoid joints, so that their vocal processes and the vocal cords attached to them become widely separated.

The Lateral crico-arytenoids close the glottis by rotating the arytenoid cartilages inward so as to approximate their vocal processes.

The Arytenoideus muscle approximates the arytenoid cartilages, and thus closes the opening of the glottis, especially at its back part.

The Crico-thyroid muscles produce tension and elongation of the vocal cords. This is effected as follows: the thyroid cartilage is fixed by its extrinsic muscles; then the Crico-thyroid muscles, when they act, draw upward the front of the cricoideal cartilage, and so depress the posterior portion, which carries with it the arytenoid cartilages, and thus elongate the vocal cords.

The Thyro-arytenoid muscles, consisting of two parts having different attachments and different directions, are rather complicated as regards their action. Their main use is to draw the arytenoid cartilages forward toward the thyroid, and thus shorten and relax the vocal cords. But, owing to the connection of the inner portion with the vocal cord, this part, if acting separately, is supposed to modify its elasticity and tension, and the outer portion, being inserted into the outer part of the anterior surface of the arytenoid cartilage, may rotate it inward, and thus narrow the rima glottidis by bringing the two cords together.

The Thyro-epiglottidei may depress the epiglottis; they assist in compressing the sacculi laryngis. The Aryteno-epiglottideus inferior constricts the superior aperture of the larynx, when it is drawn upward, during deglutition. The aryteno-epiglottideus inferior, together with some fibres of the Thyro-arytenoidei, compress the sacculus laryngis.

The Mucous Membrane of the Larynx is continuous above with that lining the mouth and pharynx, and it is prolonged through the trachea and bronchi into the lungs. It lines the posterior surface and the anterior part of the upper surface of the epiglottis, to which it is closely adherent. In the rest of the larynx, above the true vocal cords, it is lax and rests upon a considerable submucous layer. The mucous membrane, with the submucous coat, ligamentous and muscular fibres, forms the aryteno-epiglottidean folds, which folds are the lateral boundaries of the superior aperture of the larynx. It lines the whole of the cavity of the larynx; forms by its reduplication the chief part of the superior or false vocal cord; and, from the ventricle, is continued into the sacculus laryngis. It is then reflected over the true vocal cords, where it is thin and very intimately adherent; covers the inner surface of the crico-thyroid membrane and cricoid cartilage; and is ultimately continuous with the lining membrane of the trachea. The forepart of the anterior surface and the upper half of the posterior surface of the epiglottis, the upper part of the aryteno-epiglottidean folds, and the true vocal cords are covered by stratified squamous epithelium; the rest of the laryngeal mucous membrane is covered by columnar ciliated cells.

The mucous membrane above the rima glottidis is extremely sensitive, and during life the lightest touch of a foreign body produces cough.

Glands.—The mucous membrane of the larynx is furnished with numerous muciparous glands, the orifices of which are found in nearly every part; they are very numerous upon the epiglottis, being lodged in little pits in its substance; they are also found in large numbers along the posterior margin of the aryteno-epiglottidean fold, in front of the arytenoid cartilages, where they are termed the
arytenoid glands. They exist also in large numbers upon the inner surface of the sacculus laryngis. None are found on the surface of the true vocal cords.

Vessels and Nerves.—The arteries of the larynx (Fig. 990) are the laryngeal branches derived from the superior and inferior thyroid. The superior laryngeal artery from the superior thyroid courses along by the internal laryngeal nerve; the inferior laryngeal artery from the inferior thyroid courses along with the recurrent laryngeal nerve. The veins accompany the arteries; those accompanying the superior laryngeal artery join the superior thyroid vein which opens into the internal jugular vein; while those accompanying the inferior laryngeal artery join the inferior thyroid vein which opens into the innominate vein. The laryngeal lymphatics arise from a network in the mucous membrane. This network is divisible into two portions, a superior and an inferior, which are to be regarded as almost independent areas. The superior region includes all of the "laryngeal mucous membrane above the glottis, epiglottis, aryteno-epiglottidean folds, interarytenoid region, and superior vocal cords." The inferior area is the laryngeal mucous membrane below the glottis. The lymphatics of one-half of the larynx do not communicate with those of the other half in the median line in front, but do in the median line behind. The efferent vessels from the superior network accompany the superior laryngeal artery, pierce the thyro-hyoid membrane, and divide into three sets. One or two lymphatic vessels pass upward and terminate in a gland slightly below the posterior belly of the Digastric muscle. A group of vessels passes horizontally outward to terminate in the glands situated on the internal jugular vein on a level with the bifurcation of the common carotid artery. Another group descends and empties into the internal jugular group of glands at a lower level than the horizontal vessels. Trunks from the inferior network of the laryngeal mucous membrane form two groups. The anterior or supraracricoid group consists of three trunks which pass through the crico-thyroid membrane, to empty into the pre-laryngeal glands, the pre-tracheal gland, and the middle and lower deep cervical glands. The posterior group consists of

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1 Philip R. W. De Santi in the Lancet, June 18, 1904.
2 Poirier, Cunéo, Most, De Santi.
of "from three to five trunks, which pass over the crico-tracheal fascia at the junction of the lateral and posterior aspects of the trachea," and terminate in the recurrent glands about the recurrent laryngeal nerve. The nerves are derived from the internal and external laryngeal branches of the superior laryngeal nerve, from the inferior or recurrent laryngeal, and from the sympathetic. The internal laryngeal nerve is almost entirely sensor, but some motor filaments are said to be carried by it to the Arytenoideus muscle. It divides into a branch which is distributed to both surfaces of the epiglottis, a second to the aryteno-epiglottidean folds, and a third, the largest, which supplies the mucous membrane over the back of the larynx and communicates with the recurrent laryngeal. The external laryngeal nerve supplies the Crico-thyroid muscle. The recurrent laryngeal passes upward under the lower border of the Inferior constrictor, and enters the larynx between the cricoid and thyroid cartilages. It supplies all the muscles of the larynx except the Crico-thyroid and part of the Arytenoideus. The sensor branches of the laryngeal nerves form subepithelial plexuses, from which fibres ascend to end between the cells covering the mucous membrane.

Over the posterior surface of the epiglottis, in the aryteno-epiglottidean folds, and less regularly in some other parts, taste-buds, similar to those in the tongue, are found.

THE TRACHEA AND BRONCHI (Fig. 991).

The trachea or windpipe is a cartilaginous membranous, elastic, cylindrical tube, flattened posteriorly, which extends from the lower part of the larynx, on a level with the sixth cervical vertebra, to opposite the body of the fourth, or sometimes of the fifth, thoracic vertebra, where it divides (bifurcato tracheae) into two bronchi, one for each lung. This point is at the level of the spine of the fourth thoracic vertebra. The trachea is found to be more deeply placed the lower down it is examined. It is in the median line, deviating below a very little to the right side. When a cross-section is made of the trachea it is seen that its anterior and lateral walls are rounded, but its posterior wall is flat (Fig. 995). The largest diameter of the tube is the middle; from this point the diameter diminishes toward the bronchi and toward the laryngeal end. The trachea measures about four inches and a half in length; its diameter from side to side is from three-quarters of an inch to an inch, being always greater in the male than in the female.

Relations.—The anterior surface of the trachea is convex, and covered in the neck, from above downward, by the isthmus of the thyroid gland, the inferior thyroid veins, the arteria thyroididea ima (when that vessel exists), the Sterno-hyoid and Sterno-thyroid muscles, the cervical fascia, and more superficially, by the anastomosing branches between the anterior jugular veins: in the thorax it is covered from before backward by the first piece of the sternum, the remains of the thymus gland, the left innominate vein, the arch of the aorta, the innominate and left common carotid arteries, and the deep cardiac plexus. Posteriorly, it is in relation with the oesophagus; laterally, in the neck, it is in relation with the common carotid arteries, the lateral lobes of the thyroid gland, the inferior thyroid arteries, and recurrent laryngeal nerves; and, in the thorax, it lies in the upper part of the interpleural space, that is, in the superior mediastinum, and is in relation on the right to the pleura and right vagus, and near the root of the neck to the innominate artery; on its left side are the recurrent laryngeal nerve, the aortic arch, the left common carotid and subclavian arteries.

The Right Bronchus (bronchus dexter).—The unbranched portion of the right bronchus is wider, shorter, and more vertical in direction than the left, is about an inch in length, and enters the hilum of the right lung opposite the fifth thoracic

1 De Santi, in the Lancet, June 18, 1904.
vertebra. It forms an angle to the median plane of about 29 degrees. The vena azygos major arches over it from behind; and the right pulmonary artery lies below and then in front of it. About three-quarters of an inch from its commencement it gives off a branch to the upper lobe of the right lung. This is termed the eparterial branch \((\text{ramus bronchialis eparterialis})\), because it is given off above the right pulmonary artery. The bronchus now passes below the artery, and is known as the hyparterial branch \((\text{ramus bronchialis hyparterialis})\). It divides into two branches for the middle and lower lobes.

If a transverse section of the trachea is made a short distance above its point of bifurcation, and a bird's-eye view taken of its interior (Fig. 995), the septum placed at the bottom of the trachea and separating the two bronchi will be seen to occupy the left of the median line, and the right bronchus appears to be a more direct continuation than the left, so that any solid body dropping into the trachea would naturally be directed toward the right bronchus. This tendency is aided by the larger size of the right tube as compared with its fellow. This fact
serves to explain why a foreign body in the trachea more frequently falls into the right bronchus than into the left.\(^1\)

**The Left Bronchus (bronchus sinister).**—The left bronchus is smaller and longer than the right, being nearly two inches in length. It forms an angle to the median plane of about 46 degrees. It is slightly curved and enters the root of the left lung, opposite the sixth thoracic vertebra, about an inch lower than the right bronchus. It passes beneath the arch of the aorta, crosses in front of the oesophagus, the thoracic duct, and the descending aorta, and has the left pulmonary artery lying at first above, and then in front of it. The left bronchus has no branch corresponding to the eparterial branch of the right bronchus, and therefore it has been supposed by some that there is no upper lobe to the left lung, but that the so-called upper lobe corresponds to the middle lobe of the right lung. The left bronchus does have an hyparterial branch.

When the main or stem bronchus enters the lung on each side it appears to divide into nearly equal branches at the root of the lung, but a somewhat similar arrangement to what is found in many animals may be made out where each main bronchus passes downward and backward toward the extremity of the lower lobe, and ends near the posterior surface of the base of the lung, a portion of pulmonary substance which is between the Diaphragm and the wall of the chest. It gives off four branches, or *lateral bronchi* (rami bronchiales), at intervals in two directions, dorsally and ventrally, and, in addition, accessory branches, which arise from the front of the bronchus and pass mesally and dorsally into the inferior lobe. In the right bronchus the first ventral branch supplies the middle lobe, the other three and all the dorsal going to the lower lobe; in the left bronchus, the first ventral branch supplies the middle lobe, the other three and all the dorsal going to the lower lobe; in the left bronchus, the first central supplies the superior lobe, and all the others, both ventral and dorsal, go to the lower lobe. The dorsal and ventral branches divide into smaller branches, and these again into smaller branches or *bronchioles* (Fig. 994). Each bronchioles divides into minute branches (*bronchiolae respiratorii*) (Fig. 994), the walls of which show numerous areas of bulging called *alveoli* (Fig. 994). From the bronchiolae respiratorii come the terminal branches of the bronchi. These terminal branches are the *alveolar ducts* (ductuli alveolares), and they are bulged by numerous alveoli (Fig. 994). They connect by openings at their termination with several cavities of irregular form, which are called *atria*. Each atrium is connected with several or many larger cavities, known as *sacculi alveolares, air-cells*, or *air-sacs* (*infundibula*). The entire surface of the air-sacs is filled with small cavities, the *pulmonary alveoli* (alveoli pulmonis). An alveolar duct with its branches forms a *pulmonary lobule* (lobulus pulmonis) (Fig. 993).

**Structure of the Trachea.**—The trachea is composed of imperfect cartilaginous rings, fibrous membrane, muscular fibres, mucous membrane, and glands.

**The Cartilages.**—The cartilages vary from sixteen to twenty in number; each forms an imperfect ring, which surrounds about two-thirds of the cylinder of the

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\(^1\) Reigel asserts that the entrance of a foreign body into the *left* bronchus is by no means so infrequent as is generally supposed. See also Med.-Chir. Transactions, vol. lxxi., p. 121.—Ed. of 15th English edition.
trachea, being imperfect behind, where the tube is completed by fibrous membrane. The cartilages are placed horizontally above each other, separated by narrow membranous intervals. They measure about two lines in depth, and half a line in thickness. Their outer surfaces are flattened, but internally they are convex, from being thicker in the middle than at the margins. Two or more of the cartilages often unite, partially or completely, and are sometimes bifurcated at their extremities. They are highly elastic, but sometimes become calcified in advanced life. In the right bronchus the cartilages vary in number from six to eight; in the left, from nine to twelve. They are shorter and narrower than those of the trachea. The peculiar cartilages are the first and the last.

The First Cartilage is broader than the rest, and sometimes divided at one end; it is connected by fibrous membrane with the lower border of the cricoid cartilage, with which or with the succeeding cartilage it is sometimes blended.

The Last Cartilage is thick and broad in the middle, in consequence of its lower border being prolonged into a triangular hook-shaped process which curves downward and backward between the two bronchi. It terminates on each side in an imperfect ring which encloses the commencement of the bronchi. The cartilage above the last is somewhat broader than the rest at its centre.

The Fibrous Membrane.—The cartilages are enclosed in an elastic fibrous membrane which forms a double layer, one layer, the thicker of the two, passing over the outer surface of the ring, the other over the inner surface; at the upper and lower margins of the cartilages these two layers blend together to form a single membrane, which connects the rings one with another. They are thus, as it were, embedded in the membrane. In the space behind, between the extremities of the rings, the membrane forms a single distinct layer.

The Muscular Fibres.—The muscular fibres are disposed in two layers, longitudinal and transverse.
The **Longitudinal Fibres** are the most external, and consist merely of a few scattered longitudinal bundles of fibres.

The **Transverse Fibres** constitute the **Trachealis muscle of Todd and Bowman**. The most internal form a thin layer which extends transversely between the ends of the cartilages and the intervals between them at the posterior part of the trachea. The muscular fibres are of the unstriped variety.

**The Mucous Membrane.**—The mucous membrane is continuous above with that of the larynx, and below with that of the bronchi. Microscopically, it consists of areolar and lymphoid tissue, and presents a well-marked basement-membrane, supporting a layer of columnar, ciliated epithelium, between the deeper ends of which are smaller triangular cells, the bases of which, often branched, are attached to the basement-membrane. These triangular cells are mucus-secreting, and may be seen as goblet-cells or chalice-cells when their contents have been discharged. In the deepest part of the mucous membrane, and especially between the mucous and submucous layers, longitudinally arranged fibres are very abundant and form a distinct layer.

**The Tracheal Glands (glandulae tracheales).**—The tracheal glands are found in great abundance at the posterior part of the trachea. They are racemose glands, and consist of a basement-membrane lined by columnar mucus-secreting cells. They are situated at the back of the trachea, outside the layer of muscular tissue, between it and the outer fibrous layer. Their excretory ducts pierce the muscular and inner fibrous layers, and pass through the submucous and mucous layers to open on the surface of the mucous membrane. Some glands of smaller size are also found at the sides of the trachea, between the layers of fibrous tissue connecting the rings, and others immediately beneath the mucous coat. The secretion from these glands serves to lubricate the inner surface of the trachea.

**Vessels and Nerves.**—The trachea is supplied with blood by the inferior thyroid arteries. The **veins** terminate in the thyroid venous plexus. The **nerves** are derived from the vagus and its recurrent branches and from the sympathetic.
THE TRACHEA AND BRONCHI

Lymphatic Glands.—The trachea is surrounded by lax connective tissue which contains numerous lymph glands, known as the peritracheo-bronchial glands. They are divided into four groups (Baréty). A group to the right side, in the angle between the trachea and right bronchus and ascending to the region of the subclavian vessels. A group to the left side, in the angle formed by the trachea and left bronchus, and ascending to about the arch of the aorta and the recurrent laryngeal nerve. The two groups just described are usually called tracheal glands (lymphoglandulacœ tracheales). A third group is in the angle formed by the bifurcation of the trachea. These constitute the bronchial glands (lymphoglandulacœ bronchiales). They number ten or twelve (Cunéo). A fourth group, the interbronchial glands, are found in angles of bifurcation of the larger bronchi in the lung parenchyma. Very early in life the peritracheo-bronchial glands become dark or even black from the deposition of carbonaceous substance brought by the leukocytes from the bronchial tubes. This condition is called anthracosis.

Surface Form.—In the middle line of the neck some of the cartilages of the larynx can readily be distinguished. In the receding angle below the chin the hyoid bone can easily be made out, and a finger’s breadth below it is the pomum Adami, the prominence between the upper borders of the two alae of the thyroid cartilage. About an inch below this, in the middle line, is a depression corresponding to the crico-thyroid space, in which the operation of laryngotomy is performed. This depression is bounded below by a prominent arch, the anterior ring of the cricoid cartilage, below which the trachea can be felt, though it is only in the emaciated adult that the separate rings can be distinguished. The lower part of the trachea is not easily made out, for as it descends in the neck it takes a deeper position, and is farther removed from the surface. The level of the vocal cords corresponds to the middle of the anterior margin of the thyroid cartilage.

With the laryngoscope, the following structures can be seen: The base of the tongue and the upper surface of the epiglottis, with the glosso-epiglottic ligaments; the superior aperture of the larynx, bounded on either side by the aryteno-epiglottidean folds, in which may be seen two rounded eminences corresponding to the cornicula and euneiform cartilages. Beneath these, the true and false vocal cords, with the ventricle between them. Still deeper, the cricoid cartilage and some of the anterior parts of the rings of the trachea, and sometimes, in deep inspiration, the bifurcation of the trachea.

Surgical Anatomy.—Foreign bodies often find their way into the air-passages. These may be either large soft substances, as a piece of meat, which may become lodged in the upper aperture of the larynx or in the rima glottidis, and cause speedy suffocation unless rapidly got rid of, or unless an opening is made into the air-passages below, so as to enable the patient to breathe. Smaller bodies, frequently of a hard nature, such as cherry- or plum-stones, small pieces of bone, buttons, etc., may find their way through the rima glottidis into the trachea or bronchus, or may become lodged in the ventricle of the larynx. The dangers then depend not so much upon the mechanical obstruction as upon the spasm of the glottis which they excite from reflex irritation. When lodged in the ventricle of the larynx, they may produce very few symptoms beyond sudden loss of voice or alteration in the voice sounds, immediately following the inhalation of the foreign body. When, however, they are situated in the trachea, they are constantly striking against the vocal cords during expiratory efforts, and produce attacks of dyspnea from spasm of the glottis. When lodged in the bronchus, they usually become fixed there, and, occluding the lumen of the tube, cause a loss of the respiratory murmur on the affected side, which is, as stated above, more often the right.

Beneath the mucous membrane of the upper part of the air-passages there is a considerable amount of submucous tissue which is liable to become much swollen from effusion in inflammatory affections, constituting the disease known as "edema of the glottis." This effusion does not extend below the level of the true vocal cords, on account of the fact that the mucous membrane is closely adherent to these structures, without the intervention of any submucous tissue. So that, in cases of this disease in which it is necessary to open the air-passages to prevent suffocation, the operation of laryngotomy is sufficient.

Chronic laryngitis is an inflammation of the mucous glands of the larynx, which occurs in those who speak much in public, and is known as "clergyman's sore throat." It is due to the dryness induced by the large amount of cold air drawn into the air-passages during prolonged speaking, which incites increased activity in the mucous glands to keep the parts moist, and this eventually terminates in inflammation of these structures.

Ulceration of the larynx may occur from syphilis; either as a superficial ulceration, or from the softening of a gumma; from tuberculous disease (laryngeal phthisis), or from malignant disease (epithelioma).
The air-passages may be opened surgically in two different situations: through the crico-thyroid membrane (laryngotomy), or in some part of the trachea (tracheotomy); and to these some surgeons have added a third method, by opening the crico-thyroid membrane and dividing the cartilage with the upper ring of the trachea (laryngo-tracheotomy).

Laryngotomy is anatomically the more simple operation: it can readily be performed, and should be employed in those cases where the air-passages require opening in an emergency for the relief of some sudden obstruction to respiration. The crico-thyroid membrane is very superficial, being covered only in the middle line by the skin, superficial fascia, and the deep fascia. On each side of the middle line it is also covered by the Sterno-hyoid and Sterno-thyroid muscles, which diverge from each other at their upper parts, leaving a slight interval between them. On these muscles rest the anterior jugular veins. The only vessel of any importance in connection with this operation is the crico-thyroid artery, which crosses the crico-thyroid membrane, and which may be wounded, but rarely gives rise to any trouble. The operation is performed thus: the head being thrown back and steadied by an assistant, the finger is passed over the front of the neck, and the crico-thyroid depression felt for. A vertical incision is then made through the skin, in the middle line over this spot, and carried down through the fascia until the crico-thyroid membrane is exposed. A cross-cut is then made through the membrane, close to the upper border of the cricoid cartilage, so as to avoid, if possible, the crico-thyroid artery, and a tracheotomy tube is introduced. It has been recommended, as a more rapid way of performing the operation, to make a transverse instead of a longitudinal cut, through both the superficial and deep structures, and thus to open at once the air-passages. It will be seen, however, that in opening in this way the anterior jugular veins would be in danger of being wounded.

Tracheotomy may be performed either above or below the isthmus of the thyroid body, or this structure may be divided and the trachea opened behind it.

The isthmus of the thyroid gland usually crosses the second and third rings of the trachea; along its upper border is frequently to be found a large transverse communicating branch between the superior thyroid veins; and the isthmus itself is covered by a venous plexus formed between the thyroid veins of the opposite sides. Theoretically, therefore, it is advisable to avoid dividing this structure in opening the trachea.

Above the isthmus the trachea is comparatively superficial, being covered by the skin, superficial fascia, deep fascia, Sterno-hyoid and Sterno-thyroid muscles, and a second layer of the deep fascia, which, attached above to the lower border of the hyoid bone, descends beneath the muscles to the thyroid body, where it divides into two layers and enclose the isthmus.

Below the isthmus the trachea lies much more deeply, and is covered by the Sterno-hyoid and the Sterno-thyroid muscles and a quantity of loose areolar tissue in which is a plexus of veins, some of them of large size; they converge to two trunks, the inferior thyroid veins, which descend on either side of the median line on the front of the trachea and open into the innominate veins. In the infant the thymus gland ascends a variable distance along the front of the trachea, and opposite the episternal notch the windpipe is crossed by the left innominate vein. Occasionally, also, in young subjects, the innominate artery crosses the tube obliquely above the level of the sternum. The thyroidea ima artery, when that vessel exists, passes from below upward along the front of the trachea.

From these observations it must be evident that the trachea can be more readily opened above than below the isthmus of the thyroid body.

Tracheotomy above the isthmus is performed thus: the patient should, if possible, be laid on his back on a table in a good light. A pillow is to be placed under the shoulders and the head thrown back and steadied by an assistant. The surgeon standing on the right side of his patient makes an incision from an inch and a half to two inches in length in the median line of the neck from the top of the cricoid cartilage. The incision must be made exactly in the middle line, so as to avoid the anterior jugular veins, and after the superficial structures have been divided the interval between the Sterno-hyoid muscles must be found, the raphe divided, and the muscles drawn apart. The lower border of the cricoid cartilage must now be felt for, and the upper part of the trachea exposed from this point downward in the middle line. Bose has recommended that the layer of fascia in front of the trachea should be divided transversely at the level of the lower border of the cricoid cartilage, and, having been seized with a pair of forceps, pressed downward with the handle of the scalpel. By this means the isthmus of the thyroid gland is depressed, and is saved from all danger of being wounded, and the trachea is cleanly exposed. The trachea is now transfixed with a sharp hook and drawn forward in order to steady it, and is then opened by inserting the knife into it and dividing the two or three upper rings from below upward. If the trachea is to be opened below the isthmus, the incision to expose it must be made from a little below the cricoid cartilage to the top of the sternum.

In the child the trachea is smaller, more deeply placed, and more movable than in the adult. In fat or short-necked people, or in those in whom the muscles of the neck are prominently developed, the trachea is more deeply placed than in others.

A portion of the larynx or the whole of it has been removed or malignant disease, laryngectomy.
Some surgeons do preliminary tracheotomy, insert a Trendelenburg cannula to prevent the flow of blood downward into the lungs, and then remove the larynx. Other surgeons do not employ preliminary tracheotomy.

Perier's method of laryngectomy is as follows: Make a vertical incision in the median line from the level of the hyoid bone to below the level of the cricoid cartilage. Make a transverse incision at each end of the vertical incision. This makes an I-shaped wound.

Separate the soft parts from the larynx and upper part of the trachea, and separate these two structures from the oesophagus. After arresting bleeding, divide the trachea below the cricoid cartilage, introduce a special cannula, complete the removal of the larynx, suture the opening of the trachea to the lower angle of the wound, and close the rest of the wound after securing drainage. In malignant disease of the larynx the associated lymphatic glands must be removed.

Partial laryngectomy, according to Sir F. Semon, is the removal of not less than one wing of the thyroid cartilage. Removal of a lesser piece of the thyroid or of a bit of the arytenoid or cricoid he considers with the operation of thyrotomy.

**THE PLEURAE** (Figs. 997, 998, 999, 1000, 1001).

Each lung is invested, upon its external surface, by an exceedingly delicate serous membrane, the pleura, which encloses the organ as far as its root, and is then reflected upon the inner surface of the thorax. The portion of the serous membrane investing the surface of the lung and dipping into the fissures between its lobes is called the pulmonary pleura or the visceral layer of the pleura (*pleura pulmonalis*) (Fig. 997), while that which lines the inner surface of the chest is called the parietal layer of the pleura (*pleura parietalis*) (Fig. 997). The two layers join at the hilum of the lung. The space between these two layers is called the **cavity of the pleura** (*cavum pleurae*), and contains a very little clear fluid. It must be borne in mind that in the healthy condition the two layers are in contact, and there

is no real cavity until the lung becomes collapsed and separates from the wall of the chest. Each pleura is therefore a shut sac, one occupying the right, the other the left half of the thorax, and they are perfectly separate from each other.
The two pleurae do not meet in the middle line of the chest, excepting anteriorly opposite the second and third pieces of the sternum—a space being left between them, which contains all the viscera of the thorax excepting the lungs; this is the mediastinum.

**Reflections of the Pleurae** (Fig. 997). **The Pleura Pulmonalis** (Fig. 997).—The pleura pulmonalis is closely attached to the surface of the lung and enters into the depths of the interlobar fissures. It leaves the lung surface at the hilum, covers the root of the lung for a little way (Fig. 1004 and 1005), and then passes into the mediastinal pleura. Between the hilum and the mediastinal pleura there is a thickened pleural fold, triangular in outline, and called the ligamentum pulmonale or the ligamentum latum pulmonis (Figs. 1004 and 1005). It is formed by the two layers of
the pulmonary pleura coming in contact below the root of the lung. This fold passes from the lower part of the inner pulmonary surface to the pericardium, and the lower border is free or attached to the diaphragmatic pleura. In the right lung the origin of this ligament is in front of the groove for the azygos vein; in the left lung it is in front of the groove for the thoracic aorta.

The Pleura Parietalis.—The pleura parietalis is a continuous membrane, but for convenience is divided into the **cervical pleura**, costal pleura, mediastinal pleura, and diaphragmatic pleura.

The Cervical Pleura or Dome of the Pleura or Cupola (cupula pleurae) (Fig. 1000) is the dome-shaped roof of the cavity of the pleura. It projects above the apex of the lung to the neck of the first rib. As the first rib is placed obliquely, the dome of the pleura reaches from one to one and one-half inches above the anterior extremity of the first rib, and from one-half an inch to one inch above the clavicle. On the outer side of the cervical pleura are the Scalenus anticus and medius muscles. Just below the apex, on the anterior and inner surface, is a groove for the subclavian artery, which vessel passes over it in an arch (Fig. 998). A little below the groove for the subclavian artery is a broader and shallower groove for the innominate and subclavian veins. Above the subclavian artery and in front and above the cervical pleura are the cords of origin of the brachial plexus and the inferior cervical ganglion (Fig. 998). The dome is strengthened and kept in place by Sibson’s aponeurosis or the vertebro-pleural ligament (Figs. 999 and 1000). This comes from a little piece of muscle, the Scalenus minimus muscle, which originates from the transverse process of the seventh cervical vertebra, broadens and becomes aponeurotic as it descends, and is inserted into the inner margin of the first rib (Figs. 998 and 999). It is also strengthened by the costo-pleural ligament (Fig. 999), from the inner surface of the neck of the first rib to the pleura, and by fibrous bands which pass to the tissue about the subclavian sheath, trachea, and oesophagus (Fig. 999).

The Costal Pleura (pleura costalis) (Fig. 997) is the shortest portion of the pleura and is connected to the parts it covers by the **endothoracic fascia** (fascia
endothoracica), a layer of connective tissue which is much thicker back of the rib cartilages than it is posteriorly. The costal pleura covers the inner surface of part of the sternum, the costal cartilages, ribs, and intercostal muscles, and the sides of the bodies of the thoracic vertebrae. This layer is loosely attached except as it passes from the heads of the ribs to the vertebrae, where it is firmly adherent.

The Medias 

tinal Pleura (pleura mediastinalis) (Fig. 999) covers the septum of the mediastinum, which intervenes between the two pleural cavities. The mediastinal pleura extends from the inner surface of the anterior wall of the thorax to the vertebrae. It is continuous in front and back with the costal pleura of the same side, the lines of junction being known, respectively, as the anterior line of pleural reflection and the posterior line of pleural reflection. Below the mediastinal pleura passes into the diaphragmatic pleura of the same side. The portion of the mediastinal pleura which fuses with the parietal layer of the pericardium is called the pericardial pleura (pleura pericardiaca).

Above the root of the lung the mediastinal pleura passes back directly to the vertebrae. “In this region the left mediastinal pleura is applied to the arch of the aorta and the phrenic and vagus nerves; to the left innominate vein, the left superior intercostal vein, and the left common carotid and left subclavian arteries; to the oesophagus and the thoracic duct. The right mediastinal pleura, on the other hand, is applied, above the level of the root of the lung, to the upper part of the aorta and right innominate vein; to the right innominate artery; to the vena cava major, as it hooks forward above the bronchus; to the vagus and phrenic nerves; and to the right side of the trachea.” Upon the pericardium the phrenic nerve is covered by the pleura. Back of the root of the lung and the pulmonary ligament, the right mediastinal pleura passes back to the vertebrae to the left of the oesophagus; the left mediastinal pleura passes back over the descending aorta, and just above the Diaphragm and in front of the aorta over the lower end of the oesophagus.

The Diaphragmatic Pleura (pleura diaphragmatica) (Figs. 1001 and 1002) covers the upper surface of the Diaphragm outside of the base of the pericardium, but does not completely cover it; for it does not pass into the interval between the wall of the thorax and Diaphragm, and before this point is reached becomes continuous with the costal pleura.

The reflection to the costal pleura begins by the sternum, at the lower margin of the sixth rib; takes place at the junction of the cartilage of the rib with the seventh rib; posteriorly, it takes place at the lower margin of the twelfth thoracic vertebra.

In the front of the chest, where the parietal layer of the pleura is reflected backward to the pericardium, the two pleural sacs are in contact for a considerable extent. At the upper part of the chest, behind the manubrium, they are not in contact; the point of reflection being represented by a line drawn from the sternoclavicular articulation to the mid-point of the junction of the manubrium to the body of the sternum. From this point the two pleurae descend in close contact to the level of the fourth costal cartilages. Here the line of reflection on the right side is continued downward in nearly a straight line to the lower end of the gladiolus and then turns outward behind the costal cartilage of the sixth rib, continuing to descend and to run outward, it passes behind the descending part of the seventh costal cartilage, and meets the axillary line at the junction of the eighth rib with the cartilage. The line of reflection continues to descend till it reaches its lowest point at the tenth rib. This point is in the axillary line, while on the left side the line of reflection diverges outward, so that opposite the seventh cartilage it is about three-quarters of an inch from the left border of the sternum. It, however, always extends considerably farther over the pericardium than the corresponding lung. From this joint the reflections of the two sides are practically

1 Cunningham’s Text-book of Anatomy.
the same. The lower limit of the pleura is on a considerably lower level than the lower limit of the lung, but does not extend to the attachment of the Diaphragm, so that below the line of reflection of the pleura from the chest wall on to the Diaphragm the latter is in direct contact with the rib cartilages and the Internal intercostal muscles. In ordinary inspiration the thin margin of the base of the lung does not extend as low as the line of pleural reflection, with the result that the costal and diaphragmatic pleura are here in contact, the narrow slit between the two being termed the phrenico-costal sinus (sinus phrenicocostalis) (Fig. 1001). A similar condition exists behind the sternum and rib cartilages, where the anterior thin margin of the lung falls short of the line of pleural reflection, and where the slit-like cavity between the two layers of pleura forms what is sometimes called the costo-mediastinal sinus (sinus costomediastinalis).

Along the line of reflection of the diaphragmatic pleura a dense fascia passes from the costal cartilages and the uncovered portion of the Diaphragm to the costal pleura. This serves to hold it in place. It is named by Cunningham the phrenico-pleural fascia.

The inner surface of the pleura is smooth, polished, and moistened by a serous fluid; its outer surface is intimately adherent to the surface of the lung, and to the pulmonary vessels as they emerge from the pericardium; it is also adherent to the upper surface of the Diaphragm; throughout the rest of its extent it is somewhat thicker, and may be separated from the adjacent parts with extreme facility.

The right pleural sac is shorter, wider, and reaches higher in the neck than the left.

Structure of the Pleura.—The pleura is composed of connective tissue containing much elastic tissue, its free surface being covered with flat endothelial cells. It is fastened to adjacent structures by subserous areolar tissue. The subserous tissue of the visceral pleura is continuous with the areolar tissue of the lung.

Vessels and Nerves.—The arteries of the pleura are derived from the intercostal, the internal mammary, the musculo-phrenic, thymic, pericardiac, and bronchial. The veins correspond to the arteries. The lymphatics are very numerous in the pleura and subserous tissue. Many of them are in direct communication with the pleural cavity by stomata between the endothelial cells. Stomata are absent in the mediastinal pleura and over the ribs (Dyskowsky). The lymphatics of the visceral layer empty into the superficial pulmonary trunks; the lymphatics of the costal pleura empty into the intercostal trunks; of the diaphragmatic pleura, into the diaphragmatic trunks; of the mediastinal pleura, into the posterior mediastinal glands. The nerves are derived from the phrenic and sympathetic (Luschka). Kölliker states that nerves accompany the ramifications of the bronchial arteries in the pleural pulmonalis.

Surgical Anatomy.—In operations upon the kidney it must be borne in mind that the pleura may sometimes extend below the level of the last rib, and may therefore be opened in these operations, especially when the last rib is removed, in order to give more room. It is best to keep the incision at least one inch below the last rib, enlarging the wound afterward, when the finger can be introduced as a guide.

In wounds of the Diaphragm the pleura may be injured. In operations about the root of the neck, especially in the removal of glands and the ligation of the first part of the subclavian artery, the pleura may be injured.

Punctured wounds of the root of the neck are apt to reach the pleura.

Empyema is a surgical disease. In acute empyema the treatment is drainage. A portion of the fifth or sixth rib in the axillary line is removed by subperiosteal resection, the pleura is opened, and a tube is introduced. In chronic empyema the lung is contracted and adherent and cannot expand; hence drainage will not cure it. It is necessary to perform multiple rib resection in order to permit the chest-wall to sink in and obliterate the cavity, which, as the lung is unable to expand, it cannot do. The necessary operation may be the operation of Estlander, or the operation of Scheide, or the operation of Fowler (page 168).

1 Poirier, Cunéo, and Delamare on the Lymphatics. Translated and edited by Cecil H. Leaf.
If a large wound admits suddenly a quantity of air into the pleura, dangerous or fatal pneumothorax arises, and the lung collapses. This is usually met during operations by using the Fell-O’Dwyer apparatus for artificial respiration as advised by Mats. This apparatus keeps the lung expanded, in spite of the entrance of air into the pleural sac. A surgeon can open the pleura widely without any fear of the lung collapsing if he operates in a Sauerbruch chamber. The pressure within this chamber is negative. The patient’s head is outside of the chamber, his body is within it. The bronchioles are distended by the animal inhaling air at the ordinary pressure, but the exposed lung is subjected to negative pressure, hence the lung does not collapse in spite of a large wound in the pleura. In surgical pneumothorax the lung may be sutured to the chest-wall, so as to block the opening. Sometimes, in order to arrest dangerous pulmonary bleeding, a surgeon deliberately induces pneumothorax, in hope that the collapse of the lung will arrest bleeding.

When an abscess of the liver is posterior and on the dorsum, transpleural hepotomy is performed. A portion of the tenth and eleventh ribs below the angle of the scapula is removed. As a rule, the pleura is found obliterated at this point. If it is opened, it is at once sutured or closed with gauze packing. The exposed Diaphragm is incised, and, as it is usually adherent to the liver, the abscess cavity is entered. If it is not adherent, the liver is exposed and the abscess sought for with an aspirating-needle.

**THE MEDIASTINAL SPACE, INTERPLEURAL SPACE OR MEDIASTINUM.**

The mediastinum is the space left in the median portion of the chest by the non-approximation of the two pleure. It extends from the sternum in front to the spine behind. Within it are the contents of the thorax excepting the lungs. The mediastinum may be divided for purposes of description into two parts—an upper portion, above the upper level of the pericardium, which is named the superior mediastinum (Struthers); and a lower portion, below the upper level of the pericardium. This lower portion is again subdivided into three—that part which contains the pericardium and its contents, the middle mediastinum; that part which is in front of the pericardium, the anterior mediastinum; and that part which is behind the pericardium, the posterior mediastinum.

**The Superior Mediastinum** (Fig. 1003).—The superior mediastinum is that portion of the interpleural space which lies above the upper level of the pericardium between the manubrium sterni in front and the upper thoracic vertebrae behind. It is bounded below by a plane passing backward from the junction of the manubrium and gladiolus sterni to the lower part of the body of the fourth thoracic vertebra, and laterally by the lungs and pleurae. It contains the origins of the Sterno-hyoid and Sterno-thyroid muscles and the lower ends of the Longus colli muscles; the arch of the aorta; the innominate, the thoracic portion of the left carotid and subclavian arteries; the upper half of the precava and the innominate veins, and the left superior intercostal vein; the vagus, cardiac, phrenic, and left recurrent laryngeal nerves; the trachea, oesophagus, and thoracic duct; the remains of the thymus gland and some lymphatic glands.

**The Anterior Mediastinum** (Fig. 997).—The anterior mediastinum is bounded in front by the sternum, on each side by the pleura, and behind by the pericardium. It is narrow above, but widens out a little below, and, owing to the oblique course taken by the left pleura, it is directed from above obliquely downward and to the left. Its anterior wall is formed by the left Triangularis sterni muscle and the fifth, sixth, and seventh left costal cartilages. It contains a quantity of loose areolar tissue, some lymphatic vessels which ascend from the convex surface of the liver, two or three lymphatic glands (anterior mediastinal glands), and the small mediastinal branches of the internal mammary artery.

**The Middle Mediastinum** (Fig. 997).—The middle mediastinum is the broadest part of the interpleural space. It contains the heart enclosed in the pericardium, the ascending aorta, the lower half of the precava, with the vena azygos major opening into it, the bifurcation of the trachea and the two bronchi,
the pulmonary artery dividing into its two branches and the right and left pulmonary veins, the phrenic nerves, and some bronchial lymphatic glands.

The Posterior Mediastinum (Figs. 997 and 1001).—The posterior mediastinum is an irregular triangular space running parallel with the vertebral column; it is bounded in front by the pericardium and roots of the lungs, behind by the vertebral column from the lower border of the fourth thoracic vertebra, and on either side by the pleura. It contains the descending thoracic aorta, the greater and lesser azygos veins, the vagus and splanchnic nerves, the oesophagus, thoracic duct, and some lymphatic glands.

Blood-vessels.—The areolar tissue of the anterior mediastinum receives numerous mediastinal branches from the internal mammary artery. The areolar tissue
of the posterior mediastinum receives mediastinal branches from the descending thoracic aorta. The lowest mediastinal vessels lie upon the Diaphragm and are called superior phrenic arteries. The precava and internal mammary veins receive mediastinal branches.

The **anterior mediastinal lymphatic glands** are in the upper portion of the anterior mediastinum. They are five or six in number and are placed in front of the transverse arch of the aorta. Chains of glands run up from them to the root of the neck. On the right side glands are in front of the right innominate vein, between the artery and vein and behind the artery. On the left side they are around the left common carotid and left subclavian arteries.

The **posterior mediastinal glands** are around the oesophagus, particularly in front of it. The **peritracheo-bronchial glands** have been described.

**THE LUNGS (PULMONES)** (Figs. 997, 1004, 1005, 1006, 1007, 1008, 1009).

The lungs are the essential organs of respiration; they are two in number, placed one on each side of the chest, separated from each other by the heart and other contents of the mediastinum. A healthy lung hangs free within the pleural cavity. It is suspended by the root and by the ligamentum pulmonis. In many cases examined the lung does not hang free, but, as a result of former pleurisy, an area of the pulmonary pleura is adherent to the parietal pleura. Each lung is conical in shape, and presents for examination an **apex**, a **base**, two **borders**, and two **surfaces**.

**The Apex** (**apex pulmonis**).—The apex forms a tapering cone which extends into the root of the neck about an inch to two inches above the level of the anterior extremity of the first rib. The brachial plexus is in close proximity to this portion of the lung.

**The Base** (**basis pulmonis**).—The base is broad, concave, and rests, by its **diaphragmatic surface** (**facies diaphragmatica**), upon the convex surface of the
Diaphragm, which separates the right lung from the upper surface of the right lobe of the liver and the left lung from the upper surface of the left lobe of the liver, the fundus of the stomach, and the spleen; its circumference is thin, and

projects for some distance into the phrenico-costal sinus of the pleura, between the lower ribs and the costal attachment of the Diaphragm, extending lower down externally and behind than in front.
Surfaces. The External, Costal, or Thoracic Surface (facies costalis) (Figs. 1008 and 1009).—The external, costal, or thoracic surface is smooth, convex, of considerable extent, and corresponds to the form of the cavity of the chest, being deeper behind than in front. In a hardened specimen this surface has grooves and bulgings on it corresponding to the ribs and intercostal spaces.

The Inner or Mediastinal Surface (facies mediastinalis) (Figs. 1004 and 1005).—The inner or mediastinal surface is concave. It presents in front a depression corresponding to the convex surface of the pericardium, and behind a deep fissure, the hilum (hilus pulmonalis). In the hilum lie the bronchi, vessels, nerves, and lymph-nodes, which together constitute the root of the lung. On the inner and anterior surface, a little below the apex, is a groove, the subclavian groove (sulcus subclavius), for the subclavian artery. A little lower is a broader and shallower groove for the innominate and subclavian veins. The pleura lies between the lungs and these vessels. In front of the hilum and below it is a depression for the heart (impressio cardiaca). It is deeper on the left than on the right side. On the right side it passes into the groove from the precava and the vena azygos major. On the left side, behind the hilum, is a groove for the thoracic aorta; on the right side a groove for the oesophagus.

Borders. The Inferior Border (margo inferior).—The inferior border is the line of junction of the costal and diaphragmatic surfaces. Posteriorly, it is rounded and broad, and is received into the deep concavity on either side of the spinal column. It is much longer than the anterior border, and projects, below, into the phrenico-costal sinus.

The Anterior Border (margo anterior).—The anterior border is thin and sharp, overlaps the front of the pericardium, and is projected into the costo-medi-
astinal sinus of the pleura. The anterior border of the right lung is almost vertical; that of the left presents, below, an angular notch, the *incisura cardiaca*,

![Diagram of pulmonary veins](image)

**Fig. 1007.**—Pulmonary veins, seen in a dorsal view of the heart and lungs. The lungs have been pulled away from the median line, and a part of the right lung has been cut away to display the air-ducts and blood-vessels. (Testut.)

![Diagram of right lung](image)

![Diagram of left lung](image)

**Fig. 1008.**—The right lung. The outer or costal surface. (Toldt.)
**Fig. 1009.**—The left lung. The outer or costal surface. (Toldt.)

into which the heart and pericardium are received. A projection from the upper lobe comes forward beneath the cardiac notch; it is called the *lingula pulmonis*.

**The Lobes of the Lungs** (Figs. 1008 and 1009).—Each lung is divided into two lobes, an *upper* (*lobus superior*) and a *lower* (*lobus inferior*), by a long and deep
fissure (*incisura interlobaris*), which extends from the upper part of the posterior border of the organ about three inches from its apex, downward and forward to the lowest part of the lung just external to its anterior border. This fissure penetrates nearly to the root. The upper lobe is the smaller; the lower lobe is the larger. In the right lung the upper lobe is partially subdivided by a second and shorter fissure, which extends almost horizontally forward from the middle of the preceding to the anterior margin of the organ, marking off a small triangular portion, the middle lobe (*lobus medius*).

The right lung is the larger and heavier; it is broader than the left, owing to the inclination of the heart to the left side; it is also shorter by an inch, in consequence of the Diaphragm rising higher on the right side to accommodate the liver.

**The Root of the Lung** (*radix pulmonis*) (Figs. 1004, 1005, 1006, and 1007).—A little above the middle of the inner surface of each lung, and nearer its posterior than its anterior border, is its root, by which the lung is connected to the heart and the trachea. The root is formed by the bronchial tube, the pulmonary artery, the pulmonary veins, the bronchial arteries and veins, the pulmonary plexus of nerves, lymphatics, bronchial glands, and areolar tissue, all of which are enclosed by a reflection of the pleura. The root of the right lung lies behind the precava and ascending portion of the aorta, and below the vena azygos major. The root of the left lung passes beneath the arch of the aorta and in front of the descending aorta; the phrenic nerve and the anterior pulmonary plexus lie in front of each, and the vagus and posterior pulmonary plexus behind each.

The chief structures composing the root of each lung are arranged in a similar manner from before backward on both sides—viz., the two pulmonary veins in front; the pulmonary artery in the middle; and the bronchus, together with the bronchial vessels, behind. From above downward, on the two sides, their arrangement differs, thus; on the right side their position is—bronchus, pulmonary artery, pulmonary veins; but on the left side their position is—pulmonary artery, bronchus, pulmonary veins. It should be noted that the entire right bronchus does not lie above the right pulmonary artery, but only its eparterial branch (see p. 1385), which passes to the upper lobe of the right lung; the divisions of the bronchus for the middle and lower lobes lie below the artery.

The true weight of the human lungs as ascertained in the bodies of criminals executed by electricity, in which the mode of death is attended by a nearly bloodless condition of the lungs, is 215 grams (7.4 ounces) for the left lung and 240 grams (8.4 ounces) for the right lung (E. A. Spitzka, *Amer. Jour. of Anat.*, iii., 1, p. v.). Ordinarily, with the vascular channels more or less filled with blood and serum, the two lungs together weigh about 42 ounces, the right lung being 2 ounces heavier than the left, but much variation is met with according to the amount of blood or serous fluid they may contain. The lungs are heavier in the male than in the female. The specific gravity of the lung-tissue varies from 0.345 to 0.746.

The color of the lungs at birth is a pinkish-white; in adult life a dark slate-color, mottled in patches; and as age advances this mottling assumes a black color. The coloring matter consists of granules of a carbonaceous substance deposited in the areolar tissue near the surface of the organ. It increases in quantity as age advances, and is more abundant in males than in females. The posterior surface of the lung is usually darker than the anterior.

The surface of the lung is smooth, shining, and marked out into numerous polyhedral spaces, indicating the lobules of the organ; the area of each of these spaces is crossed by numerous lighter lines.

The substance of the lung is of a light, porous, spongy texture; it floats in water and crepitates when handled, owing to the presence of air in the tissue; it is also highly elastic; hence the collapsed state of these organs when they are removed from the closed cavity of the thorax.

**The Foetal Lung.**—After respiration has been established, the lung fills the pleural cavity. In the foetus, as the lung has never been distended with air
and has never received a large amount of blood, it is gathered into a small mass at the back of the thorax. It will sink in water and feels solid to the touch.

**Structure.**—The structure of the lung is such that the blood brought by the pulmonary artery comes into close relation with the air which enters from the bronchioles. The blood gives materials to the air, and the air gives elements to the blood, and the process of respiration causes the dark blood brought from the heart by the pulmonary artery to return to the heart as red blood in the pulmonary vein. The lungs are composed of an **external serous coat**, a **subserous areolar tissue**, and the **pulmonary substance or parenchyma**.

**The Serous Coat.**—The serous coat is thin, transparent, and invests the entire organ as far as the root. It is known as the pulmonary pleura (p. 1392).

**The Subserous Areolar Tissue.**—The subserous areolar tissue contains a large proportion of elastic fibres; it invests the entire surface of the lung, and extends inward between the lobules, and at the hilum forms the pulmonary scaffold or framework.

**The Parenchyma.**—The parenchyma is composed of **lobules** which, although closely connected together by an interlobular areolar tissue, are quite distinct from one another, and may be teased asunder without much difficulty in the fetus. The lobules vary in size; those on the surface are large, of pyramidal form, with the bases turned toward the surface; those in the interior are smaller and of various forms. Each lobule is composed of one of the ramifications of a bronchial tube and its terminal air-cells, and of the ramifications of the pulmonary and bronchial vessels, lymphatics, and nerves, all of these structures being connected together by areolar tissue.

**The Bronchus** (pp. 1384 and 1386) (Figs. 993, 994, and 995).—The bronchus, upon entering the substance of the lung, divides and subdivides bipinately, throughout the entire organ. Sometimes three branches arise together, and occasionally small lateral branches are given off from the sides of a main trunk. Each of the smaller subdivisions of the bronchi enters a pulmonary lobe, and is termed a **lobular bronchial tube** or **bronchiole** (bronchioli). Each bronchiole divides into minute branches (bronchioli respiratorii), the walls of which now begin to present irregular dilatations, **bronchial alveoli**. These are present at first sparingly and on one side of the tube only, but as it proceeds onward these dilatations become more numerous and surround the tube on all sides, so that it loses its cylindrical character. The terminal branches come from the bronchioli respiratorii. These terminal branches are called the **alveolar ducts** or **alveolar passages** (ductuli alveolares). The alveolar ducts show numerous alveoli (Fig. 994) and join with cavities called **atria**. Each atrium joins several larger cavities, the **air-cells** or **air-sacs** (infundibula). The numerous small cavities on the surface of the air-sacs are the **pulmonary alveoli** (alveoli pulmonis). The bronchiole now becomes widened out and terminates in an irregular cul-de-sac, the **air cell**, **air sac** alveolus or infundibulum. The walls of the infundibulum are closely beset in all directions by **pulmonary alveoli** or **pulmonary air cells**. Professor Gerrish remarks that the first of the alveoli seen on the bronchioles before the coreal ends are formed would seem an effort on the part of nature to form an infundibulum before all the necessary conditions are favorable.

**Changes in the Structure of the Bronchi in the Lungs.**—Within the lungs the bronchial tubes are circular, not flattened (Fig. 995), and present certain peculiarities of structure.

**In the Lobes of the Lungs.**—In the lobes of the lungs the following changes take place: The **cartilages** are not imperfect rings, but consist of thin laminae, of varied form and size, scattered irregularly along the sides of the tube, being most distinct at the points of division of the bronchi. They may be traced into tubes, the diameter of each of which is only one-fourth of a line. Beyond this point the tubes are wholly membranous. The **fibrous coat** is continued into the
smallest ramifications of the bronchi. The **muscular coat** is disposed in the form of a continuous layer of annular fibres, which may be traced upon the smallest bronchial tubes, and consists of the unstriped variety of muscular tissue. The **mucous membrane** lines the bronchi and their ramifications throughout, and is covered with columnar ciliated epithelium.

**In the Lobules of the Lung.**—In the lobular bronchial tubes and in the infundibula the following changes take place: The **muscular tissue** begins to disappear, so that in the infundibula there is scarcely a trace of it. The **fibrous coat** becomes thinner, and degenerates into areolar tissue. The **epithelium** becomes non-ciliated and flattened. This occurs gradually; thus, in the lobular bronchioles patches of non-ciliated flattened epithelium may be found scattered among the columnar ciliated epithelium; then these patches of non-ciliated flattened epithelium become more and more numerous, until in the infundibula and air-cells all the epithelium is of the non-ciliated pavement variety. In addition to these flattened cells, there are small polygonal granular cells in the air-sacs, in clusters of two or three, between the others.

The air-cells are small, polyhedral recesses composed of a fibrillated connective tissue and surrounded by a few involuntary muscular and elastic fibres. Free in their cavity are to be seen under the microscope granular, rounded, ameoboid cells (cosinophile leukocytes), often containing carbonaceous particles. The air-cells are well seen on the surface of the lung, and vary from $\frac{1}{20}$ to $\frac{1}{10}$ of an inch in diameter, being largest on the surface at the thin borders and at the apex, and smallest in the interior.

**Mucous Glands.**—In the larger bronchi the mucous membrane contains goblet cells. When the tubes diminish to 1 mm. in diameter the glands grow fewer. In the smaller bronchi there are no mucous glands.

**Vessels of the Lungs.**—The **pulmonary artery** (Figs. 1006 and 1007) conveys the venous blood to the lungs; it divides into branches which accompany the bronchial tubes, and terminates in a dense capillary network upon the walls of the intercellular passages and air-cells. In the lung the branches of the pulmonary artery are usually above and in front of a bronchial tube, the vein below.

The **pulmonary capillaries** form plexuses which lie immediately beneath the mucous membrane in the walls and septa of the air-cells and of the infundibula. In the septa between the air-cells the capillary network forms a single layer. The capillaries form a very minute network, the meshes of which are smaller than the vessels themselves; their walls are also exceedingly thin. The arteries of neighboring lobules are independent of each other, but the veins freely anastomose together.

The **pulmonary veins** commence in the pulmonary capillaries, the radicles coalescing into larger branches, which run along through the substance of the lung, independently from the minute arteries and bronchi. After freely communicating with other branches they form large vessels, which ultimately come into relation with the arteries and bronchial tubes, and accompany them to the hilum of the organ. Finally they open into the left auricle of the heart, conveying oxygenated blood to be eventually distributed to all parts of the body by the aorta.

The **bronchial arteries** supply blood for the nutrition of the lung. The thoracic aorta usually gives off two left bronchial arteries. The single right bronchial artery usually arises from the first right aortic intercostal, but sometimes from the superior left bronchial artery, or from the aorta. In the root of the lung they are posterior to the bronchus, they accompany the bronchial tubes, supply the tubes and pulmonary tissue, and give branches to the walls of the larger pulmonary vessels, the oesophagus, pericardium, and bronchial glands. Those

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1 The meshes are only 0.002" to 0.008" in width, while the vessels are 0.003" to 0.005" (Köllikker, Human Microscopic Anatomy).—Ed. of 15th English edition.
supplying the bronchial tubes form a capillary plexus in the muscular coat, from which branches are given off to form a second plexus in the mucous coat. This plexus communicates with branches of the pulmonary artery, and empties itself into the pulmonary vein. Others are distributed in the interlobular areolar tissue, and terminate partly in the deep, partly in the superficial, bronchial veins. Lastly, some ramify upon the surface of the lung beneath the pleura, where they form a capillary network. There may be but one bronchial artery; there may be three or four.

The bronchial veins are not found in the walls of the very small bronchi. The small bronchial veins run along by the front and back of the median sized and larger tubes, and from two trunks at the root of each lung. These vessels terminate on the right side in the vena azygos major, and on the left side in the superior intercostal or left upper azygos vein. Tracheal and posterior mediastinal veins open into the bronchial veins. The venous blood from the smaller tubes passes to the pulmonary veins.

The lymphatics begin in networks about the lobules and form networks about the bronchi and beneath the bronchial mucous membrane. The superficial collecting trunks arise about the lobules and beneath the pleura. According to Sappey, the superficial trunks from the upper lobe begin on the costal surface; one set passes around the anterior border, another set around the posterior border, and a third into the incisura interlobaris. The same observer says that the superficial trunks from the middle lobe unites with the trunks from the upper and lower lobes; and the superficial trunks from the lower lobe, like those of the upper lobe, are in three sets. One set passes around the posterior margin, one around the anterior margin, and one into the incisura interlobaris. All of the superficial trunks convey lymph to the glands of the hilum. Some of the deep collecting trunks begin by the sides of the small bronchi; others course along by the pulmonary veins or pulmonary arteries. All of them pass to the glands of the hilum. The glands of the hilum are in communication with the peritracheo-bronchial glands.

Nerves.—The lungs are supplied from the anterior and posterior pulmonary plexuses, formed chiefly by branches from the sympathetic and vagus. The filaments from these plexuses accompany the bronchial tubes, and are lost upon them. Small ganglia are found upon these nerves.

Surface Form.—The apex of the lung is situated in the neck, behind the interval between the two heads of origin of the Sterno-mastoid muscle. The height to which it rises above the clavicle varies very considerably, but is generally about one inch. It may, however, extend as much as an inch and a half or an inch and three-quarters, or, on the other hand, it may scarcely project above the level of this bone. In order to mark out the anterior margin of the lung, a line is to be drawn from the apex-point, one inch above the level of the clavicle, and rather nearer the posterior than the anterior border of the Sterno-mastoid muscle, downward and inward across the sterno-clavicular articulation and first piece of the sternum until it meets, or almost meets, its fellow of the other side opposite the articulation of the manubrium and gladiolus. From this point the two lines are to be drawn downward, one on either side of the mesial line and close to it, as far as the level of the articulation of the fourth costal cartilages to the sternum. From here the two lines diverge; the left is to be drawn at first passing outward with a slight inclination downward, and then taking a bend downward with a slight inclination outward to the apex of the heart, and thence to the sixth costo-chondral articulation. The direction of the anterior border of this part of the left lung is denoted with sufficient accuracy by a curved line with its convexity directed upward and outward from the articulation of the fourth right costal cartilage of the sternum to the fifth intercostal space, an inch and a half below and three-quarters of an inch internal to the left nipple. The continuation of the anterior border of the right lung is marked by a prolongation of its line from the level of the fourth costal cartilages vertically downward as far as the sixth, when it slopes off along the line of the sixth costal cartilage to its articulation with the rib.

The lower border of the lung is marked out by a slightly curved line with its convexity downward from the articulation of the sixth costal cartilage to its rib to the spine of the tenth thoracic vertebra. If vertical lines are drawn downward from the nipple, the mid-axillary line, and the apex of the scapula, while the arms are raised from the sides, they should intersect

1 The Lymphatics, by Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
this convex line, the first at the sixth, the second at the eighth, and the third at the tenth rib. It will thus be seen that the pleura extends farther down than the lung, so that it may be wounded, and a wound may pass through its cavity into the Diaphragm, and the abdominal viscera may be injured without the lung being involved.

The posterior border of the lung is indicated by a line drawn from the level of the spinous process of the seventh cervical vertebra, down either side of the spine, corresponding to the costo-vertebral joints as low as the spinous process of the tenth thoracic vertebra. The trachea bifurcates opposite the spinous process of the fourth thoracic vertebra, and from this point the two bronchi are directed outward.

"The position of the great fissure of the lungs may be indicated by a line drawn from the third dorsal spine obliquely downward in such a manner as to reach the sixth rib close to the mid-clavicular line. The interlobar fissure between the upper and middle lobes of the right lung corresponds to a line drawn from the apex of the axilla almost horizontally to the sternum, reaching the latter at about the level of the fourth costal cartilage" (Erendrath).

Surgical Anatomy.—The lungs may be wounded or torn in three ways: (1) By compression of the chest, without any injury to the ribs. (2) By a fractured rib penetrating the lung. (3) By stabs, gunshot wounds, etc.

The first form, where the lung is ruptured by external compression without any fracture of the ribs, is very rare, and usually occurs in young children, and affects the root of the lung—i.e., the most fixed part—and thus, implicating the great vessels, is frequently fatal. It would seem to be a most unusual injury, and the exact mode of its causation is difficult to understand. The probable explanation is that immediately before the compression is applied a deep inspiration is taken and the lungs are fully inflated; owing then to spasm of the glottis at the moment of compression, the air is unable to escape from the lung, the lung is not able to reede, and consequently gives way.

In the second variety, when the wound in the lung is produced by the penetration of a broken rib, both the pleura costalis and the pleura pulmonalis must necessarily be injured, and consequently the air taken into the wounded air-cells may find its way through these wounds into the cellular tissue of the parieties of the chest. This it may do without collecting in the pleural cavity; the two layers of the pleura are so intimately in contact that the air may pass straight through from the wounded lung into the subcutaneous tissue. Emphysema constitutes, therefore, an important sign of injury to the lung in cases of fracture of the ribs. Pneumothorax, or air in the pleural cavity, is much more likely to occur in injuries to the lungs of the third variety; that is to say, from external wounds, from stabs and gunshot injuries, in which cases air passes either from the wound of the lung or from an external wound into the cavity of the pleura during the respiratory movements. In these cases there is generally no emphysema of the subcutaneous tissue unless the external wound is small and valvular, so that the air drawn into the wound during inspiration is then forced into the cellular tissue around during expiration because it cannot escape from the external wound. Occasionally in wounds of the parieties of the chest no air finds its way into the cavity of the pleura, because the lung at the time of the accident protrudes through the wound and blocks the opening. This occurs where the wound is large, and constitutes a so-called hernia of the lung. True hernia of the lung occurs, though very rarely, after wounds of the chest-wall, when the wound has healed and the cicatrix subsequently yields from the pressure of the viscous behind. It forms a globular, elastic, crepitating swelling, which enlarges during expiratory efforts, falls during inspiration, and disappears on holding the breath. Wounds of the lung may produce dangerous or fatal hemorrhage into the pleural sac. In many cases the bleeding is spontaneously arrested; in others the surgeon must interfere to save life. In some cases air has been admitted by intercostal incision and the insertion of a tube, and pulmonary collapse has arrested bleeding. In other cases it is necessary to resect portions of several ribs, and stop bleeding by ligatures or suture ligatures. In one case of a furious secondary hemorrhage following a gunshot wound, the editor resected several ribs, packed the pleural cavity about the lung with sterile gauze, to obtain a base of support, and then arrested the bleeding by packing iodoform gauze against the firmly supported lung. This patient recovered.

Incision of the lung (pneumotomy) is performed for pulmonary abscess (either tuberculous or pyogenic), pulmonary gangrene, hydatid cysts, and bronchiectasis. In pulmonary abscess, locate the area by physical signs and the x-ray, resect a portion of rib over it, and note if the pleura is adherent. If it is adherent, continue the operation. If it is not adherent, insert stitches of catgut through the two layers of pleura and the superficial part of the lung, so as to encircle a considerable area, and then wait several days for adhesions to form. Adhesions protect the pleura from infection, and, by keeping air from the pleural sac, prevent pneumothorax. When ready to continue the operation, locate the abscess with an aspirating-needle and syringe, open it with a cautery at a dull-red heat, and drain by means of a tube.

Pneumothorax is very unsatisfactory in tuberculous cavities and bronchiectasis. In tuberculosis, excision of the diseased area (pneumectomy) has been employed, but it is not to be advised. Operations upon the lungs can be most safely performed with the patient in a Sauerbruch chamber. The danger of collapse of the lung is thus eliminated.
THE DUCTLESS GLANDS.

THESE glands do not possess excretory ducts. They furnish materials which are added to the blood or lymph as it passes through them. The material from each gland is known as an internal secretion. Some of these secretions are powerful materials and influence profoundly the body nutrition. The ductless glands are usually given as follows: the spleen, the lymphatic glands, the pineal gland, the pituitary body, the suprarenal capsules, the thyroid gland, the para-thyroids, the thymus, the carotid body, and the coccigeal body. The lymphatic glands were described in a special section (p. 772). The lymphatic glands are not considered to be really glands, but, nevertheless, as lymph passes through the lymph glands, it receives a product of the glands, namely, lymphocytes. There is no evidence that the spleen furnishes an active internal secretion, and this organ has been studied with the abdominal viscera. The pineal gland (p. 915) and pituitary body or hypophysis (p. 917) were considered with the brain. The suprarenal capsules (p. 1437) are described with the kidneys. Some glands, for instance, the liver, pancreas, and testicle, have an external secretion and also an internal secretion.

THE THYROID BODY OR GLAND (GLANDULA THYREOIDEA) (Fig. 1010).

The thyroid gland is an extremely vascular body, situated at the front and sides of the neck, and extending upward upon each side of the larynx. It is a single gland, varying greatly in size in different individuals. It is larger relatively in females and in children than in men. It is frequently asymmetrical. In early embryonal life the gland has a duct, the thyro-glossal duct (ductus thyroglossus), which passes from the isthmus of the thyroid to the foramen caecum of the dorsum of the tongue. The lumen of this duct is obliterated early and becomes a cord of epithelium. The lower portion of the duct often remains open for a little way. The upper portion remains as the foramen caecum. The situation of this obliterated foetal duct may be marked by the third or middle lobe of the thyroid gland. The thyroid surrounds the upper portion of the trachea like a horseshoe. It consists of two lateral lobes connected across the middle line by a narrow transverse portion, the isthmus.

The weight of the gland is somewhat variable, but is usually about one ounce. It is somewhat heavier in the female, in whom it becomes enlarged during menstruation and pregnancy. As age advances the weight of the thyroid diminishes.

The color of the thyroid, as seen from the surface, is reddish-blue. The gland is completely surrounded by a closely adherent thin fibrous-tissue capsule of the pretracheal layer of deep cervical fascia. From the inner surface of the capsule come delicate septa, which enter into the thyroid body and separate it into lobes and also separate the lobes into lobules. The blood-vessels lie beneath the capsule. The anterior and lateral portions of the gland are covered by the capsule. "Passing around the side of the gland to its posterior surface, this capsule then splits into two portions. One remains in contact with the gland and invests its posterior surface. The other, the thicker of the two, passes to the posterior surface of the pharynx.
and oesophagus, thus enclosing them with the larynx, trachea, and thyroid gland, in a common sheath.\textsuperscript{1} There is also a layer from the thyroid capsule which passes between the trachea and oesophagus.\textsuperscript{2}

The \textit{lateral lobes} are conical in shape, the apex of each being directed upward and outward as far as the junction of the middle with the lower third of the thyroid cartilage; the base looks downward, and is on a level with the fifth or sixth tracheal ring. The summit of the lateral lobe not unusually is pointed and reaches to the level of the oblique line upon the ala of the thyroid cartilage or even higher. The right is, as a rule, somewhat larger than the left lobe. The lower portion of the gland, when the head is extended, is about one inch above the upper margin of the sternum; when the head is flexed, it is at the level of the upper border of the sternum or even below and behind it. The portion of the lateral lobe above the level of the superior border of the isthmus is called the \textit{upper horn}, the portion below the level of the inferior margin of the isthmus is called the \textit{lower horn}. The lower horn "is usually much smaller than the upper horn; frequently it is altogether absent."\textsuperscript{3}

At the inner and posterior part of each lateral lobe is the \textit{hilum}. At the hilum the inferior thyroid artery passes into the gland. "Here the \textit{recurrent laryngeal nerve} comes into close contact with the gland, lying in the space between it and the trachea and oesophagus.\textsuperscript{4}

The \textit{external} or \textit{superficial surface} is convex, and covered by the skin, the superficial fascia, the deep fascia, the Sterno-mastoid, the anterior belly of the Omo-hyoid, the Sterno-hyoid and Sterno-thyroid muscles, and beneath the last-named muscles by the pre-tracheal layer of the deep fascia, which forms a capsule for the gland.

The \textit{deep} or \textit{internal surface} is moulded over the underlying structures—viz., the thyroid and cricoid cartilages, the trachea, the inferior constrictor and posterior part of the Crico-thyroid muscles, the oesophagus (particularly on the left side of the neck), the superior and inferior thyroid arteries, and the recurrent laryngeal nerves.

The deep surface of each lobe is fixed by bands of fibrous tissue passing from the capsule of the isthmus and lateral lobes to the sides of the cricoid cartilage and the posterior fascia of the trachea. These bands are called the \textit{lateral} or \textit{suspensory ligaments}. Because of this fixation to the larynx and trachea by the capsule and by the lateral ligaments, the thyroid gland moves with the trachea and ascends during the act of swallowing. The recurrent laryngeal nerve on each side is in contact with the outer and posterior surface of the suspensory ligament.

The \textit{anterior border} is thin, and inclines obliquely from above downward and inward toward the middle line of the neck, while the \textit{posterior border} is thick and overlaps the common carotid artery. Each lobe is about two inches in length, its greatest width is about one inch and a quarter, and its thickness about three-

\textsuperscript{1} Diseases of the Thyroid Gland. By James Berry.
\textsuperscript{2} C. H. Mayo, Surgery, Gynecology, and Obstetrics, July, 1907.
\textsuperscript{3} Loc. cit.
\textsuperscript{4} Ibid.
quarters of an inch. The posterior border is over the common carotid artery and touches the oesophagus and pharynx. The carotid artery usually makes a groove upon the gland.

The Isthmus (isthmus glandulae thyreoidea).—The isthmus connects the lower third of the two lateral lobes; it measures about half an inch in breadth and the same in depth, and usually covers the second and third rings of the trachea, but sometimes also the first and fourth rings. Its situation presents, however, many variations, a point of importance in the operation of tracheotomy. In the middle line of the neck it is covered by the skin and fascia, and close to the middle line, on either side, by the Sterno-hyoid muscle. Across its upper border run branches of the superior thyroid artery and vein; at its lower border is a branch of the inferior thyroid veins. Sometimes the isthmus is altogether wanting, the two lateral lobes being completely separate.

The third, pyramidal or middle lobe is called the pyramid of Lalouette. It is not constant, but is frequently found. Occasionally it arises from the upper part of the isthmus, or from the adjacent portion of either lobe, but most commonly from the left lobe, and ascends in front of the thyroid cartilage in the direction of the middle of the hyoid bone. It may reach the bone or may not reach it. If it reaches the bone it is attached to it. If it does not reach the bone, fibrous tissue, which often contains muscle, is prolonged from the tip of the pyramid to the back of the bone or to the thyro-hyoid membrane. The pyramid is occasionally quite detached, or divided into two or more parts, or altogether wanting.

A few muscular bands, derived from the Thyro-hyoid muscles, are occasionally found attached, above, to the body of the hyoid bone, and below to the isthmus of the gland or its pyramidal process. These form a muscle, which was named by Soemmerring the Levator glandulae thyreoidea.

Accessory Thyroids (glandulae thyreoideaæ accessoriae).—Frequently small isolated masses of thyroid tissue exist. They are found particularly about the lateral lobes of the thyroid gland in the sides of the neck or just above the hyoid bone, and are called accessory thyroids. Accessory thyroids may also exist by the side of the pyramidal lobe or upon the trachea, as low even as the level of the arch of the aorta. John B. Murphy¹ says, the field in which accessory thyroids "may be found can be roughly represented by an inverted trapezoid, the larger base being a line running from one apex of the mastoid process to the other; the smaller base is a line tangential to the arch of the aorta, and the sides are the two sternomastoid muscles." These isolated portions of gland tissue represent isolated portions of the median thyroid rudiment. Sometimes accessory thyroid tissue is found in the root of the tongue or in the interior of the larynx. Berry points out that a distinction must be made between true congenital accessory thyroid and masses of encapsulated thyroid tissue which "have been extruded from the gland," and still retain a connection with the gland. Such masses are false accessory thyroids.

Structure of the Thyroid (Fig. 1011).—The thyroid body is invested by a thin capsule of connective tissue which projects into its substance as a framework and imperfectly divides it into masses of irregular form and size, known as lobules. More slender septa separate the secretory alveoli from one another. When the organ is cut into, it is of a brownish-red color, and is seen to be made up of a number of closed vesicles or alveoli containing a yellow glairy fluid and separated from each other by intermediate connective tissue.

According to Baber, who has published some important observations on the minute structure of the thyroid,² the vesicles of the thyroid of the adult animal are generally closed cavities; but in some young animals (e.g., young dogs) the vesicles are more or less tubular and branched. This appearance he supposes

¹ Journal of the American Medical Association, December 16, 1905.
² Researches on the Minute Structure of the Thyroid Glands, Phil. Trans., part iii., 1881.
to be due to the mode of growth of the gland, and merely indicating that an increase in the number of vesicles is taking place. Each vesicle is lined by a single layer of epithelium, the cells of which are cubical or cylindrical. Between the epithelial cells exists a delicate reticulum. The vesicles are of various sizes and shapes, and contain as a normal product a viscid, homogeneous, semi-fluid, slightly yellowish material which frequently contains blood, the red corpuscles of which are found in it in various stages of disintegration and decolorization, the yellow tinge being probably due to the haemoglobin, which is thus set free from the colored corpuscles. This normal product is known as colloid material, and it is secreted by the epithelium. What part if any the colloid plays in the formation of the internal secretion of the gland is not known. It is quite possible that the colloid corresponds to the external secretion of glands with ducts and that the true internal secretion passes directly into the capillaries which form a network about the alveoli (Szymonowicz), or passes into the lymphatics. In the thyroid gland of the dog, Baber has found large round cells, parenchymatous cells, each provided with a single oval-shaped nucleus, which migrate into the interior of the gland-vesicles. Between the thyroid vesicles in the human being are collections of round cells. They are, in reality, miniature vesicles, and are much more numerous in youth than in old age.

The capillary blood-vessels form a dense plexus in the connective tissue around the vesicles, between the epithelium of the vesicles and the endothelium of the lymph-spaces, which latter surround a greater or smaller part of the circumference of the vesicles. These lymph-spaces empty themselves into lymphatic vessels which run in the interlobular connective tissue, not uncommonly surrounding the arteries which they accompany, and communicate with a network in the capsule of the gland. Small glands may be connected with this network. Baber has found in the lymphatics of the thyroid a viscid material which is morphologically identical with the normal constituent of the vesicle.

**Vessels and Nerves.**—The arteries (Figs. 394 and 395; see also p. 604) supplying the thyroid are the superior thyroid from the external carotid, and the inferior thyroid from the thyroid axis of the first part of the subclavian. Sometimes there is an additional vessel, the thyroidea media or ima, usually arising from the
innominate artery, but sometimes from the arch of the aorta or the common carotid. It ascends upon the front of the trachea. The superior thyroid artery reaches the summit of the upper horn of the gland, and usually at this point gives off a vessel which courses down the posterior surface of the gland. The main trunk passes downward and inward at the junction of the inner and anterior border of the upper horn, giving branches to adjacent structures and sending branches over the anterior surface of the thyroid gland. It reaches the isthmus and crosses the isthmus at its upper border to anastomose with the artery from the other side. The inferior thyroid artery, which is usually larger than the superior, after it has passed posterior to the sheath of the carotid and the sympathetic nerve, reaches the posterior surface of the gland. At this point branches are given off; some pass into the hilum; the others go to the posterior surface of the gland. The relation of the artery to the recurrent laryngeal nerve is very important to the surgeon. "Usually the main trunk of the artery passes behind the nerve; sometimes the artery breaks up before reaching the nerve; in this case one or more of the branches may pass in front of it. Much less commonly the main trunk or all its branches will be found to lie in front of the nerve." 1 If the thyroidea ima is present it goes to the lower part of the gland. The larger branches of the thyroid arteries are beneath the capsule and upon the surface of the gland; smaller branches pass to the interior of the gland. 2 (Berry). The arteries are remarkable for their large size and frequent anastomoses.

The thyroid veins (Figs. 447 and 448; see also p. 731) form a plexus upon the surface of the gland and beneath the capsule. Here and there veins pass through the capsule and go to adjacent venous trunks. Berry, accepting Kocher's description, notes the following veins: The superior thyroid vein runs with the superior thyroid artery and passes to the internal jugular vein. A transverse vein of the upper border of the isthmus joins the two superior thyroid veins. A single vein, the middle thyroid, sometimes emerges from the side of the gland and passes to the internal jugular. Usually, however, instead of this single vein there are two veins, the superior and inferior accessory thyroids. The superior accessory thyroid emerges from the outer side of the upper horn, below the apex, and passes to the internal jugular. The inferior accessory thyroid emerges from the posterior and inferior portion of the gland and passes to the internal jugular. The veins from the lower border of the gland vary greatly. A vein passes vertically down on each side in front of the trachea from the isthmus and from the inner side of the inferior horn. It is called by Kocher the thyroidea ima. The vein of the left side passes to the left innominate; the vein of the right side passes to the right innominate or left innominate. As Berry points out, the vein of one side may be small or may be absent, or the two veins may unite and form one vein which enters the left innominate. An inferior thyroid vein is often present. It is of small size, emerges at the inferior and external part of the gland, and passes to the corresponding innominate vein. 3

The lymphatics are numerous and of large size. Collecting trunks arise from a network within the capsule. Some trunks ascend from the upper margin of the isthmus and reach the gland in front of the larynx; others ascend along the superior thyroid artery and reach the glands at the bifurcation of the carotid. Descending trunks from the lower margin of the isthmus reach the glands in front of the trachea; trunks from the side of the gland descend to the glands about the recurrent laryngeal nerve. 4

The nerves are derived from the middle and inferior cervical ganglia of the sympathetic, and from the inferior laryngeal nerves. Probably there is also a branch from each superior laryngeal nerve.

Surgical Anatomy.—The thyroid gland may be congenitally absent, and when it is the individual suffers from the worst form of cretinism. One lobe may be congenitally absent, but this will provoke no trouble unless the other lobe undergoes atrophy.

1 Diseases of the Thyroid Gland. By James Berry.
2 Ibid.
3 The Lymphatics. By Poirier, Cunéo, and Delamaré. Translated and edited by Cecil H. Leaf.
Complete removal of the thyroid and parathyroids will produce operative myxoedema (cachexia strumipriva), unless accessory thyroids enlarge and perform the functions of the thyroid. The thyroid gland may be congenitally enlarged. The gland tends to atrophy in old age. It is atrophied in myxoedema and cretinism. Some forms of thyroid enlargement are called goitre.

When all parts of the gland enlarge the condition is known as parenchymatous goitre. Adenomatous goitre consists of an adenoma or of adenomata. In cystic goitre there is one or more cysts due to cystic degeneration of adenomata or to fusion of adjacent follicles. A pulsating goitre is one which receives impulses from the carotid pulsations. In a fibroid goitre there is increase of interstitial connective tissue. A goitre which passes back of the sternum is known as substernal or intrathoracic. A goitre may extend back of the trachea or back of the oesophagus.

Exophthalmic goitre, Graves’s disease or Basedow’s disease, is a remarkable disease. Its three chief symptoms are enlargement of the thyroid, or goitre; prominence of the eyeballs, or exophthalmos, and very rapid pulse, or tachyaeardia. Dyspnoea, tremor, and various other symptoms are usually found. The thyroid gland may be the seat of a carcinoma or sarcoma (malignant goitre), syphilis or tuberculous disease, ordinary inflammation, suppuration, or hydatid disease; for the relief of ordinary goitre various methods have been employed. Tapping, injection of astringents, simple incision, and the seton are obsolete. Ligature of the thyroid arteries is rarely performed as a curative measure. The superior and inferior thyroids of one side have been tied in some cases; all four thyroids in other cases. Jaboulay has performed exothyropexy. In this operation the gland is dislocated from its bed, brought out of the wound, and left exposed, in hope that it will atrophy. Division of the isthmus is occasionally practised to relieve dyspnoea. The operation sometimes succeeds, but often fails.

Exirption of one-half or two-thirds of the gland is a very successful operation. Removal of the entire gland will be followed by operative myxoedema. Removal or injury of the parathyroids causes tetany.

In exirpating a lobe of the thyroid by the method until recently in vogue, great care must be taken to avoid tearing the capsules, as if this happens the gland-tissue bleeds profusely. The thyroid arteries should be ligatured on the diseased side before an attempt is made to remove the mass, and in ligaturing the inferior thyroid the position of the recurrent laryngeal nerve must be borne in mind, so as not to include it in the ligature. In order to preserve the parathyroids from injury, C. H. Mayo recommends that after the vessels entering and leaving the thyroid have been double clamped and divided, the entire lobe should be elevated, the capsule split along the side of the gland and pushed back with gauze, and the gland lifted and removed without disturbing the posterior portion of the capsule.

A cystic or solid tumor of the thyroid may be removed by intraglandular enucleation. If operation becomes necessary in exophthalmic goitre, partial extirpation is usually preferred. Bilateral extirpation of the cervical ganglia of the sympathetic (sympathectomy or Jannsen’s operation) has been practised by some surgeons for exophthalmic goitre. The value of the procedure is uncertain.

THE PARATHYROID GLANDS (Fig. 1012).

The parathyroid glands or the epithelial corpuscles of Kohn were first described as anatomical entities by Sandstrom in 1850. Owen had seen the parathyroids in the rhinoceros in 1862, but he did not recognize any peculiarities of structure. Virchow observed them in man in 1863 but he regarded them as lymph-glands or detached portions of thyroid tissue. Gley, in 1891, called attention to glands within the body of the thyroid. In 1895 Kohn affirmed that the parathyroids are separate organs and not a part of the thyroid gland. If the thyroid gland has been carefully detached, two round bodies of small size may be found embedded

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2 I am indebted to Dr. F. D. Patterson for collecting the literature upon the parathyroids.
upon the trachea or upon the surface of the lateral lobe of the gland, between the terminal branches of the inferior thyroid artery. "These are the parathyroids, about the size of orange-seeds, and brownish-red in color." They are smaller in infants than in adults. Welsh describes them in adults as from 6 to 7 mm. in length, 3 to 4 mm. in breadth, and 1½ to 2 mm. in thickness. These masses are constant in man. There is no record of a case in which they were congenitally absent. Although the parathyroids lie on or in the thyroid, they are always completely separated from it by capsules of connective tissue. Although there are usually four parathyroids, there may be but three, or there may be six or even eight. Parathyroid tissue may exist within the thyroid gland even when the superior parathyroids are present. Accessory parathyroids may be found over a wide area. Rogers and Ferguson found one in the middle of the posterior portion of the pharynx. Ogle found a gland in the thorax which was partly parathyroid. The parathyroids are divided from their situation into external and internal. The former, usually two in number, are situated, one on each side, in relation to the postero-internal surface of the lateral lobe of the thyroid; sometimes they are duplicated. The latter, also usually two in number, are placed one in or on each lateral lobe of the thyroid, generally near its mesal surface.

Structure.—The structure of the parathyroids is different from that of the thyroid. They are composed of solid masses of epithelial cells arranged in a more or less columnar fashion with numerous intervening capillaries. The columns of the parathyroids anastomose. There is a certain type of cell, but the form varies. These variations result from changes due to episodes of rest and activity (Verebely). MacCallum's studies seem to lead to the same conclusion. Thompson states that he finds only one type of cell in the infant gland, and that in the adult there is primarily but one type of cell, the other cells noted being modifications of the principal cell due to degeneration or hyperfunction. There is much lymphoid tissue connected with the columns. The nerves of the parathyroids are derived from the sympathetic system. Each parathyroid gland is supplied by a parathyroid artery. The inferior parathyroid artery is always a branch of the inferior thyroid artery or of the anastomosing channel between the superior and inferior thyroid arteries of one side (Geist). The superior parathyroid artery may be a branch of the superior thyroid (Poole), but it is usually a branch of the inferior thyroid or of the anastomosing channel. Ginsburg has shown that each of the glands has an accessory blood supply by anastomotic channels from the opposite side.

Embryology.—The parathyroids develop chronologically in advance of the thyroid. They are derived from the third and fourth branchial clefts of each side. An independent accessory parathyroid may develop from the fifth cleft (Getzowa, Michand). Some have regarded the parathyroids as embryonic portions of the thyroid, but, as MacCallum says, "there is no histological proof that parathyroid tissue can ever become converted into thyroid tissue." Most observers regard the parathyroids as distinct glands possessed of a special function. Certain it is, as Gley and others have shown, removal of the parathyroids from herbivora leaving the thyroid intact is followed by spasms, tetany, etc., just as complete thyroidectomy is followed by such symptoms in carnivora.

Surgical Anatomy.—Surgeons have become convinced that removal of the parathyroids in man causes tetany, and that damage to them may produce serious symptoms. Because of this danger most surgeons now prefer to remove a goitre from within the capsule of the thyroid gland after the plan of the Mayos, and thus avoiding the parathyroids.

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1. Practical Anatomy, By Prof. Alfred W. Hughes.
2. Journal of Anatomy and Physiology, 1897-1898.
THE THYMUS GLAND (Fig. 1013).

The thymus gland is a temporary organ, attaining its full size at the end of the second year, when it ceases to grow and remains practically stationary until puberty, at which period it rapidly degenerates. It does not entirely disappear, for the shrunken and-degenerated mass, even later in life, maintains a likeness to the original form and retains within its substance small portions of thymus tissue (Waldeyer). If examined when its growth is most active, it will be found to consist of two lateral lobes placed in close contact along the middle line, situated partly in the superior mediastinum, partly in the neck, and extending from the level of the fourth costal cartilage upward as high as the lower border of the thyroid gland. It is covered by the sternum and by the origins of the Sterno-hyoid and Sterno-thyroid muscles. Below, it rests upon the pericardium, being separated from the arch of the aorta and great vessels by a layer of fascia. In the neck it lies on the front and sides of the trachea, behind the Sterno-hyoid and Sterno-thyroid muscles. The two lobes generally differ in size; they are occasionally united so as to form a single mass, and are sometimes separated by an intermediate lobe. The thymus is of a pinkish-gray color, is soft and is lobulated on its surfaces. It is about two inches in length, one and a half inches in breadth below, and about three or four lines in thickness. At birth it weighs about half an ounce.

Structure (Figs. 1014 and 1015).—Each lateral lobe is composed of numerous lobules held together by delicate areolar tissue, the entire gland being enclosed in an investing capsule of a similar but denser structure. The primary lobules vary in size from a pin's head to a small pea, and are made up of a number of small nodules or follicles which are irregular in shape and are more or less fused together, especially toward the interior of the gland. Each follicle consists of a
medullary and cortical portion, which differ in many essential particulars from each other. The cortical portion is mainly composed of lymphoid cells supported by a delicate reticulum. In addition to this reticulum, of which traces only are found in the medullary portion, there is also a network of finely branched cells which is continuous with a similar network in the medullary portion. This network forms an adventitia to the blood-vessels. In the medullary portion there are but few lymphoid cells, but there are, especially toward the centre, granular cells and concentric corpuscles. The granular cells are rounded or flask-shaped masses attached (often by fibrillated extremities) to blood-vessels and to newly formed connective tissue. The concentric corpuscles are composed of a central mass consisting of one or more granular cells, and of a capsule which is formed of epithelioid cells which are continuous with the branched cells forming the network mentioned above.

Each follicle is surrounded by a capillary plexus from which vessels pass into the interior and radiate from the periphery toward the centre, and form a second zone just within the margin of the medullary portion. In the centre of the medulla there are very few vessels, and they are of minute size.

Watney has made the important observation that haemoglobin is found in the thymus either in cysts or in cells situated near to or forming part of the concentric corpuscles. This haemoglobin varies from granules to masses exactly resembling colored blood-corpuscles, oval in the bird, reptile, and fish; circular in all mammals except in the camel. Dr. Watney has also discovered in the lymph issuing from the thymus similar cells to those found in the gland, and, like them, containing haemoglobin either in the form of granules or masses. From these facts he arrives at the physiological conclusion that the thymus is one source of the colored blood-corpuscles.

Vessels and Nerves.—The arteries supplying the thymus are derived from the internal mammary and from the superior and inferior thyroid. The veins terminate in the two innominate veins, and in the internal mammary and the thyroid veins. The lymphatics are of large size, arise in the substance of the gland, and are said to terminate in the internal jugular vein. The nerves are
exceedingly minute; they are derived from the vagus and sympathetic. Branches from the descendens hypoglossi and phrenic reach the investing capsule, but do not penetrate into the substance of the gland.

**THE CAROTID GLAND OR CAROTID BODY (GLOMUS CAROTICUM)**

This body, when present, lies in the carotid bifurcation, to the inner side of the common carotid below the bifurcation, or on the posterior surface of the internal or of the external carotid artery. Gomez finds it "most commonly between the internal and external carotid arteries, resting posteriorly on the bifurcation of the common carotid." It is often absent. Funke found it absent in 7 foetuses out of 8. In 50 human cases examined by Gomez it was absent in 5 cases. In 4 of Gomez's cases it was found only on one side. It lies in fatty tissue and is surrounded by a fibrous capsule which is attached to the carotid sheath, upon which it lies by a short stump known as the ligament of Mayer. The carotid gland is about the size of a grain of corn; it is oval or rounded in shape and reddish-brown in color. The capsule of the gland sends septa inward. The septa divide the organ into follicles or cell-balls. These cell-balls are composed of endothelial cells and are associated with blood capillaries. A branch (or branches) from the carotid artery, upon which the gland

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1 American Journal of Medical Sciences, July, 1908
lies, enters the carotid gland through the ligament of Mayer. Many nerve filaments surround the carotid gland, and they usually, but not always, form a plexus, known as the inter-carotid plexus. According to Poirier and Charpy these filaments come from the superior cervical ganglion of the sympathetic, the glossopharyngeal, the hypoglossal, the superior laryngeal, and the nervi molles of Haller. (This structure has been recently studied by John Funke, Reclus and Chevasson, Paltauf, Kartschenko, Marchand, and Gomez.)

**Surgical Anatomy.**—Tumors may arise from this structure. Such a tumor is apt to be above the level of the upper margin of the thyroid cartilage, and in most cases it moves with each arterial beat.

**THE COCCYGEAL GLAND OR COCCYGEAL BODY OR LUSCHKA’S GLAND (GLOMUS COCCYGEUM).**

Lying near the tip of the coccyx in a small tendinous interval formed by the union of the Levator ani muscles and just above the coccygeal attachment of the Sphincter ani, is a small conglobate body about as large as a lentil or a pea, first described by Luschka, and named by him the coccygeal gland. Its most obvious connections are with the arteries of the part. It is similar in structure to the carotid body.

**Structure.**—It consists of a congeries of small arteries with little aneurismal dilatations derived from the middle sacral and freely communicating with each other. These vessels are enclosed in one or more layers of polyhedral granular cells, and the whole structure is invested in a capsule of connective tissue which sends in trabeculae, dividing the interior into a number of spaces in which the vessels and cells are contained. Nerves pass into this little body from the sympathetic, but their mode of termination is unknown. Macalister believes the glomerulus of vessels “consists of the condensed and convoluted metameric dorsal arteries of the caudal segments embedded in tissue which is possibly a small persisting fragment of the neurenteric canal.” It resembles the carotid gland in structure, and is probably one of the ductless glands.

**THE PARASYMPATHETIC BODIES (ORGANA PARASYMPATHETICA OF ZUCKERKANDL).**

The parasympathetic bodies were discovered in 1901 by Zucker kendl. They are from one to four in number, situated retroperitoneally, ventrad of the abdominal aorta at the level of the third and fourth lumbar vertebrae. Each parasympathetic body is from 6 to 10 mm. in length and from 2 to 4 mm. in width. These bodies are usually supplied by fine arterial twigs from the aorta. They are best developed in the foetus and in infancy, and in their structure they resemble the carotid and coccygeal bodies.

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1 American Medicine, vol. viii., No. 3.
3 American Journal of Medical Sciences, July, 1908.
THE URINARY ORGANS.

THE KIDNEYS (RENES) (Figs. 1016, 1017, 1018).

The Kidneys are large glands. They are two in number, and are situated in the back part of the abdomen, near the spinal column. Their function is to separate from the blood certain materials which, when dissolved in a quantity of water, also separated from the blood by the kidneys, constitute the urine.

They are placed in the loins, one on each side of the vertebral column, behind the peritoneum, and are surrounded by a mass of fat and loose areolar tissue, which constitutes the fatty capsule (capsula adiposa) (Figs. 1021 and 1022). There are two distinct layers in this fatty capsule. The superficial fatty layer is the pararenal fat. Keen calls this layer the transversalis layer of fat, because it is derived from the

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1 See Gerota, Arch. f. Anatomie, Leipzig, 1895; Zuckerkindl, Medizinische Jahrbücher, Vienna, 1883.
transversalis fascia. The deeper and thicker perirenal layer is the true perinephric fat (Fig. 1022). The deeper layer of fat completely surrounds the kidney, and is somewhat adherent to the fibrous renal capsule. The fat about the kidney does not look like fat in other regions, but is soft, delicate, and of a canary yellow color. These two fatty layers are separated by a layer of connective tissue, which is the posterior layer of the perirenal fascia, and is called by Zuckerkandl the retrorenal fascia (fascia retrorenalis) (Fig. 1021). The true capsule of the kidney (tunica fibrosa) is thin, smooth, and glistening. The inner part of this capsule (tunica muscularis) contains unstriated muscle fibres. The true capsule can be easily separated from the underlying glandular structure. The upper extremity of the kidney is on a level with the upper border of the twelfth thoracic vertebra, the lower extremity on a level with the third lumbar vertebra (Fig. 1019). The right kidney is usually on a slightly lower level than the left, probably on account of the vicinity of the liver. In the female the kidneys are a little lower than in the male.

Each kidney is about four and a half inches in length, two to two and a half in breadth, and rather more than one inch in thickness. The left is somewhat longer, though narrower, than the right. The weight of the kidney in the adult male varies from 4½ ounces to 6 ounces; in the adult female, from 4 ounces to 5½ ounces. The combined weight of the two kidneys in proportion to the body is about 1 in 240.

The kidney has the characteristic form of a "flattened bean" (Spalteholz). It is flattened on its sides and presents at one part of its circumference a hollow. It is larger at its upper than at its lower extremity. The kidney presents for examination two surfaces, two borders, and an upper and lower extremity.

Surfaces. The Anterior Surface (facies anterior) (Figs. 1016 and 1017).—Its anterior surface is convex, looks forward and outward, and is partially covered by peritoneum. The right kidney in its upper three-fourths is in contact with the posterior part of the under surface of the right lobe of the liver. This area of the right kidney is flattened (impressio hepatica). Toward its inner border it is covered by the second part of the duodenum, while its lower and outer part is in relation with the hepatic flexure of the colon. The relation of the second part of the duodenum to the front of the right kidney is a varying one. The left kidney is covered above

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1 W. W. Keen, in American Medicine, January 31, 1903.
by the posterior surface of the stomach, below the stomach by the pancreas, behind which are the splenic vessels. The region in contact with the stomach is markedly depressed (impressio gastrica). Its lower half is in contact with some of the coils

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**Fig. 1019.**—Posterior surface of the kidneys. (Poirier and Charpy.)

**Fig. 1020.**—Relation of the kidney to the vertebral column, ribs, muscles, and lumbo-costal ligaments. (Poirier and Charpy.)
of the small intestine and sometimes with the third part of the duodenum. Near its outer border the anterior surface lies behind the spleen and the splenic flexure of the colon.

The kidneys are partly covered in front by peritoneum and partly uncovered. On the right kidney, the hepatic area, that is to say that portion of the kidney which produces the renal impression on the liver, is covered by peritoneum, which therefore separates the kidney from the liver; the duodenal and colic areas are not peritoneal, and these structures are connected to the kidney by loose connective tissue; at the lower and inner extremity is a small area, the mesocolic area, which is covered by a layer of peritoneum of the greater sac and by the colic vessels. On the left kidney the gastric area is covered by the peritoneum of the lesser sac; the pancreatic and colic areas are non-peritoneal; while, as on the right side, at the lower and inner extremity, is an area, mesocolic area, which is covered by the peritoneum of the greater sac and by the colic vessels.

The Posterior Surface (facies posterior) (Fig. 1018).—The posterior surface of the kidney is flatter than the anterior and is directed backward and inward. It is

![Diagram of the kidney showing the layers and fat.]
and when this is the case the perirenal areolar tissue is in immediate apposition with the diaphragmatic pleura. In the lower part of the posterior surface of the kidney is an impression produced by the Quadratus lumborum muscle and called the impressio muscularis. A little internal to this a flattening, caused by the Psoas muscle, is often recognizable. At the upper part of the posterior surface is a sulcus produced by contact with the Diaphragm.

**Borders. The External Border** (margo lateralis) (Figs. 1017 and 1018).—The external border is convex, and is directed outward and backward, toward the postero-lateral wall of the abdomen. On the left side it is in contact, at its upper part, with the spleen (Fig. 1016).

**The Internal Border** (margo medialis) (Figs. 1017 and 1018).—The internal border is concave, and is directed forward, inward, and a little downward. It presents a deep longitudinal fissure, bounded by a prominent overhanging anterior and posterior lip. This fissure is named the hilum (hillus renalis) (Fig. 1023), and allows of the passage of the vessels, nerves, and ureter into and out of the kidney.

**Extremities. The Superior Extremity** (extremitas superior) (Figs. 1017 and 1018).—The superior extremity, directly slightly inward as well as upward, is thick and rounded, and is surmounted by the suprarenal capsule (Fig. 1023), which covers also a small portion of the anterior surface.

**The Inferior Extremity** (extremitas inferior) (Figs. 1017 and 1018).—The inferior extremity, directed a little outward as well as downward, is smaller and thinner than the superior. It extends to within two inches of the crest of the ilium.

At the hilum of the kidney the relative position of the main structures passing into and out of the kidney is as follows: the vein is in front, the artery in the middle, and the duct or ureter behind and toward the lower part (Fig. 1018). By a knowledge of these relations the student may distinguish between the right and left kidney. The kidney is to be laid on the table before the student on its posterior surface, with its lower extremity toward the observer—that is to say, with the ureter behind and below the other vessels; the hilum will then be directed to the side to which the kidney belongs.

**General Structure of the Kidney.**—The kidney is surrounded by a distinct investment of fibrous tissue, which forms the firm, smooth true capsule covering the entire organ. The capsule passes over the margins of the hilum, enters the interior of the kidney, and covers the wall of the sinus. The true capsule is closely and firmly adherent to the renal pelvis where it is attached to the sinus. It closely invests it, but can be easily stripped off, in doing which, however, numerous fine processes of connective tissue which pass to the intrarenal connective tissue and numerous small blood-vessels are torn through. Beneath this fibrous layer a thin wide-meshed network of unstriped muscular fibre forms an incomplete covering to the organ. When the true capsule is stripped off, the surface of the kidney is found to be smooth, even, and of a deep-red color.

In infants fissures extending for some depth may be seen on the surface of the organ, a remnant of the lobular construction of the gland (Fig. 1040). The kidney is dense in texture, but is easily lacerable by mechanical force. In order to obtain a knowledge of the structure of the gland, a vertical section must be made from its convex to its concave border, and the loose tissue and fat removed around the vessels and the excretory duct (Fig. 1023). It will be then seen that the kidney consists of a central cavity surrounded at all parts but one by the proper kidney-substance. This central cavity is called the sinus (sinus renalis), and is lined by a prolongation of the fibrous coat of the kidney, which enters through a longitudinal fissure, the hilum (Fig. 1023), which is situated at that part of the cavity which is not surrounded by kidney structure. Through this fissure the blood-vessels of the kidney and its excretory duct pass, and therefore these structures, upon entering the kidney, are contained within the sinus.
THE URINARY ORGANS (Fig. 1017). The excretory duct or ureter, after entering, dilates into a wide, funnel-shaped sac named the pelvis (pelvis renalis) (Figs. 1023 and 1024). This divides into two or three tubular divisions, which subdivide into several short, truncated branches named calices or infundibula (calyces renales), all of which are contained in the central cavity of the kidney (Figs. 1023 and 1024). The blood-vessels of the kidney, after passing through the hilum, are contained in the sinus or central cavity, lying between its lining membrane and the excretory apparatus, before entering the kidney-substance (Fig. 1024).

This central cavity, as before mentioned, is surrounded on all sides except at the hilum by the substance of the kidney, which is at once seen to consist of two parts—viz., of an external granular investing part, which is called the cortical portion (substantia corticalis); and of an internal part, the medullary portion (substantia medullaris), made up of a number of dark-colored pyramids, with their bases resting on the cortical part and their apices converging toward the centre, where they form prominent papillae, the renal papillae (papillae renales), which project into the interior of the calices (Fig. 1023.)

The cortical substance (Figs 1023 and 1030) is of a bright reddish-brown color, soft, granular, and easily lacerable. It is found everywhere immediately beneath the capsule, and is seen to extend in an arched form over the base of each medullary pyramid. Prolongations of the cortical substance pass between the pyramids toward the renal sinus. These prolongations are the cortical columns or the columns of Bertin (columnae renales) (Fig. 1023, B B). The columns contain blood-vessels, nerves, and lymphatics. The base of each pyramid (basis pyramidis) is known as the intermediate zone. That portion of the cortical substance which stretches from one cortical column to the next, and intervenes between the base of the pyramid and the capsule (marked by the dotted line extending from A to A' in Fig. 1023), is called a cortical arch, the depth of which varies from a third to half an inch.
The medullary substance (Figs. 1023 and 1030), as before stated, is seen to consist of red-colored, striated, conical masses, the pyramids of Malpighi (pyramides renales) (Fig. 1023), the number of which, varying from eight to eighteen, corresponds to the number of lobes of which the organ in the foetal state is composed. The pyramids are composed of straight tubes which pass between the apices of the papillae and the cortical margin. They enter the cortex in masses called the pyramids of Ferrein (see below). The sides of the pyramids of Malpighi are contiguous with the cortical columns, while the apices, known as the papillae of the kidney (Figs. 1023 and 1027), project into the calices of the ureter, each calyx receiving two or three papillae. Radiating from the bases of the pyramids of Malpighi are ridges of cortical substance with distinct depressions between them.

These ridges are the medullary rays (pars radiata) or pyramids of Ferrein (Figs. 1026 and 1030). The labyrinth of the cortex (Fig. 1026) is constituted by the kidney substance between the rays. The pyramids of Ferrein look like direct continuations of the medullary substance, but, in reality, they are in the cortex, and are formed by the straight tubes extending in masses into the cortex. The pyramids of Ferrein are much smaller than the pyramids of Malpighi. In the columns of
Bertin blood-vessels, nerves, and lymphatics pass to and emerge from the sinus by way of small foramina. The summit of a papilla contains a number of orifices of papillary ducts. Such an area is called an area cribrosa (Fig. 1027).

These two parts, cortical and medullary, so dissimilar in appearance, are very similar in structure, being made up of urinary tubes and blood-vessels united and bound together by a connecting matrix or stroma.

**Minute Anatomy.**—The uriniferous tubes, urinary canals or tubuli uriniferi (tubuli renales) (Figs. 1025 and 1030), of which the kidney is for the most part made up, commence in the cortical portion of the kidney. Each tubule begins between the medullary rays (Fig. 1026) in a sac, Bowman's capsule or the Malpighian capsule (see below). The tubules, as a rule, after pursuing a very circuitous course through the cortical and medullary parts of the kidney, finally terminate at the apices of the Malpighian pyramids by open mouths, so that the fluid which they contain is emptied into the dilated extremity of the ureter contained in the sinus of the kidney. If the surface of one of the papillae is examined with a lens, it will be seen to be studded over with a number of small depressions (foramina papillaria), from sixteen to twenty in number, and in a fresh kidney, upon pressure being made, fluid will be seen to exude from these depressions. They are the orifices of the tubuli uriniferi, which terminate in this situation. The tubuli uriniferi being in the cortex as the Malpighian bodies or corpuscles (corpuscula renis) (Figs. 1025, 1026, 1028, and 1031), which are small rounded masses, varying in size, but average, about \( \frac{1}{12} \) of an inch in diameter. They are of a deep-red color, and are found only in the cortical portion of the kidney. Each of these little bodies is composed of two parts—a central glomerulus of vessels, called a Malpighian tuft, and a membranous envelope, the Malpighian capsule or capsule of Bowman (capsula glomeruli), which latter is a small pouch-like commencement of a uriniferous tubule.

The Malpighian Tuft or Vascular Glomerulus (Figs. 1028, 1030, 1035, and 1036) is a network of convoluted capillary blood-vessels held together by scanty connective tissue and grouped into from two to five lobules. This capillary network is derived from a small arterial twig, the afferent vessel, which pierces the wall of the capsule, generally at a point opposite that at which the latter is connected.
with the tube; and the resulting efferent vessel emerges from the capsule at the same point. The afferent vessel is usually the larger of the two (Fig. 1028). The Malpighian or Bowman's capsule (capsula glomeruli) (Figs. 1028, 1029, and 1030), which surrounds the glomerulus, is formed of a hyaline membrane supported by a small amount of connective tissue which is continuous with the connective tissue of the tube. It is lined on its inner surface with a layer of squamous epithelial cells which are reflected from the lining membrane on to the glomerulus at the point of entrance or exit of the afferent and efferent vessels. The whole surface of the glomerulus is covered with a continuous layer of the same cells on a delicate supporting membrane, which with the cells dips in between the lobules of the glomerulus, closely surrounding them. Thus, between the glomerulus and the capsule a space is left, forming a cavity lined by a continuous layer of cells, which varies in size according to the state of secretion and the amount of fluid present in it. The cells, as above stated, are squamous in the adult, but in the foetus and young subject they are polyhedral or even columnar.

The Tubuli Uriniferi, commencing in the Malpighian bodies, in their course present many changes in shape and direction (tubuli renales contorti), and are contained partly in the medullary and partly in the cortical portions of the organ.

At the junction of a tubule with the Malpighian capsule there is a somewhat constricted portion which is termed the neck (Fig. 1031). Beyond this the tubule becomes convoluted, and pursues a considerable course in the cortical structure, constituting the proximal or first convoluted tubule (Figs. 1030 and 1031). After a time the convolutions disappear, and the tubule approaches the medullary portion of the kidney in a more or less spiral manner. This section of the tubule has been called the spiral tube of Schachowa (Fig. 1031). Throughout this portion of their course the tubuli uriniferi have been contained entirely in the cortical structure, and have presented a pretty uniform calibre. They now enter the medullary portion, and suddenly become much smaller, quite straight in direction (tubuli renales recti), and each tubule dips down for a variable depth into the pyramids, constituting the descending limb of Henle's loop (Figs. 1030 and 1031). Bending on itself, it forms a kind of loop near the apex of the pyramid, the loop of Henle, and, reascending, becomes suddenly enlarged and again spiral.
in direction, forming the ascending limb of Henle's loop (Figs. 1030 and 1031), and re-enters the cortical structure. This portion of the tubule does not present a uniform calibre, but becomes narrower as it ascends and irregular or somewhat spiral in outline (Fig. 1031). As a narrow tube it enters the cortex and ascends for a short distance, when it again becomes dilated, irregular, and angular. This section is termed the irregular tubule (Fig. 1031); it terminates in a convoluted tubule which exactly resembles the proximal convoluted tubule; and is called the distal or second convoluted tubule (Figs. 1030 and 1031). This again terminates in a narrow curved or junctional tubule, which enters the straight or collecting tube.

Each straight collecting or receiving tube (Figs. 1030 and 1031) commences by a small orifice on the summit of a papilla, thus opening and discharging its contents into the interior of one of the calices. Traced into the substance of the pyramid, these tubes are found to run from apex to base, dividing dichotomously in their course and slightly diverging from each other. Thus dividing and subdividing, they reach the base of the pyramid, and enter the cortical structure greatly increased in number. Upon entering the cortical portion they continue a straight course for a variable distance, and are arranged in groups, several of these groups corresponding to a single pyramid. The tubes in the centre of the group are the longest, and reach almost to the surface of the kidney, while the external ones are shorter, and advance only a short distance into the cortex. In consequence of this arrangement the cortical portion presents a number of conical masses, the apices of which reach the periphery of the organ, and the bases are applied to the medullary portion. These are termed the medul-

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**Fig. 1029.—A section through the cortex of an ape's kidney. A Malpighian corpuscle, together with the beginning of the urinary canal, is shown. X350.**
lary rays or the pyramids of Ferrein (Fig. 1026; also p. 1426). As they run through the cortical portion the straight tubes receive on either side the curved extremity of the convoluted tubes, which, as stated above, commence at the Malpighian bodies. Each collecting tube receives a number of tubules, and several collecting tubes unite together to form a papillary duct (Fig. 1030) and open by a foramen (Fig. 1027) at the surface of the papilla.

It will be seen from the above description that there is a continuous series of tubes from their commencement in the Malpighian bodies to their termination at the orifices on the apices of the pyramids of Malpighi, and that the urine,
the secretion of which commences in the capsule, finds its way through these tubes into the calices of the kidney, and so into the ureter. To recapitulate:

1. The tube first presents a constricted portion, (1) the neck.
2. It forms a wide convoluted tube, the proximal convoluted tube.
3. It becomes spiral, the spiral tubule of Schachowa.
4. It enters the medullary structure as a narrow, straight tube, the descending limb of Henle’s loop.
5. Forming a loop and becoming dilated, it ascends somewhat spirally, and, gradually diminishing in calibre, again enters the cortical structure, the ascending limb of Henle’s loop.
6. It now becomes irregular and angular in outline, the irregular tubule.
7. It then becomes convoluted, the distal convoluted tubule.
8. Diminishing in size, it forms a curve, the curved or junctional tubule.
9. Finally, it joins a straight tube, the straight collecting tube, which is continued downward through the medullary substance and joins other straight tubes to form a papillary duct, which opens in a foramen at the apex of a pyramid.

**The Tubuli Uriniferi: Their Structure** (Figs. 1032, 1033, and 1034).

The tubuli uriniferi consist of basement-membrane lined with epithelium. The
epithelium varies considerably in different sections of the urinary tubes. In the neck the epithelium is continuous with that lining the Malpighian capsule, and, like it, consists of flattened cells with an oval nucleus. The cells are, however, very indistinct and difficult to trace, and the tube has here the appearance of a simple basement-membrane unlined with epithelium. In the proximal convoluted tubule and the spiral tubule of Schachowa the epithelium is polyhedral in shape, the sides of the cells not being straight, but fitting into each other, and in some animals so fused together that it is impossible to make out the lines of junction. In the human kidney the cells often present an angular projection of the surface next the basement-membrane. These cells are made up of more or less rod-like fibres, which rest by one extremity on the basement-membrane, whilst the other projects toward the lumen of the tube. This gives to the cells the appearance of distinct striation. In the descendine limb of Henle's loop the epithelium resembles that found in the Malpighian capsule and the commencement of the tube, consisting of flat transparent epithelial plates with an oval nucleus (Fig. 1032). In the ascending limb, on the other hand, the cells partake more of the character of those described as existing in the proximal convoluted tubule, being polyhedral in shape and presenting the same appearance of striation. The nucleus, however, is not situated in the centre of the cell, but near the lumen (Fig. 1034). After the ascending limb of Henle's loop becomes narrower upon entering the cortical structure, the striation appears to be confined to the outer part of the cell; at all events, it is much more distinct in this situation, the nucleus, which appears flattened and angular, being still situated near the lumen. In the irregular tubule the cells undergo a still further change, becoming very angular, and presenting thick bright rods or markings, which render the striation much more distinct than in any other section of the urinary tubules. In the distal convoluted tubule the epithelium appears to be somewhat similar to that which has been described as existing in the proximal convoluted tubule, but presents a peculiar refractive appearance. In the curved tubule, just before its entrance into the straight collecting tube, the epithelium varies greatly as regards the shape of the cells, some being angular with short processes, others spindle-shaped, others polyhedral.

In the straight tubes the epithelium is more or less columnar; in its papillary portion the cells are distinctly columnar and transparent (Fig. 1033), but as the tube approaches the cortex the cells are less uniform in shape; some are polyhedral, and others angular with short processes.
The Renal Blood-vessels.—The kidney is plentifully supplied with blood by the renal artery (Figs. 1018 and 1024), a large offset of the abdominal aorta. Previously to entering the kidney, each artery divides into four or five branches, which are distributed to its substance. At the hilum these branches lie between the renal vein and ureter, the vein being in front, the ureter behind. Each vessel gives off a small branch to the suprarenal capsules, the ureter, and the surrounding cellular tissue and muscles. It has been pointed out by Hyrtl (p. 680) that the renal artery gives off a branch which divides and supplies the dorsal portion of the kidney and a branch which divides and supplies the ventral portion of the kidney. Between these two vascular systems is a non-vascular zone, called by Robinson the exsanguinated renal zone of Hyrtl. It "is one-half inch dorsal to the lateral longitudinal renal border." Frequently there is a second renal artery, which is given off from the abdominal aorta at a lower level, and supplies the lower portion of the kidney. It is termed the inferior renal artery. The branches of the renal arteries pass to the kidney substance between the pyramids and are known as interlobar arteries (arteriae interlobares renis) (Figs. 1026, 1030, 1037, and 1038). At the junction of the cortical and medullary portions these vessels turn and for a short distance pursue a course parallel to the kidney surface. There are thus formed a series of incomplete vascular arches across the bases of the pyramids, the arcuate arteries (arteriae arciformes) (Figs. 1030, 1035, and 1036). From these arches two sets of vessels come. The vessels of one set go to the periphery and enter the labyrinth, those of the other set pass toward the centre and enter the intermediate zone of the medulla. These last vessels are the arteriolae recti (Figs. 1030, 1035, and 1036). Because of these vessels the kidney exhibits striations on section. Each of the arteriolae recti in the medulla divides into numerous small branches which are nearly parallel to each other and supply the tubules of this region. The arteries which arise from the arches and pass to the periphery are the interlobular arteries (arteriae interlobulares) (Figs. 1030, 1035, 1036, and 1039). They traverse the labyrinth and pass toward the surface of the kidney. A number of short branches, the vasa afferentia, are given off by the interlobular arteries (Figs. 1030, 1035, 1036, and 1039). Each afferent vessel passes to a capsule of Bowman. On reaching the capsule the vessel forms a capillary mass, the glomerulus, which is within the invaginated capsule (Figs. 1030, 1035, and 1039).

Emerging from each glomerulus is a small vessel, the vas efferens (Figs. 1030, 1035, and 1039).
1028, 1030, 1035, and 1039). This vessel divides into capillaries which are distributed to the tubules of the labyrinth and medullary rays. Blood is gathered from the capillaries about the tubules by veins which correspond to the interlobular arteries and arteriolae recti. These veins form a set of arches across the bases of the pyramids. From the arches veins arise and pass between the pyramids to the sinus of the kidney, where they unite and form branches of the renal vein.

**Nerves of the Kidney.**—The nerves of the kidney, although small, are about fifteen in number. They have small ganglia developed upon them, and are derived from the renal plexus, which is formed by branches from the solar plexus, the lower and outer part of the semilunar ganglion and aortic plexus, and from the lesser and smallest splanchnic nerves. They communicate with the spermatic plexus, a circumstance which may explain the occurrence of pain in the testicle in affections of the kidney. So far as they have been traced, they seem to accompany the renal artery and its branches, but their exact mode of termination is not known.

**The Lymphatics.**—The lymphatics consist of a superficial and deep set.

The superficial lymphatics are just beneath the capsule. From them come two sets of collecting trunks (Sappey). One set joins the deep collectors by entering the kidney substance or passing to the hilum. Another set pass into the lymphatics of the fatty capsule.

The deep collectors emerge from the hilum and lie about the renal artery and vein. From the right kidney some of the trunks pass to the glands about the postcava and possibly also in the glands in front of the aorta. Others end in the glands back of the postcava (Stahr).

From the left kidney the trunks pass to the glands which lie along the left side of the abdominal aorta.¹ The lymphatics of the fatty capsule of the kidney pass to the same glands as do the deep collectors of the kidney (Stahr).

**Connective Tissue or Intertubular Stroma.**—Although the tubules and vessels are closely packed, a certain small amount of connective tissue, continuous with the capsule, binds them firmly together. This tissue was first described by Good sir, and subsequently by Bowman. Ludwig and Zawarykin have observed distinct fibres passing around the Malpighian bodies, and Henle has seen them between the straight tubes composing the medullary structure.

**Variations and Abnormalities.**—Congenital absence of the kidney has been observed. Not unusually one kidney is considerably larger than the other; occasionally one is very large and the other is very small, from atrophy, the large organ having become large in response to a functional need, which causes it to compensate for the insufficiency of the small kidney. If a kidney is removed surgically, the other kidney enlarges. As previously stated, the kidneys of the foetus and of the young child show distinct fissures which makes each organ lobulated (Fig. 1040). The adult kidneys frequently exhibit remains of these fissures. A horseshoe kidney is a condition in which the lower poles of the two kidneys are united by kidney structure, the bend of union crossing the middle line. The strip of kidney tissue which effects the junction may be slight in amount,

¹ The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
considerable, or extensive. Sometimes the two kidneys are completely fused together into one large organ with two ureters.

**Surface Form.**—The kidneys, being situated at the back part of the abdominal cavity and deeply placed, cannot be felt unless enlarged or misplaced. They are situated on the confines of the epigastric and umbilical regions internally, with the hypochondriac and lumbar regions externally. The left is somewhat higher than the right. According to Morris, the position of the kidney may be thus defined: *Anteriorly:* "1. A horizontal line through the umbilicus is below the lower edge of each kidney. 2. A vertical line carried upward to the costal arch from the middle of Poupart's ligament has one-third of the kidney to its outer side and two-thirds to its inner side—i.e., between this line and the median line of the body." In adopting these lines it must be borne in mind that the axes of the kidneys are not vertical, but oblique, and if continued upward would meet about the ninth dorsal vertebra. *Posteriorly:* The upper end of the left kidney would be defined by a line drawn horizontally outward from the spinous process of the eleventh dorsal vertebra, and its lower end by a point two inches above the iliac crest. The right kidney would be half to three-quarters of an inch below. Morris lays down the following rules for indicating the position of the kidney on the posterior surface of the body: "1. A line parallel with, and one inch from, the spine, between the lower edge of the tip of the spinous process of the eleventh dorsal vertebra and the lower edge of the spinous process of the third lumbar vertebra. 2. A line from the top of this first line outward at right angles to it for two and three-quarter inches. 3. A line from the lower end of the first transversely outward for two and three-quarter inches. 4. A line parallel to the first and connecting the outer extremities of the second and third lines just described."

The hilum of the kidney lies about two inches from the middle line of the back, at the level of the spinous process of the first lumbar vertebra.

**Surgical Anatomy.**—Cases of congenital absence of a kidney, of atrophy of a kidney, and of horseshoe kidney are of great importance, and must be duly taken into account, when nephrectomy is contemplated. A more common malformation is where the two kidneys are fused together. They may be only joined together at their lower ends by means of a thick mass of renal tissue, so as to form a horseshoe-shaped body, or they may be completely united, forming a disk-like kidney, from which two ureters descend into the bladder. These fused kidneys are generally situated in the middle line of the abdomen, but may be misplaced as well.

One or both kidneys may be misplaced as a congenital condition, and remain fixed in this abnormal position. They are then very often misshapen. They may be situated higher or lower than normal or removed farther from the spine than usual or they may be displaced into the iliac fossa, over the sacro-iliac joint, on to the promontory of the sacrum, or into the pelvis between the rectum and bladder or by the side of the uterus. In these latter cases they may give rise to very serious trouble. The kidney may also be misplaced as a congenital condition, but may not be fixed. It is then known as a floating kidney. It is believed to be due to the fact that the kidney is completely enveloped by peritoneum, which then passes backward to the spine as a double layer, forming a mesonephron, which permits of movement taking place. The kidney may also be misplaced as an acquired condition; in these cases the kidney is mobile in the tissues by which it is surrounded, either moving in or moving with its fatty capsule. This condition is known as movable kidney (nephroptosis), and is more common in the female than in the male, and on the right than the left side. If a displaced kidney becomes fixed in an abnormal position, it is said to be dislocated. Movable kidney cannot be distinguished from floating kidney until the kidney is exposed by incision. Other malformations are the persistence of the foetal lobulation; the presence of two pelves or two ureters to the one kidney. In some rare instances a third kidney may be present.

The kidney is embedded in a large quantity of loose fatty tissue, and is but partially covered by peritoneum; hence, rupture of this organ is not nearly so serious an accident as rupture of the liver or spleen, since the extravasation of blood and urine which follows is, in the majority of cases, outside the peritoneal cavity. Occasionally the kidney may be *bruised* by blows in the loin or by being compressed between the lower ribs and the ilium when the body is violently bent forward. This is followed by a little transient *haematuria*, which, however, speedily passes off. Occasionally, when rupture involves the pelvis of the kidney or the commencement of the ureter, this duct may become blocked, and *hydropnephrosis* follows.

The loose cellular tissue around the kidney may be the seat of suppuration, constituting *perinephritic abscess*. This may be due to injury, to disease of the kidney itself, or to extension of inflammation from neighboring parts. The abscess may burst into the pleura, causing empyema; into the colon or bladder; or may point externally in the groin or loin. *Tumors of the kidney,* of which, perhaps, sarcoma in children is the most common, may be recognized by their position and fixity; by the resonant colon lying in front of it; by their not moving with respiration; and by their rounded outline, not presenting a notched anterior margin like the spleen, with which they are most likely to be confounded. The *examination of the kidney* should be bimanual; that is to say, one hand should be placed in the flank and firm pressure made forward, while
the other hand is buried in the abdominal wall, over the situation of the organ. Manipulation of the kidney frequently produces a peculiar sickening sensation and some faintness.

The kidney has, of late years, been frequently attacked surgically. It may be exposed and opened for exploration or the evacuation of pus (nephrotomy); it may be incised for the removal of stone (nephro-lithotomy); it may be sutured when wounded (nephropraxy); it may be fixed in place by sutures (nephropexy) or gauze pads when movable or floating; or it may be removed (nephrectomy).

The kidney may be exposed either by a lumbar or abdominal incision. The operation is best performed by a lumbar incision, except in a case of very large tumor or of wandering kidney with a loose mesonephron, on account of the advantages which it possesses of not opening the peritoneum and of affording admirable drainage. It may be performed either by an oblique a vertical, or a transverse incision. A common incision for exposing the kidney begins an inch below the twelfth rib at the margin of the Erector spinae muscle and passes obliquely downward and forward, exposing the anterior border of the Latissimus dorsi and the posterior border of the Internal oblique. The surgeon divides the posterior leaflet of the lumbar fascia, draws aside or incises the Quadratus lumbarum, and cuts the anterior leaflet of the lumbar fascia and also the transversalis fascia. He opens the fatty capsule down to the kidney and strips it from the true capsule, bringing the kidney outside of the body for inspection. The vertical incision at the edge of the Erector spinae muscle is frequently used. A gridiron or muscle-splitting operation is used by some in order to avoid the division of nerves, vessels, and muscular fibre.

The abdominal operation is best performed by an incision in the linea semilunaris on the side of the kidney to be removed, as recommended by Langenbuch; the kidney is then reached from the outer side of the colon, ascending or descending, as the case may be, and the vessels of the colon are not interfered with. If the incision were made in the linea alba, the kidney would be reached from the inner side of the colon, and the vessels running to supply the colon would necessarily be interfered with. The incision is made of varying length according to the size of the kidney, and commences just below the costal arch. The abdominal cavity is opened. The intestines are held aside, and the outer layer of the mesocolon incised, so that the fingers can be introduced behind the peritoneum and the renal vessels are sought for. These vessels are then to be ligatured: if tied separately, care must be taken to ligature the artery first. The kidney must now be enucleated, and the vessels and the ureter divided, and the latter disinfected and tied, and, if it is thought necessary, stitched to the edge of the wound.

THE URETER (Figs. 1017, 1018, 1019, 1024, 1041, 1042).

The ureters are the two tubes which conduct the urine from the kidneys into the bladder. The ureter commences within the sinus of the kidney by a number of short truncated branches, the calices or infundibula, which unite either directly or indirectly to form a dilated pouch, the pelvis (Fig. 1023), from which the ureter, after passing through the hilum of the kidney, descends to the bladder. The calices are cup-like tubes encircling the apices of the Malpighian pyramids; but inasmuch as one calyx may include two or even more papillae, their number is generally less than the pyramids themselves. The calices vary in number from eight to eighteen. These calices converge into two or three tubular divisions which by their junction form the pelvis or dilated portion of the ureter. The portion last mentioned, where the pelvis merges into the ureter proper, is found opposite the spinous process of the first lumbar vertebra, in which situation it is accessible behind the peritoneum (Fig. 1019).

The Ureter Proper.—The ureter proper is a cylindrical membranous tube, about sixteen inches in length and of the diameter of a goosequill, extending from the pelvis of the kidney to the bladder. Its course is obliquely downward and inward through the lumbar region (pars abdominalis) (Fig. 1042), into the cavity of the pelvis (pars pelvina) (Fig. 1042), where it passes downward, forward, and inward across that cavity to the base of the bladder, into which it then opens by a constricted orifice (orificeum ureteris) (Fig. 1039), after having passed obliquely for nearly an inch between its muscular and mucous coats (Fig. 1041). The lower part of the abdominal portion of the ureter exhibits a spindle-shaped dilatation.

Relations (Fig. 1042).—In its course it rests upon the Psoas muscle, being covered by the peritoneum, and crossed obliquely, from within outward, by the
spermatic vessels; the right ureter is crossed by the branches of the mesenteric arteries, which are distributed to the ascending colon, and the left ureter by those for the descending colon; the right ureter lying close to the outer side of the postcava. Opposite the first piece of the sacrum it crosses either the common or external iliac artery and vein, lying behind the ileum on the right side and behind the sigmoid flexure of the colon on the left side. In the pelvis it enters the posterior false ligament of the bladder, below the obliterated hypogastric artery, the vas deferens in the male passing between it and the bladder. In the female the ureter is to the inner side of the uterine artery at the wall of the pelvis, it passes forward and inward below the posterior layer of the broad ligament running through the parametrium, passing along the side of the neck of the uterus and upper part of the vagina, being in contact with the anterior and lateral vaginal walls and being crossed anteriorly by the uterine artery (Fig. 1115). At the base of the bladder the ureter is situated about two inches from its fellow: lying, in the male, about an inch and a half from the vesical orifice of the urethra, at one of the posterior angles of the trigone (Fig. 1059).

**Structure.**—The ureter is composed of three coats—fibrous, muscular, and mucous.

**The Fibrous Coat** (*tunica adventitia*).—The fibrous coat is the same throughout the entire length of the duct, being continuous at one end with the fibrous capsule of the kidney at the floor of the sinus, while at the other it is lost in the fibrous structure of the bladder.
The Muscular Coat (tunica muscularis).—In the pelvis of the kidney the muscular coat consists of two layers, longitudinal and circular; the longitudinal fibres become lost upon the sides of the papillae at the extremities of the calices; the circular fibres may be traced surrounding the medullary structure in the same situation. In the ureter proper the muscular fibres are very distinct, and are arranged in three layers—an external longitudinal (stratum externum), a middle circular (stratum medium), and an internal layer (stratum internum), less distinct than the other two, but having a general longitudinal direction. According to Kölliker, this internal layer is only found in the neighborhood of the bladder.

The Mucous Coat (tunica mucosa).—The mucous coat is smooth, and presents a few longitudinal folds which become effaced by distention. It is continuous with the mucous membrane of the bladder below, whilst it is prolonged over the papillae of the kidney above. Its epithelium is of a peculiar character, and resembles that found in the bladder. It is known by the name of transitional epithelium. It consists of several layers of cells, of which the innermost—that is to say, the cells in contact with the urine—are quadrilateral in shape, with concave margins on their outer surface, into which fit the rounded ends of the cells of the second layer. These, the intermediate cells, more or less resemble columnar epithelium, and are pear-shaped, with a rounded internal extremity which fits into the concavity of the cells of the first layer, and a narrow external extremity which is wedged in between the cells of the third layer. The external or third layer consists of conical or oval cells varying in number in different parts, and presenting processes which extend down into the basement-membrane.

Vessels and Nerves.—The arteries supplying the ureter are branches from the renal, spermatic, internal iliac, and inferior vesical.

The nerves are derived from the inferior mesenteric, spermatic, and pelvic plexuses.

Surgical Anatomy.—Subcutaneous rupture of the ureter is not a common accident, but occasionally occurs from a sharp, direct blow on the abdomen, as from the kick of a horse. The ureter may be either torn completely across, or only partially divided, and, as a rule, the peritoneum escapes injury. If torn completely across the urine collects in the retroperitoneal tissues; if it is not completely divided, the lumen of the tube may become obstructed and hydro-nephrosis or pyo-nephrosis results. The ureter may be accidentally wounded in some abdominal operations; if this should happen, the divided ends must be sutured together, or, failing to accomplish this, the upper end must be implanted into the bladder or the intestine.

THE SUPRARENAL CAPSULE OR GLAND (GLANDULA SUPRARENALIS) (Figs. 1023, 1043, 1044).

The suprarenal capsules belong to the class of ductless glands. They are two small flattened bodies, of a yellowish color, situated at the back part of the abdomen, behind the peritoneum, and immediately above and in front of the upper end of each kidney; hence their name. The right one (Fig. 1043) is somewhat triangular in shape, bearing a resemblance to a cocked hat; the left (Fig. 1044) is more semilunar, usually larger and placed at a higher level than the right. They vary in size in different individuals, being sometimes so small as to be scarcely detected; their usual size is from an inch and a quarter to nearly two inches in length, rather less in width, and from two to three lines in thickness. Their average weight is from one to one and a half drachms each.

Relations.—The relations of the suprarenal capsules differ on the two sides of the body.

The Right Suprarenal (Fig. 1043).—The right suprarenal is roughly triangular in shape, its angles pointing upward, downward, and outward. It presents two surfaces for examination, an anterior and a posterior. The anterior surface (facies
anterior) presents two areas, separated by a furrow, the hilum (hilus glandulae suprarenalis): one area occupying about one-third of the whole surface, is situated above and internally; it is depressed, uncovered by peritoneum, and is in contact in front with the posterior surface of the right lobe of the liver, and along its inner border with the postcava; the remaining area is elevated, and is divided into a non-peritoneal portion, in contact with the hepatic flexure of the duodenum, and a portion covered by peritoneum forming the hepato-renal fold. The posterior surface (facies posterior) is slightly convex, and rests upon the Diaphragm. The base (basis glandulae suprarenalis) is concave, and is in contact with the upper end and the adjacent part of the anterior surface of the kidney.

The Left Suprarenal (Fig. 1044).—The left suprarenal is crescentic in shape, its concavity being adapted to the upper end of the left kidney. It presents an inner border which is convex, and an outer which is concave; its upper border is narrow, and its lower rounded. Its anterior surface (facies anterior) presents two areas: an upper one, covered by the peritoneum forming the lesser sac, which separates it from the cardiac end of the stomach and to a small extent from the superior extremity of the spleen; and a lower one, which is in contact with the pancreas and splenic artery, and is therefore not covered by the peritoneum. A hilum is present, as in the right suprarenal. Its posterior surface (facies posterior) presents a vertical ridge, which divides it into two areas. The ridge lies in the sulcus between the kidney and crus of the Diaphragm, while the area on either side of it lies on these parts respectively; the outer area, which is thin, resting on the kidney, and the inner and smaller area resting on the left crus of the Diaphragm. The surface of the suprarenal gland is surrounded by areolar tissue containing much fat, and closely invested by a thin fibrous coat, which is difficult to remove, on account of numerous fibrous processes and vessels which enter the organ through the furrows on its anterior surface and base.

Accessory Suprarenal Glands (glandulae suprarenales accessoriae).—Small accessory suprarenals are often to be found in the connective tissue around the suprarenals. The smaller of these, on section, show a uniform surface, but in some of the larger a distinct medulla can be made out.

Structure (Figs. 1045, 1046, and 1047).—On making a perpendicular section (Fig. 1045), the suprarenal gland is seen to consist of two substances—external or cortical and internal or medullary. The former, which constitutes the chief part of the organ, is of a deep-yellow color. The medullary substance is soft, pulpy,
and of a dark-brown or black color, whence the name atrabiliary capsules formerly given to these organs. In the centre is often seen a space, not natural, but formed by breaking down after death of the medullary substance.

The Cortical Portion (substantia corticalis) (Fig. 1045).—The cortical substance consists chiefly of narrow columnar masses placed perpendicularly to the surface. This arrangement is due to the disposition of the capsule, which sends into the interior of the gland processes passing in vertically and communicating with each other by transverse bands so as to form spaces which open into each other. These spaces are of slight depth near the surface of the organ, so that there the section somewhat resembles a net; this is termed the zona glomerulosa; but they become much deeper or longer farther in, so as to resemble pipes or tubes placed endwise,

the zona fasciculata. Still deeper down, near the medullary part, the spaces become again of small extent; this is named the zona reticularis. These processes or trabeculae, derived from the capsule and forming the framework of the spaces, are composed of fibrous connective tissue with longitudinal bundles of unstriped muscular fibres. Within the interior of the spaces are contained groups of polyhedral cells, which are finely granular in appearance, and contain a spherical nucleus, and not infrequently fat-globules. These groups of cells do not entirely fill the spaces in which they are contained, but between them and the trabeculae of the framework is a channel which is believed to be a lymph-path or sinus, and which communicates with certain passages between the cells composing the
group. The lymph-path is supposed to open into a plexus of efferent lymphatic vessels which are contained in the capsule.

The Medullary Portion (substantia medullaris) (Fig. 1045).—In the medullary portion the fibrous stroma seems to be collected together into a much closer arrangement, and forms bundles of connective tissue which are loosely applied to the large plexus of veins of which this part of the organ mainly consists. In the interstices lie a number of cells compared by Frey to those of columnar epithelium. They are coarsely granular, do not contain any fat-molecules, and some of them are branched. Luschka has affirmed that these branches are connected with the nerve-fibres of a very intricate plexus which is found in the oblongata; this statement has not been verified by other observers, for the tissue of the medullary substance is less easy to make out than that of the cortical, owing to its rapid decomposition.

Vessels and Nerves.—The numerous arteries which enter the suprarenal bodies from the sources mentioned below penetrate the cortical part of the gland, where they break up into capillaries in the fibrous septa, and these converge to the very numerous veins of the medullary portion, which are collected together into the suprarenal vein, which usually emerge as a single vessel from the centre of the gland.

The arteries supplying the suprarenal capsules are three in number and of large size; they are derived from the aorta, the phrenic, and the renal; they subdivide into numerous minute branches previous to entering the substance of the gland.

The suprarenal vein returns the blood from the medullary venous plexus, and receives several branches from the cortical substance; it emerges from the hilum and opens on the right side into the postcava, on the left side into the renal vein.

The lymphatics form several collections which are about the beginning of the suprarenal vein. They terminate in the glands to the corresponding side of the aorta.

The nerves are exceedingly numerous, and are derived from the solar and renal plexuses, and, according to Bergmann, from the phrenic and vagus nerves. They enter the lower and inner part of the capsule, traverse the cortex, and terminate about the cells of the oblongata. They have numerous small ganglia developed upon them, from which circumstance the organ has been conjectured to have some function in connection with the sympathetic nerve system.

THE CAVITY OF THE PELVIS.

The cavity of the pelvis is that part of the general abdominal cavity which is below the level of the ilio-pectineal lines and the promontory of the sacrum.

Boundaries.—It is bounded behind by the sacrum, the coccyx, the Pyriformis muscles, and the great sacro-sciatic ligaments; in front and at the sides by the portions of the innominate bones below the ilio-pectineal lines. In front and to the sides the bony sides of the pelvic cavity are partly covered by the internal Obturator muscles, and internal to these muscles by the parietal part of the pelvic fascia. Above, it communicates with the cavity of the abdomen; and below, the outlet is closed by the triangular ligament, the Levatores ani and Coccygei muscles, and the visceral layer of the pelvic fascia, which is reflected from the wall of the pelvis on to the viscera.

Contents.—The viscera contained in this cavity are—the urinary bladder, the rectum, and some of the generative organs peculiar to each sex, and some convolutions of the small intestines. The pelvic viscera are partially covered by the peritoneum, and supplied with blood-vessels, lymphatics, and nerves.
THE URINARY BLADDER (VESICA URINARIA) (Figs. 1050, 1051, 1069, 1070).

The urinary bladder is the reservoir for the urine. It is a musculo-membranous sac situated in the pelvis, behind the pubes, and in front of the rectum in the male, the cervix uteri and vagina intervening between it and that intestine in the female. The shape, position, and relations of the bladder are greatly influenced by age, sex, and the degree of distention of the organ. During infancy it is conical in shape, and projects above the symphysis pubis into the hypogastric region. In the adult, when quite empty and contracted (Figs. 1048 and 1049), it is cup-shaped, and on vertical median section its cavity, with the adjacent portion of the urethra, presents a Y-shaped cleft, the stem of the Y corresponding to the urethra. It is placed deeply in the pelvis, flattened from before backward, and reaches as high as the upper border of the symphysis pubis. When slightly distended, it has a rounded form, and is still contained within the pelvic cavity (Fig. 1049), and when greatly distended (Figs. 1049 and 1051), it is ovoid in shape, rising into the abdominal cavity, and often extending nearly as high as the umbilicus. It is larger in its vertical diameter than from side to side, and its long axis is directed from above obliquely downward and backward, in a line directed from some point between the symphysis pubis and umbilicus (according to its distention) to the end of the coccyx. The bladder, when distended, is slightly curved forward toward the anterior wall of the abdomen, so as to be more convex behind than in front. In the female it is larger in the transverse than in the vertical diameter, and its
capacity is said to be greater than in the male. When moderately distended, it measures about five inches in length, and three inches across, and the ordinary amount which it can contain without serious discomfort is about a pint.

The bladder is divided for purposes of description into a superior, an antero-inferior, and two lateral surfaces, a base or fundus, and a summit or apex.

**Surfaces.** The Superior or Abdominal Surface (Figs. 865, 1051, 1052, and 1070).

—The superior or abdominal surface is entirely free, and is covered throughout by peritoneum. It looks almost directly upward into the abdominal cavity, and extends in an antero-posterior direction from the apex to the base of the bladder. It is in relation with the small intestine and sometimes with the sigmoid flexure, and, in the female, with the uterus. On each side, in the male, a portion of the vas deferens is in contact with the hinder part of this surface, lying beneath the peritoneum.

The Antero-inferior or Pubic Surface (Figs. 1051, 1052, and 1070).—The antero-inferior or pubic surface looks downward and forward. In the undistended condition it is uncovered by peritoneum, and is in relation with the Obturator internus muscle on each side, with the recto-vesical fascia, and anterior true ligaments of the bladder. It is separated from the body of the pubis by a triangular interval, the space of Retzius, occupied by fatty tissue. As the bladder ascends into the abdominal cavity during distention the distance between its apex and the umbilicus is necessarily diminished, and the urachus (Fig. 865 and 1070) is thus relaxed; so that, instead of passing directly upward to the umbilicus, it descends first on the upper part of the anterior surface of the bladder, and then,

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1 According to Henle, the bladder is considerably smaller in the female than in the male.—Ed. of 15th English edition.
curving upward, ascends on the back of the abdominal wall. The peritoneum, which follows the urachus, thus comes to form a pouch (plica vesicalis transversa) of varying depth between the anterior surface of the viscus and the abdominal wall (Fig. 1052). The fold passes to the neighborhood of the internal abdominal rings. Thus, when the bladder is distended, the upper part of its anterior surface is in relation with the urachus and is covered by peritoneum. The lower part of its anterior surface, a distance of about two inches above the symphysis pubis, is devoid of peritoneum, and is in contact with the abdominal wall.

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**The Lateral Surfaces.**—The lateral surfaces are covered behind and above by peritoneum, which extends as low as the level of the obliterated hypogastric artery; below and in front of this, these surfaces are uncovered by peritoneum, and are separated from the Levatores ani muscles and walls of the pelvis by a quantity of loose areolar tissue containing fat. In front this surface is connected to the recto-vesical fascia by a broad expansion on either side, the lateral true ligaments. The vas deferens crosses the hinder part of the lateral surface obliquely, and passes between the ureter and the bladder. When the bladder is empty the peritoneum descends on the pelvic wall as low as the lateral border of the bladder and enters a groove known as the paravesical fossa. The lateral surfaces, the pubic surface, and the abdominal surface together constitute the **body of the bladder** (corpus vesicae).

**The Fundus or Base** (fundus vesicae) (Figs. 1052, 1067, and 1070).—The fundus or base is directed downward and backward, and is partly covered by peritoneum.

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**Fig. 1052.—Vertical median section of the male pelvis.** (Henle.)
and is in part not covered by it. In the male the upper portion, to within about an inch and a half of the prostate, is covered by the recto-vesical pouch of peritoneum (Fig. 868). The lower part is in direct contact with the anterior wall of the second part of the rectum and the vesiculae seminales and vasa deferentia (Figs. 1067 and 1069). The ureters enter the bladder at the upper part of its base, about an inch and a half above the base of the prostate gland (Fig. 1059).

The portion of the bladder in relation with the rectum corresponds to a triangular space, bounded, below, by the prostate gland; above, by the recto-vesical fold of the peritoneum; and on each side, by the vesicula seminalis and vasa deferens. It is separated from direct contact with the rectum by the recto-vesical fascia. When the bladder is very full, the peritoneal fold is raised with it, and the distance between its reflection and the anus is about four inches; but this distance is much diminished when the bladder is empty and contracted. In the female, the base of the bladder is connected to the anterior aspect of the cervix uteri by areolar tissue, and is adherent to the anterior wall of the vagina (Fig. 866). Its upper surface is separated from the anterior surface of the body of the uterus by the utero-vesical pouch of the peritoneum (Fig. 866).

The so-called neck or cervix of the bladder (collum vesicae) is the point of commencement of the urethra; there is, however, no tapering part, which would constitute a true neck, but the bladder suddenly contracts to the opening of the urethra (Fig. 1052). In the male it is surrounded by the prostate gland and its direction is oblique when the individual is in the erect posture (Figs. 1051 and 1052). In the female its direction is obliquely downward and forward.
The Summit or Apex (\textit{vertex vesicae}).—The summit or apex is the portion of the bladder which when that organ is empty or nearly empty is nearest to the upper border of the symphysis. It is directed upward and forward. In a distended bladder the apex is well above the pubes in the abdominal cavity.

The Urachus or Middle Umbilical Ligament (\textit{ligamentum umbilicale medium}) (Fig. 1070).—The urachus is a connective-tissue cord and is the obliterated remains of the tubular canal of the allantois, which existed in the embryo, and a portion of which expanded to form the bladder. It passes upward, from the apex of the bladder, between the transversalis fascia and peritoneum, to the umbilicus, becoming thinner as it ascends. It is composed of fibrous tissue, mixed with plain muscular fibres. The urachus causes the formation of a peritoneal fold, the \textit{plica umbilicalis media} (Fig. 865). On each side of it is placed a fibrous cord, the obliterated portion of the \textit{hypogastric artery}, which, passing upward from the side of the bladder, approaches the urachus above its summit. Over each cord is the fold known as the \textit{plica umbilicalis lateralis} (Fig. 865). In the infant, at birth, the urachus is occasionally found pervious, so that the urine escapes at the umbilicus, and calculi have been found in its canal.

Ligaments.—The bladder is retained in its place by ligaments, which are divided into true and false. The true ligaments are five in number: two anterior, two lateral, and the urachus. The false ligaments, also five in number, are formed by folds of the peritoneum.

The two \textit{anterior true ligaments}, the \textit{pubo-prostatic} or \textit{pubo-vesical} ligaments (\textit{ligamenta puboprostatica}) extend from the back of the \textit{ossa pubis}, one on each side of the symphysis, to the front of the neck of the bladder, over the anterior surface of the prostate gland. These ligaments are formed by the \textit{recto-vesical fascia}, and contain a few muscular fibres prolonged from the bladder.

The two \textit{lateral true ligaments}, formed by expansions from the fascia lining the lateral wall of the pelvis, are broader and thinner than the preceding. They are attached to the lateral parts of the prostate gland and to the sides of the base of the bladder.

The \textit{urachus} or \textit{middle umbilical ligament} is the fibro-muscular cord already mentioned, extending between the summit of the bladder and the umbilicus. It is broad below, at its attachment to the bladder, and becomes narrower as it ascends.
The two posterior false ligaments pass forward, in the male, from the sides of the rectum (plicae rectovesicales); in the female, from the sides of the uterus (plicae rectouterinae) to the posterior and lateral aspect of the bladder; they form in the male the lateral boundaries of the recto-vesical pouch (excavatio rectovesicalis) (Figs. 939 and 1052); they form in the female the lateral boundaries of the pouch or cul-de-sac of Douglas (excavatio rectouterina [Douglasii]) (Figs. 866 and 940). The posterior false ligaments contain the obliterated hypogastric arteries and the ureters, together with vessels and nerves. In the base of each fold is smooth muscle-fibre, the Recto-vesical muscle (m. rectovesicalis).

The two lateral false ligaments are reflections of the peritoneum, from the iliac fossae and lateral walls of the pelvis to the sides of the bladder. Each lateral false ligament (ligamentum umbilicale laterale) passes in front into the plica umbilicalis lateralis over the corresponding hypogastric artery. The two lateral reflections of peritoneum are continuous in front of the apex vesicae, at which point the peritoneum passes upon the urachus.

The superior or anterior false ligament or the suspensory ligament (plica umbilicalis media) is the prominent fold of peritoneum extending from the summit of the bladder to the umbilicus. It is carried off from the bladder by the urachus and the obliterated hypogastric arteries. The peritoneal fold over each obliterated hypogastric artery is called the plica umbilicalis lateralis (Fig. 865), and is the prolongation forward of the ligamentum umbilicale laterale. Besides the true and false ligaments, the bladder receives support from the fibrous tissue and unstriated muscle about the seminal vesicles, and terminations of the ureters and vasa deferentia. In the female the connection with the anterior vaginal wall supports the base of the bladder. In both sexes the most solidly fixed part of the bladder is about the orifice of the urethra.

Structure.—The bladder is composed of four coats—serous, muscular, submucous, and mucous.

The Serous Coat (tunica serosa).—The serous coat is partial, and derived from the peritoneum. It invests the superior surface and the upper part of the lateral surfaces and base, and is reflected from these parts on to the abdominal and pelvic walls.

The Muscular Coat (tunica muscularis) (Figs. 1054, 1055, and 1056).—The muscular coat consists of three layers of unstripped muscular fibre: an external layer, composed of fibres having for the most part a longitudinal arrangement; a middle layer, in which the fibres are arranged, more or less, in a circular manner; and an internal layer, in which the fibres have a general longitudinal arrangement.

The fibres of the external longitudinal layer (stratum externum) arise from the posterior surface of the body of the os pubis in both sexes (m. pubovesicalis), and in the male arise also from the adjacent part of the prostate gland and its capsule. They pass, in a more or less longitudinal manner, up the anterior surface of the bladder, over its apex, and then descend along its posterior surface to its base, where they become attached to the prostate in the male and to the front of the vagina in the female. At the sides of the bladder the fibres are arranged obliquely and intersect one another. The external longitudinal layer has been named the Detrusor urinae muscle.

The middle circular layers (stratum medium) are very thinly and irregularly scattered on the body of the organ, and, though to some extent placed transversely to the long axis of the bladder, are for the most part arranged obliquely. Toward the lower part of the bladder, around the neck and the commencement of the urethra, they are disposed in a thick circular layer, forming the sphincter vesicae, which is continuous with the muscular fibres of the prostate gland.

The internal longitudinal layer (stratum internum) is thin, and its fasciculi have a reticular arrangement, but with a tendency to assume for the most part a longitudinal direction. Two bands of oblique fibres, originating behind the orifices of the ureters, converge to the back part of the prostate gland, and are inserted, by
means of a fibrous process, into the middle lobe of that organ. They are the muscles of the ureters, described by Sir C. Bell, who supposed that during the contraction of the bladder they served to retain the oblique direction of the ureters, and so prevent the reflux of the urine into them.

The Submucous Coat (tela submucosa).—The submucous coat consists of a layer of areolar tissue connecting together the muscular and mucous coats, and intimately united to the latter.

The Mucous Coat (tunica mucosa).—The mucous coat is thin, smooth, and of a pale rose color. It is continuous above through the ureters with the lining membrane of the uriniferous tubes, and below with that of the urethra. Except at the trigone, it is connected very loosely to the muscular coat by a layer of areolar tissue, and is therefore thrown into folds or rugae when the bladder is empty (Fig. 1060). The mucous membrane over the trigone never presents rugae. The epithelium covering it is of the transitional variety, consisting of a superficial layer of polyhedral flattened cells, each with one, two, or three nuclei (Fig. 1057); beneath these is a stratum of large club-shaped cells with the narrow extremity of each cell directed downward and wedged in between smaller spindle-shaped cells, each an oval nucleus (Fig. 1058). There are no true glands in the mucous membrane of the bladder, though certain mucous follicles which exist, especially near the neck of the bladder, have been regarded as such.

Objects Seen on the Inner Surface.—Upon the inner surface of the bladder are seen the mucous membrane, orifices of the ureters, the trigone, and the commencement of the urethra.

The Mucous Membrane.—The mucous membrane of the empty bladder is thrown into folds or rugae, except over the trigone, where it is firmly adherent to the muscular coat and is smooth (Figs. 1059 and 1060). The folds disappear when the bladder is distended.

The Orifices of the Ureters (Figs. 1059 and 1060).—These are situated at the base of the trigone, being distant from each other about two inches when the bladder is moderately distended. Each orifice is about an inch and a half from the base of the prostate and the commencement of the urethra in the moderately distended bladder.

The Vesical Trigone or the Trigonum Vesicae (Fig. 1000) is a triangular smooth surface, with the apex directed forward, situated at the base of the bladder, immediately behind the urethral orifice. It is paler in color than the rest of the interior, and never presents any rugae, even in the collapsed condition of the organ, owing to the intimate adhesion of its mucous membrane to the subjacent tissue. It is bounded at each posterior angle by the orifice of a ureter, and in front by the orifice of the urethra. Projecting from the lower and anterior part of the bladder, and reaching to the orifice of the urethra, is a slight elevation of mucous membrane, particularly prominent in old persons, called the uvula vesicae. It is formed by a thickening of the submucous tissue.
Stretching from one ureteral opening to the other is a smooth, slightly curved ridge, the convexity of which is toward the urethra. It is produced by transverse muscle-fibres beneath the mucous membrane. The outer prolongations of this ridge beyond the ureteral orifices are called the ureteral folds (*plicae uretericae*). They are created by the ureters as they traverse the bladder wall. About the ureteral orifice are slight radial folds of mucous membrane, which are continuous with the longitudinal folds of the prostatic urethra. "In the empty bladder the ureteral orifice and the openings of the two ureters lie at the angles of an approximately equilateral triangle, whose sides are about one inch in length. When the bladder is distended the distance between the openings may be increased to one and a half inches or more."\(^1\)

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The muscles of the ureters were referred to on p. 1447.

The internal urethral orifice (orificium urethrae internum) is sickle-shaped and is surrounded by a circular prominence (annulus urethralis), which is most distinct in the male.

Vessels and Nerves.—The arteries (Fig. 427) supplying the bladder are the superior, middle, and inferior vesical in the male, with additional branches from the uterine and vaginal in the female. They are all derived from the anterior trunk of the internal iliac. The obturator and sciatic arteries also supply small visceral branches to the bladder. The veins form a complicated plexus around the neck, sides, and base of the bladder (Fig. 474). The veins communicate below with the plexus about the prostate and terminate in the internal iliac vein.

The lymphatics form two plexuses, one in the muscular and another in the submucous coat. They accompany the blood-vessels. The mucous membrane of the bladder contains no lymphatics whatever (Sappey). The muscular tissue contains a few lymphatics. The subperitoneal tissues contain the usual number. The collecting trunks from the anterior surface terminate in the external iliac glands. The trunks from the posterior surface terminate in the internal iliac glands, the hypogastric glands and the glands in front of the sacral promontory.

The nerves are derived from the pelvic plexus of the sympathetic and from the third and fourth sacral nerves; the former supplying the upper part of the organ, the latter its base and neck. According to F. Darwin, the sympathetic fibres have ganglia connected with them, which send branches to the vessels and to the muscular coat.

Surface Form.—The surface form of the bladder varies with its degree of distention and under other circumstances. In the young child it is represented by a conical figure, the apex of which, even when the viscus is empty, is situated in the hypogastric region, about an inch above the level of the symphysis pubis. In the adult, when the bladder is empty, its apex does not reach above the level of the upper border of the symphysis pubis, and the whole organ is situated in the pelvis; the neck, in the male, corresponding to a line drawn horizontally backward through the symphysis a little below its middle. As the bladder becomes distended, it gradually rises out of the pelvis into the abdomen, and forms a swelling in the hypogastric region, which is perceptible to the hand as well as to percussion. In extreme distention it reaches into the umbilical region. Under these circumstances the lower part of its anterior surface, for a distance of about two inches above the symphysis pubis, is closely applied to the abdominal wall, without the intervention of peritoneum, so that it can be tapped by an opening in the middle line just above the symphysis pubis, without any fear of wounding the serous membrane. When the rectum is distended, the prostatic portion of the urethra is elongated and the bladder lifted out of the pelvis and the peritoneum pushed upward. Advantage is taken of this by some surgeons in performing the operation of suprapubic cystotomy. The rectum is distended by an India-rubber bag which is introduced into this cavity empty, and is then filled with ten or twelve ounces of water. If now the bladder is injected with about half a pint of some antiseptic fluid, it will appear above the pubes plainly perceptible to the sight and touch. The peritoneum will be pushed out of the way, and an incision three inches long may be made in the linea alba, from the symphysis pubis upward, without any great risk of wounding the peritoneum. Other surgeons object to the employment of this bag, as its use is not unattended with risk, and because it causes pressure on the prostatic veins and hence produces congestion of the vessels over the bladder and a good deal of venous hemorrhage.

When distended, the bladder can be felt in the male, from the rectum, behind the prostate, and fluctuation can be perceived by a bimanual examination, one finger being introduced into the rectum and the distended bladder being tapped on the front of the abdomen with the finger of the other hand. This portion of the bladder—that is, the portion felt in the rectum by the finger—is uncovered by peritoneum.

Surgical Anatomy.—A certain defect of development in which the bladder is implicated is known under the name of extroversion of the bladder. In this condition the lower part of the abdominal wall and the anterior wall of the bladder are wanting, so that the posterior surface of the bladder presents on the abdominal surface, and is pushed forward by the pressure of the viscera within the abdomen, forming a red, vascular protrusion, on which the openings of the ureters are visible. The penis, except the glans, is rudimentary and is cleft on its dorsal surface, exposing the floor of the urethra—a condition known as epispadias. The pelvic bones are also arrested in development (see page 222).

The bladder may be ruptured by violence applied to the abdominal wall when the viscus is
distended without any injury to the bony pelvis, or it may be torn in case of fracture of the pelvis. The rupture may be either intraperitoneal or extraperitoneal—that is, may implicate the superior surface of the bladder in the former case, or one of the other surfaces in the latter. Rupture of the antero-inferior surface alone is, however, very rare. Until recently intraperitoneal rupture was uniformly fatal, but now abdominal section and suturing the rent with Lambert sutures often saves the patient. The sutures are inserted only through the peritoneal and muscular coats in such a way as to bring the serous surfaces at the margins of the wound into apposition, and one is also inserted just beyond each end of the wound. The bladder should be tested as to whether it is water-tight before closing the external incision.

The muscular coat of the bladder undergoes hypertrophy in cases in which there is any persistent obstruction to the flow of urine. Under these circumstances the bundles of which the muscular coat consists become much increased in size, and, interfacing in all directions, give rise to what is known as the fasciculated bladder. Between these bundles of muscular fibres the mucous membrane may bulge out, forming sacculi, constituting the sacculated bladder, and in these little pouches phosphatic concretions may collect, forming encysted calculi. The mucous membrane is very loose and lax, except over the trigone, to allow of the distention of the viscus.

Various forms of tumours have been found springing from the wall of the bladder. The innocent tumours are the papilloma and the mucous polypus, arising from the mucous membrane; the fibrous tumor, from the submucous tissue; and the myoma, originating in the muscular tissue; and, very rarely, dermoid tumors, the exact origin of which it is difficult to explain.

Of the malignant tumors, epitheliomata are the most common, but sarcomata are occasionally found in the bladders of children.

**Puncture of the bladder** is performed above the pubes without wounding the peritoneum. Puncture by the rectum is not now performed, as a permanent fistula may be left from abscess forming between the rectum and the bladder; or pelvic cellulitis may be set up; moreover, it is exceedingly inconvenient to keep a cannula in the rectum. In some cases in performing this operation the recto-vesical pouch of peritoneum has been wounded, inducing fatal peritonitis. The operation, therefore, has been abandoned. Suprapubic cystotomy is considered above under the heading of Surface Form. This operation may be employed to permit of the removal of a calculus and is then called suprapubic lithotomy.

**THE MALE URETHRA (URETHRA VIRILIS)** (Figs. 1061, 1062, 1063, 1064, 1069).

The urethra in the male extends from the neck of the bladder at the **internal orifice of the urethra** (orificium urethrae internum) to the **meatus urinarius**, the external orifice of the urethra (orificium urethrae externum), at the end of the penis. The internal orifice has been described (p. 1449). The urethra presents a double curve in the flaccid state of the penis (Fig. 1069), but in the erect state of this organ it forms only a single curve, the concavity of which is directed upward. Its length varies from eight to nine inches; and it is divided into three portions, the **prostatic, membranous,** and **spongy,** the structure and relations of which are essentially different. Except during the passage of the urine or semen, the urethra is a mere cleft or slit, transverse, T-shaped or crescentic (Fig. 1063), with its upper and under surfaces in contact. At the meatus urinarius the slit is vertical, and in the prostatic portion somewhat arched (Fig. 1063).

**The First or Prostatic Portion** (pars prostatica) (Figs. 1051, 1061, 1062, 1070, and 1071).—The first or prostatic portion is the widest and most dilatable part of the canal. It is between the internal orifice of the urethra and the superior layer of the triangular ligament and is within the pelvic cavity. It passes between the two lateral lobes of the prostate gland, from the base to the apex of the gland, lying nearer its anterior than its posterior surface. The gland seems to completely surround this portion of the urethra (Fig. 1068), but the glandular matter of the gland does not (Fig. 1066). The gland is like a buckle open in front, and the open part of the buckle is closed by the prostatic muscle. The prostatic urethra is about an inch and a quarter in length; the form of the canal is spindle-shaped, being wider in the middle than at either extremity, and narrowest below, where it joins the membranous portion. Except during the passage of fluid, the canal is in a collapsed state, the anterior wall resting upon the posterior wall (Fig. 1063), and the mucous membrane exhibiting longitudinal folds. When distended, the largest portion of the prostatic urethra has a diameter of about one-third of an inch.
A transverse section of the canal as it lies in the prostate is horseshoe-shaped, the convexity being directed forward (Figs. 1063 and 1066). The direction of the canal is nearly vertical, there being a slight curve, which is concave forward (Figs. 1051 and 1052).

Upon the posterior wall or floor of the canal is a narrow longitudinal ridge, the crest of the urethra (crista urethralis), formed by an elevation of the mucous membrane and its subjacent tissue (Fig. 1061). This crest begins at the uvula vesicae, and passes through the prostatic portion and into the membranous portion of the urethra (Fig. 1071), and usually bifurcates at its distal end; it contains, according to Kobelt, muscular and erectile tissues. On this longitudinal ridge is an enlargement, the verumontanum or caput gallinaginis (colliculus seminalis) (Figs. 1061 and 1071).

When distended, it may serve to prevent the passage of the semen backward into the bladder. On each side of the verumontanum is a slightly depressed fossa, the floor of which is perforated by numerous apertures, the orifices of the prostatic ducts (Figs. 1061 and 1071), from the lateral lobes of the glands; the ducts of the middle lobe open behind the verumontanum. At the forepart of the verumontanum, in the middle line, is a depression, the prostatic sinus, prostatic utricle, prostatic vesicle, uterus masculinus or sinus peculiaris (utriculus prostaticus) (Figs. 1052 and 1071); and upon or within its margins are the slit-like openings of the ejaculatory ducts (ductus ejaculatorii) (Fig. 1071).

The sinus peculiaris forms a cul-de-sac about a quarter of an inch in length, which runs upward and backward in the substance of the prostate behind the transverse band of prostatic tissue which joins the lateral lobes behind the posterior wall of the urethra; its prominent anterior wall partly forms the verumontanum. Its walls are composed of fibrous tissue, muscular fibres, and mucous membrane, and numerous small glands open on its inner surface. It has been called by Weber, who discovered it, the uterus masculinus, from its being developed from the united lower ends of the atrophied Müllerian ducts, and therefore being homologous with the uterus and vagina in the female.

The Second, Muscular or Membranous Portion (pars membranacea) (Figs. 1061, 1062, and 1071) extends downward and forward between the apex of the prostate and the bulb of the corpus spongiosum. It is the narrowest part of the canal (excepting the meatus), and measures three-quarters of an inch along its upper, and half an inch along its lower, surface, in consequence of the bulb projecting backward beneath it. Its anterior concave surface is placed about an inch below and behind the pubic arch, from which it is separated by the dorsal vessels and nerves of the penis, and some muscular fibres. Its posterior convex surface is separated from the rectum by a triangular space, which constitutes the perineum. The membranous portion of the urethra lies chiefly between the inferior and superior layers of
the triangular ligament (Fig. 308). The termination of this part of the urethra is overlapped by the bulb, and is in front of the triangular ligament (Fig. 308). As it pierces the inferior layer, the fibres around the opening are prolonged over the tube and fix the two structures firmly to each other. The membranous urethra is surrounded by cavernous tissue and by the Compressor urethrae muscle (m. sphincter urethrae membranaceae) (Fig. 309). On the floor of the membranous urethra is the anterior extremity of the crista urethralis. Behind this part of the urethra, on each side of the middle line, are Cowper's glands (Figs. 307 and 1071). The canal enters the bulb a little in front of the posterior extremity, and the anterior wall or roof of the membranous urethra is a little longer than the posterior wall or floor. The backward projection of the bulb hangs over most of the floor of the membranous urethra (Figs. 307, 308, 1061, 1071, and 1073). When the urethra is empty the mucous membrane of the second part is thrown into longitudinal folds, which are obliterated by distention.

![Fig. 1062.—Proximal portions of urethra with surrounding parts. (After Testut.]

The Third, Penile, Pendulous, Cavernous or Spongy Portion (pars cavernosa) (Figs. 1051, 1061, 1062, and 1064) is the longest part of the urethra, and is contained in the corpus spongiosum. It is about six inches in length, and extends from the termination of the membranous portion to the meatus urinarius. It is surrounded throughout its entire course by the erectile tissue of the corpus spongiosum and glans penis. Its proximal end is fixed in position and unchangeable in direction. Its distal end is movable and changeable in direction. Commencing just below the triangular ligament it is first directed forward through the bulb; it then passes downward and forward, the turn beginning at the seat of attachment of the suspensory ligament of the penis (Fig. 1051). The direction of the third portion of the urethra is changed by alterations in the position of the penis. When the canal is closed the anterior and posterior walls are in contact (roof and floor), except in the glans penis, where the lateral walls come together. "Thus the first part of the canal when empty is represented in cross-section by a transverse slit, and the terminal part by a vertical slit"\(^1\) (Fig. 1063). The calibre of the spongy urethra varies in different portions of the tube. It is of larger diameter in the bulb (bulbous portion of urethra) and in the glans than between these two points. In the

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\(^1\) Professor A. Francis Dixon, in Professor D. J. Cunningham's 'Text-book of Anatomy.'
body of the penis the canal is of uniform size, and is about one-quarter of an inch in diameter. The fossa navicularis (fossa navicularis urethrae [Morgagni]) is an oblong dilatation of the terminal portion of the penile urethra (Figs. 1051, 1061, and 1075). In the front of the fossa navicularis there is a transverse fold of mucous membrane, the valve of Guerin (valvulae fossae navicularis). It is part of a distinct depression or pocket. The fossa navicularis opens anteriorly by the meatus urinarius.

The meatus urinarius or external orifice of the urethra (orificium urethrae externum) (Figs. 1061 and 1074) is the most contracted part of the urethra; it is a vertical slit (Fig. 1063), about three lines in length, bounded on each side by a small lip or labium.

The inner surface of the lining membrane of the urethra, especially on the floor of the spongy portion, presents the orifices of numerous mucous glands (Fig. 1064) situated in the submucous tissue, and named the glands of Littre (glandulae urethrales). A number of little recesses or follicles, called lacunae (lacunae urethrales), open into the penile urethra. Some of the glands of Littre open into the lacunae; some do not. They vary in size, and their orifices are directed forward, so that they may easily intercept the point of a catheter in its passage along the canal. One of these lacunae, larger than the rest, is situated in the upper surface of the fossa navicularis, about half an inch from the orifice; it is called the lacuna magna (Fig. 1075). Into the bulbous portion are found opening the ducts of Cowper's glands.

Structure.—The urethra is composed of a continuous mucous membrane, supported by a submucous tissue which connects it with the various structures through which it passes.

The Mucous Coat.—The mucous coat forms part of the genito-urinary mucous membrane. It is continuous with the mucous membrane of the bladder, ureters, and kidneys; externally with the integument covering the glans penis; and is prolonged into the ducts of the glands which open into the urethra—viz., Cowper's glands and prostate gland—into the vasa differentia and the seminal vesicles through the ejaculatory ducts. The mucous membrane is arranged in longitudinal
folds when the tube is empty. Small papillae are found upon it near the orifice, and its epithelial lining is of the columnar variety, excepting near the meatus, where it is squamous.

The Glands and Crypts of the Urethral Mucous Membrane (Fig. 1063).—There is a pocket, the lacuna magna (Fig. 1060), opening to the front in the upper wall of the fossa navicularis. The fossa is bounded by the valve of Guerin (valvulae fossa navicularis). The lacunae of Morgagni are in the spongy urethra back of the valve of Guerin. The lacunae look forward. The largest of them is on the roof of the fossa navicularis, one and one-half inches from the orifice (see above). Some of the lacunae receive the secretion from the glands of Littré; others do not, because some of the glands open on the free surface. The larger lacunae are one-third of an inch deep and are placed in a longitudinal row upon the anterior wall. The smaller lacunae are in longitudinal rows at the sides of the tube. The glands of Morgagni are present throughout the urethra, except in its most anterior part. In the prostatic urethra they are arranged in rows. In the membranous urethra they are scattered irregularly. In the spongy portion they are most numerous on the anterior wall and are more plentiful on the sides than on the floor. Besides the lacunae and racemose glands, there are the opening of the prostatic glands, the ejaculatory ducts, Cowper's glands, and the opening of the sinus peculiaris.

The Submucous Tissue.—The submucous tissue consists of a vascular erectile layer. It contains the glands of Littré, especially in the posterior part. These glands are lined with cylindrical epithelium and enter the submucous coat.

The Muscular Layer.—The muscular layer is continuous with the muscle of the prostate and bladder. It is composed of non-striated muscle arranged in an outer layer of circular fibres (stratum circulare) and an inner layer of longitudinal fibres (stratum longitudinale). It is placed external to the submucous coat. In the penile urethra there is only a thin layer of longitudinal fibres. In the membranous urethra and the prostatic urethra there are two layers of muscle, an inner thin layer of longitudinal fibres and a thicker layer of circular fibres. The longitudinal fibres, when contracted, shorten the urethra and increase its diameter. The circular fibres are in a state of tonic contraction and close the urethra. In fact, they constitute the real sphincter (Zeissl, Zuckerkrandl). The so-called sphincter of the urethra, the Accelerator urinae, is a voluntary muscle and is not the real sphincter. Outside of the muscular layer of the urethra is the tissue of the corpus spongiosum.

Surgical Anatomy.—The urethra may be ruptured by the patient falling astride of any hard substance and striking his perineum, so that the urethra is crushed against the pubic arch. Bleeding will at once take place from the urethra, and this, together with the bruising in the perineum and the history of the accident, will at once point to the nature of the injury.

Rupture of the urethra leads to extravasation of urine. In rupture back of the superior layer of the triangular ligament the urine usually follows the rectum and reaches the margin of the anus. Rupture between the two layers of the triangular ligament liberates urine between the two layers, where it remains until a path of exit is made by suppuration or the surgeon's knife. In rupture in front of the anterior layer of the ligament the urine passes into the scrotum and may mount up to the abdomen between the symphysis and the pubic spine, between which points the deep layer of the superficial fascia is not attached. It cannot pass to the thigh nor cross the mid-line, because the fascia is attached to the fascia lata and at the mid-line.

The surgical anatomy of the urethra is of considerable importance in connection with the passage of instruments into the bladder. Otis was the first to point out that the urethra is capable of great dilatation, so that, excepting through the external meatus, an instrument corresponding to 18 English gauge (29 French) can usually be passed without damage. The orifice of the urethra is not so dilutable, and therefore may require slitting, although the introduction of the Oberlander dilator, which is expanded after introduction, renders slitting of the meatus seldom necessary in cases of chronic gonorrhoea. A recognition of this dilatability caused Bigelow to very considerably modify the operation of lithotrity and introduce that of litholapaxy. In passing a fine catheter, the point of the instrument after it has passed the lacuna magna should be kept as far as possible along the upper wall of the canal, as the point is otherwise very liable to enter one of the lacunae. Stricture of the urethra is a disease of very common
occurrence, and is generally situated in the spongy portion of the urethra, most commonly in the bulbous portion, just in front of the membranous urethra, but in a very considerable number of cases in the penile or ante-serotinal part of the canal. Even in a normal urethra, and very markedly in an inflamed urethra, a bougie encounters resistance behind the bulb. This is usually supposed to be due to spasm of the Compressor urethrae muscle.

In *irrigation of the urethra by gravity* fluid tends to block at the same point, especially if it is thrown in suddenly or forcibly. If a reservoir is raised seven and one-half feet from the floor, and if a patient sits on a chair or lies upon a bed, fluid can be readily made to pass by hydraulic pressure from the meatus to the bladder. Spasm may temporarily prevent the inflow, but the weight of the column of fluid soon tires out the muscle and causes it to relax. Relaxation is favored by having the patient take slow, deep breaths and make efforts at urination (Valentine).

*Chronic gonorrhoea* is frequently kept up by persistent inflammation of the ducts and follicles in the mucous membrane. This condition is known as *chronic glandular urethritis* or *paraurthritis*. In these crypts and glands gonococci may remain when gonorrhoea appears to have passed away, and from time to time reinfecion of the urethra may arise from such a source.

*Median urethrotomy* or *perineal section* is opening of the membranous urethra. Through such an opening the bladder can be drained and explored, and the operation is sometimes called *median cystotomy*.

In *lateral lithotomy* the knife enters the membranous urethra and strikes the groove of the staff. Its edge is then turned toward the left ischial tuberosity and is carried along the groove into the bladder, dividing the membranous urethra, the prostatic urethra, the posterior layer of the triangular ligament, the Compressor urethrae muscle, anterior fibres of the Levator ani muscle and the left lobe of the prostate gland.

THE FEMALE URINARY BLADDER.

The female bladder is situated at the anterior part of the pelvis. It is in relation, *in front*, with the symphysis pubis; *behind*, with the uro-vesical pouch of peritoneum, which separates it from the body of the uterus; its *base* lies in contact with the connective tissue in front of the cervix and upper part of the vagina. *Laterally*, is the recto-vesical fascia. The bladder is said by some anatomists to be larger in the female than in the male. At any rate, it does not rise above the symphysis pubis till more distended than in the male, but this is perhaps owing to the more capacious pelvis rather than to its being of actually larger size. It is described in the section on the Bladder (p. 1441).

THE FEMALE URETHRA (URETHRA MULIEBRI).  

The female urethra is a narrow membranous canal, about an inch and a half in length, extending from the internal urethral orifice (orificium urethrae internum) at the neck of the bladder to the vestibule of the vagina, where it ends, being called at its termination the external orifice of the urethra or the meatus urinarius (orificium urethrae externum). The meatus is usually a vertical slit. The urethra is placed behind the symphysis pubis, embedded in the anterior wall of the vagina; and its direction is obliquely downward and forward, its course being slightly curved, the concavity directed forward and upward. Its diameter when undilated is about a quarter of an inch. The urethra perforates both layers of the triangular ligament, and its external orifice is situated directly in front of the vaginal opening and about an inch behind the glans clitoridis. Except above, the posterior wall of the urethra is firmly connected to the anterior wall of the vagina.

Structure.—The urethra consists of three coats: *muscular*, *erectile*, and *mucous*.

The *Muscular Coat* (tunica muscularis).—The muscular coat is continuous with that of the bladder; it extends the whole length of the tube, and consists of an internal layer of *non-striated longitudinal fibres* (stratum longitudinale) and an external layer of *non-striated circular fibres* (stratum circulare). Superficial to the circular fibres "lies a layer of cross-striped muscle-fibres, which form a closed ring near the bladder only."
The Submucous Coat (*tunica submucosa*).—Internal to the muscular coat is the submucous coat, which contains a venous plexus, networks from which pass between the muscular layers and impart to these layers an erectile or spongy nature (*corpus spongiosum urethrae*). In addition to this, between the two layers of the triangular ligament, the female urethra is surrounded by the Compressor urethrae muscle, as in the male.

The Mucous Coat (*tunica mucosa*).—The mucous coat is pale, continuous externally with that of the vulva, and internally with that of the bladder. It is thrown into longitudinal folds, one of which, placed along the floor of the canal, extends from the vesical trigone almost to the external orifice of the urethra. It is called the crest (*crista urethralis*). The outline of the urethra is stellate when collapsed, because of the formation of numerous longitudinal folds. It is lined by laminated epithelium, which becomes transitional near the bladder. Many mucous glands open into the urethra, and there are numerous lacunae. External to the external orifice, on each side, a group of mucous glands opens by a common duct, the ductus para-urethralis.

The urethra, because it is not surrounded by dense resisting structures, as in the male, admits of great dilatation, which enables the surgeon to remove with considerable facility calculi or other foreign bodies from the cavity of the bladder.
THE MALE ORGANS OF GENERATION.

THE PROSTATE GLAND (PROSTATA) (Figs. 1062, 1066, 1067, 1068, 1069, 1070, 1071, 1072).

The prostate gland (προστατήμα, to stand before) is a structure accessory to the true generative organs and furnishes a viscid, opalescent secretion in which spermatozoïds will live (W. G. Richardson). It is a pale, firm, partly glandular and partly muscular body, which is placed immediately below the neck of the bladder and about the commencement of the urethra in the male. The prostate appears to completely surround the first portion of the urethra (Figs. 1068 and 1072), but the glandular matter does not in reality completely surround the tube (Figs. 1066 and 1072). As Spalteholz says, it partly surrounds it as a broad clasp, open in front. This opening in the glandular tissue is closed, and a complete ring is established about the urethra by the prostatic muscle (m. prostaticus) (Figs. 1066 and 1072). This muscle below is composed of striated fibres and is continuous with the Compressor urethrae (m. sphincter urethrae membranacea);

above it is composed of non-striated muscle, and is continuous with the circular muscular fibres of the bladder which surround the internal urethral orifice and
constitute the Sphincter vesicae (Fig. 1067). The general course of the fibres is transverse, with radiations into the gland substance. The apex of the gland for about one-quarter of an inch is completely surrounded by the muscle (Fig. 1067).

Ascending from the apex the fibres cover for a short distance only the front of the gland and are attached at the sides to the fascia (Fig. 1067). Higher up the muscle passes between the sheath and the capsule and ascends to the base of the prostate, uniting the sheath to the capsule along the mid-line in front. The prostate is placed in the pelvic cavity, behind the lower part of the symphysis pubis, and above the
deep layer of the triangular ligament, and rests upon the rectum, through which it may be distinctly felt, especially when enlarged (Fig. 1070).

The ejaculatory ducts (Figs. 1068, 1069, and 1070) enter the prostate at the margin which separates the base from the posterior surface of the gland; they pass downward, inward, and forward through the prostate, and open into the prostatic urethra. The prostate when surrounded by its sheath resembles a chestnut in shape. When dissected out from its sheath and capsule and from the Prostatic muscle, it resembles an "open clasp" or horseshoe. The sheath of the prostate

is derived from the recto-vesical fascia. It is called the prostatic fascia (fascia prostaticae), is distinct and dense, and covers the entire prostate, except at the apex and at the attachment of the base of the prostate to the neck of the bladder. The prostatic fascia is a distinct structure, though it is thin. The veins of the prostatic plexus lie in the layers of the sheath, "and are everywhere separated from the prostatic capsule proper by a layer of this sheath." In an enlarged prostate the sheath is thick and fibrous. It is very difficult to shell out a normal prostate from its sheath, but it is easy to shell out an enlarged prostate. Within the prostatic sheath (which, be it remembered, carries the veins) is the true or proper capsule

of the prostate. The true capsule is a continuous investment from the entrance of the urethra above to the triangular ligament below. It is thin, but firm and fibrous. It is not everywhere absolutely distinct from the sheath, but may be fused
with it here and there, and many bands of fibres run from the sheath to the capsule. The capsule is continuous with the stroma of the gland and cannot be stripped off as can the kidney capsule. Any attempt to strip off the capsule tears away fragments of gland. The capsule is composed of fibrous tissue and unstriated muscle-fibres. From its deep surface the capsule is continuous with the stroma of the prostate (W. G. Richardson). Sir Henry Thompson, half a century ago, pointed out the distinction between true capsule and sheath, and suggested these names. The prostate is divided for study into a base, apex, posterior surface, anterior surface, and lateral surfaces.

The Base (basis prostatae).—The base is directed upward, and is situated immediately below the base of the bladder. It is in contact with and supports the base of the bladder. The external longitudinal muscular layer of the bladder is attached to the posterior portion of the base of the prostate, and some of the fibres reach and adhere to the true capsule. The anterior portion of the base is called the isthmus (isthmus prostatae) (Fig. 1068).

The Apex (apex prostatae).—The apex is directed downward and rests upon the deep layer of the triangular ligament. The apex is fixed, except for the slight mobility of the triangular ligament; the rest of the gland is somewhat movable.

Surfaces. — The Posterior Surface (facies posterior).—The posterior surface is flattened, marked by a slight longitudinal furrow, and rests on the second part of the rectum, and is distant about one inch and a half from the anus. At the upper and posterior border of the gland are the seminal vesicles. Their direction is downward and inward; in fact, almost transverse.

The Anterior Surface (facies anterior).—The anterior surface is convex, and placed about three-fourths of an inch behind the pubic symphysis, from which it is separated by a plexus of veins and a quantity of loose fat. It is connected to the pubic bone on either side by the pubo-prostatic ligament. It is shorter than the posterior surface.

The Lateral Surfaces. — The lateral surfaces are prominent, and are covered by the anterior portions of the Levatores ani muscles, which are, however, separated from the gland by a plexus of veins.

The prostate measures about an inch and a half transversely at the base, an inch in its antero-posterior diameter, and an inch and a quarter in its vertical diameter. Its weight is about four and a half drachms. It is held in position by the anterior ligaments of the bladder (ligamenta puboprostatica); by the deep layer of the triangular ligament, which invests the commencement of the membranous portion of the urethra and prostate gland; and by the anterior portions of the Levatores ani muscles, which pass backward from the os pubis and embrace the sides of the prostate. These portions of the Levatores ani, from the support they afford to the prostate, are named the Levator prostatae.

The prostate consists of two lateral lobes and a middle lobe.

The Lateral Lobes (lobus dexter et sinister).—The two lateral lobes are of equal size, separated by a deep notch above, and by a furrow upon the anterior and posterior surfaces of the gland, which indicates the bilobed condition of the organ in some animals. At the upper and posterior portion of the prostate the two lobes are united by two bands of gland-tissue. One of these bands is in front of the ejaculatory ducts, the other is below them. "The upper limit of the gland is thus in the form of a horseshoe, open in front." Below the level of the prostatic ducts the prostate and urethra are in relation, but are not closely connected. Above this level the connection is intimate (J. W. Thomson Walker).

The So-called Middle Lobe (lobus medius).—The middle lobe is not in reality a lobe, and the name is usually employed to describe an enlargement of the region of the prostate on the posterior portion of the urethra in front of the ejaculatory ducts. The so-called third or middle lobe is an abnormal condition. It is due to enlargement of the transverse band of prostatic tissue which joins the lateral lobes beneath the

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1 W. G. Richardson on the Development and Anatomy of the Prostate Gland.
base of the bladder, behind the posterior wall of the urethra and in front of the ejaculatory ducts. This mass of tissue is beneath the uvula vesicae. Walker points out that frequently nodules of enlarged prostate protrude into the bladder, being covered only by bladder mucous membrane. This is accomplished by the enlarging prostate forcing its way through the lumen of the vesical sphincter and dilating it, and separating and passing between the strands of the internal longitudinal muscle of the bladder. "The so-called middle lobe is formed by the protrusion of a nodule between the two bands of muscle which pass into the trigone from the ureters, and unite on the posterior wall of the prostatic urethra."

The urethra passes forward between the lateral lobes of the prostate. The prostate is perforated by the ejaculatory ducts. The urethra usually lies on the level of the junction of the anterior and middle thirds of a lateral lobe. The ejaculatory ducts pass obliquely downward and forward through the posterior part of the prostate, and open into the prostatic portion of the urethra.

**Structure** (Fig. 1072).—As previously stated (p. 1459), the prostate is surrounded by a sheath from the recto-vesical fascia, and possesses also a true capsule.

The glands of the prostate are of the branched tubular variety and number forty or fifty. Many of the ducts join and form from fifteen to twenty-five smaller ducts, which empty into the prostatic urethra, to the sides of the verumontanum (Fig. 1071). The ducts and glands are lined with cubical epithelium. The *prostatic secretion* or *prostatic fluid* (*sueus prostaticus*) is a viscid, opalescent, serous secretion, alkaline in reaction, containing a ferment, but no mucus. The substance of the prostate is of a pale, reddish-gray color, of great density and not easily torn. It consists of glandular substance and muscular tissue.

The muscular tissue, according to Köllicker, constitutes the proper stroma of the prostate, the connective tissue being very scanty, and simply forming thin trabeculae between the muscular fibres, in which the vessels and nerves of the gland run. The true capsule is continuous with the stroma. The stroma lies between the glandular substance and strands of stroma pass in convergent lines toward the prostatic urethra, especially toward the dorsum of the urethra. These strands or septa divide the prostate into small irregular subdivisions called *lobules*. Next to the urethra, the stroma forms a thick layer. As age advances the interstitial tissue of the prostate increases and the glandular substance shrinks.

**Vessels and Nerves.**—The arteries supplying the prostate are derived from the *internal pudic*, *inferior vesical*, and *middle haemorrhoidal*. Branches of the vessels enter the gland in the septa between the lobules and send off minute branches to the lobules (Walker). The veins form a plexus around the sides and base of the gland between layers of the fascial sheath; they receive in front the *dorsal vein of the penis*, and terminate in the *internal iliac vein*. The lymphatics of the prostate begin as networks about the acini of the gland, pass to beneath the capsule, and form another network, and from this peripheral network collecting trunks arise. Several trunks pass from the posterior portion of the gland. One trunk passes to the *external iliac glands*, one to the *internal iliac glands*, and several end in the *lateral sacral glands*, and the glands of the sacral promontory. An anterior trunk is joined by lymphatics from the membranous urethra and prostatic urethra and passes to a gland on the *internal pudic artery*. The nerves are derived from the hypogastric plexus.

**Surgical Anatomy.**—The relation of the prostate to the rectum should be noted: by means of the finger introduced into the gut the surgeon detects enlargement or other disease of the prostate; he can feel the apex of the gland, which is the guide to *Cock's operation* for stricture; he is enabled also by the same means to direct the point of a catheter when its introduction is attended with difficulty either from injury or disease of the membranous or prostatic portions of the urethra. When the finger is introduced into the bowel the surgeon may, in some cases, especially in boys,

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2 Pollier and Charpy. Human Anatomy.
learn the position, as well as the size and weight, of a calculus in the bladder. In the operation for the removal of a calculus, if, as is not unfrequently the case, the stoeie should be lodged behind an enlarged prostate, it may be displaced from its position by pressing upward the base of the bladder from the rectum. The prostate gland is occasionally the seat of suppuration, either due to injury, gonorrhoea, or tuberculous disease. The gland is enveloped in a dense unyielding capsule, which determines the course of an abscess, and also explains the great pain which is present in acute inflammation. The abscess most frequently bursts into the urethra, the direction in which there is least resistance, but may occasionally burst into the rectum, or more rarely in the perineum. In advanced life the prostate often becomes considerably enlarged, and may project into the bladder so as to impede the passage of the urine. According to Dr. Messer’s researches, conducted at Greenwich Hospital, it would seem that such obstructions exist in 20 per cent. of all men over sixty years of age. The prostate may be enlarged by the growth of innocent tumors, adenomata, fibromata, myomata, and myofibromata. The entire gland may be hypertrophied. A tumor may be encapsulated, but often is surrounded by an area of hyperplasia of prostatic tissues, and usually the area of hyperplasia is much more extensive than the tumor. A tumor may be beneath the mucous membrane, deep in the gland, or beneath the sheath. The growth called the third lobe is submucous. In some cases the enlargement affects principally the lateral lobes, which may undergo considerable enlargement without causing much inconvenience. In other cases it would seem that the nodule forms the so-called middle lobe, and even a small enlargement of this character may act injuriously, by forming a sort of valve over the urethral orifice, preventing the passage of the urine, and the more the patient strains, the more completely will it block the opening into the urethra. In consequence of the enlargement of the prostate a pouch is formed at the base of the bladder behind the projection, in which urine collects and cannot entirely be expelled. The urine becomes decomposed and ammoniacal, and leads to cystitis. If the prostate enlarges the urethra is lengthened, often dilated, altered in shape, or distorted.

The relation of the enlarged prostate to the neck of the bladder is greatly altered from the relation of the normal prostate. Normally, it is extravesical; when enlarged it may encase the “neck of the bladder in a cuff-like manner, extending several inches upward on its wall,” and often it protrudes “into the vesical cavity, carrying on its surface the mucosa vesicae.” In many cases of prostatic enlargement the gland should be removed (prostatectomy). One method is enucleation through a suprapubic incision; another method is enucleation through a perineal incision; another method is carried out by both incisions (the combined method).

The Bottini operation is prostatectomy, effected by a special instrument for the purpose of cauterizing the gland and thus causing shrinking.

In elderly individuals the gland tubules may form round, indurated, and sometimes calcified masses, about 1 mm. in diameter, and called prostatic stones.

COWPER’S GLANDS (GLANDULAE BULBO-URETHRALES) (Figs. 1071, 1078).

Cowper’s glands are two small, rounded, and somewhat lobulated bodies of a yellow color, about the size of peas, placed behind the forepart of the membranous portion of the urethra, between the two layers of the triangular ligament. They lie close above the bulb, and are enclosed by the transverse fibres of the Compressor urethrae muscle. Their existence is said to be constant; they gradually diminish in size as age advances.

Structure.—Each gland consists of several lobules held together by a fibrous investment. Each lobule consists of a number of acini lined by columnar epithelial cells, opening into one duct, which, joining with the ducts of other lobules outside the gland, form a single excretory duct (ductus excretorius). The excretory duct of each gland, nearly an inch in length, passes obliquely forward beneath the mucous membrane, and opens by a minute orifice on the floor of the bulbous portion of the urethra.

THE PENIS (Figs. 1073, 1074, 1075, 1076, 1077, 1078).

The penis is a long body of prismatic shape placed below and in front of the symphysis pubis. It surrounds the greatest length of the urethra. It consists of a root, body, and extremity or glans penis. The root and the posterior portion

1 John B. Murphy, in the Journal of the American Medical Association, May 28, 1904.
of the body lie beneath the scrotum and the integument of the perineum (Fig. 1069), and are firmly fixed to the triangular ligament, the pubic bones, and the symphysis; hence this portion of the organ is called the fixed portion (pars fixa) (Fig. 309). The balance of the organ is free and movable (Fig. 1069), and is called the mobile portion (pars mobilia). When the penis is relaxed there is an angle between the fixed and mobile portions; when the penis is erect, the angle disappears.

The Root (radix penis).—The root is firmly connected to the rami of the os pubis and ischium by two strong tapering, fibrous processes, the crura (Figs. 1073, 1077, and 1078), and to the front of the symphysis pubis by the suspensory ligament (Fig. 1076), a strong band of fibrous tissue which passes downward from the front of the symphysis pubis to the root of the penis.

The extremity, acorn, or glans penis (Figs. 1074 and 1075) presents the form of an obtuse cone, flattened from above downward. At its summit is a vertical fissure, the external orifice of the urethra or the meatus urinarius (orificium urethrae externum). The base of the glans forms a rounded projecting border, the corona glandis, and behind the corona is a deep constriction, the cervix or neck (collum glandis). Upon both the corona and neck numerous small sebaceous glands are found, the glandulae Tysonii odoriferae. They secrete a sebaceous matter of very peculiar odor, which probably contains casein and becomes easily decomposed.

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1 Stieda (Comptes-rendus du XII. Congrès International de Médecine, Moscow, 1897) asserts that Tyson’s glands are never found on the corona glandis, and that what have hitherto been mistaken for glands are really large papillae.—En of 15th English edition.
The Body of the Penis (corpus penis).—The body of the penis is the part between the root and extremity. In the flaccid condition of the organ it is cylindrical, but when erect it has a triangular prismatic form with rounded angles, the broadest side being turned upward, and called the dorsum penis. The lower surface of the body of the penis is called the urethral surface (facies urethralis). The body is covered by integument, and contains in its interior a large portion of the urethra. The integument covering the penis is remarkable for its thinness, its dark color, its looseness of connection with the deeper parts of the organ, and for the absence of adipose tissue. At the root of the penis the integument is continuous with that upon the pubes and scrotum, and at the neck of the glans it leaves the surface and becomes folded upon itself to form the prepuce (praeputium) (Fig. 1074). The internal layer of the prepuce is attached behind to the cervix or neck (Fig. 1074), and approaches in character to a mucous membrane; from the cervix it is reflected over the glans penis, and at the meatus urinarius is continuous with the mucous lining of the urethra.

The integument covering the glans penis contains no sebaceous glands, but projecting from its free surface are a number of small, highly sensitive papillae.

At the back part of the meatus urinarius a fold of mucous membrane passes backward to the bottom of a depressed raphé, where it is continuous with the prepuce; this fold is termed the fraenum (frenulum praeputii). The skin of the penis covers the mobile parts of the organ. It is thin, extremely elastic, and contains very few hairs. Beneath the skin of the penis is the dartos layer (Figs. 1076 and 1083), continuous with the scrotal dartos, containing chiefly non-striated muscular fibres arranged longitudinally. It passes forward to the orifice of the prepuce, and then turns backward, growing thinner and thinner, and finally disappearing at the cervix. Beneath the dartos and extending forward to the orifice of the prepuce is a sheath of areolar tissue. It is a lax sheath rich in elastic tissue and containing almost no fat. The superficial vessels and nerves are in the areolar sheath. Beneath the areolar sheath of the penis, from the corona to the root, is the fascia of the penis (fascia penis) (Fig. 1083). It covers the organ from the root to the corona, and also covers the dorsal artery, veins, and nerves. It is continuous behind with the superficial perineal fascia and suspensory ligament. It is composed chiefly of elastic tissue.

Structure of the Penis.—The penis is composed of a mass of erectile tissue enclosed in three cylindrical fibrous compartments. Of these, two, the corpora...
cavernosa, are placed side by side along the upper part of the organ; the third, or corpus spongiosum, encloses the urethra and is placed below.

The Two Corpora Cavernosa (corpora cavernosa penis) (Figs. 1077 and 1078).—The two corpora cavernosa form the chief part of the body of the penis. They consist of two fibrous cylindrical tubes, placed side by side, and intimately connected along the median line for their anterior three-fourths, whilst at their back part they separate from each other to form the crura penis, which are two strong tapering fibrous processes or roots firmly connected to the rami of the os pubis and ischium (Figs. 1073, 1077, and 1078). Each crus commences by a
blunt-pointed process in front of the tuberosity of the ischium, and before its junction with its fellow to form the body of the penis it presents a slight enlargement, named by Kobelt the **bulb of the corpus cavernosum**. Just beyond this point they become constricted, and retain an equal diameter to their anterior extremity, where they form a single rounded end which is received into a fossa in the base of the glans penis (Figs. 1075 and 1077). A median groove on the upper surface lodges the dorsal arteries, nerves, and veins of the penis (Figs. 1081, 1082, and 1083), and the groove on the under surface receives the corpus spongiosum (Fig. 1077). The root of the penis is connected to the symphysis pubis by the suspensory ligament.

**Structure** (Fig. 1083).—Each corpus cavernosum is composed of erectile tissue. The erectile tissue is surrounded by a strong fibrous envelope, the **tunica albuginea**, **corpora cavernosa**, consisting of two sets of fibres—the one, longitudinal in direction, being common to the two corpora cavernosa, and investing them in a common covering; the other, internal, circular in direction, and being proper to each corpus cavernosum. The internal circular fibres of the two corpora cavernosa form, by their junction in the mesial plane, an incomplete partition or septum, the **septum penis**, between the two bodies.

![Fig. 1079.—The dartos. (Poirier and Charpy.)](image)

The **septum** between the two corpora cavernosa is thick and complete behind, but in front it is incomplete, and consists of a number of vertical bands, which are arranged like the teeth of a comb, whence the name which it has received, **septum pectiniforme**. These bands extend between the dorsal and the urethral surface of the corpora cavernosa. The fibrous-investment of the corpora cavernosa is extremely dense, of considerable thickness, and consists of bundles of shining white fibres, with an admixture of well-developed elastic fibres, so that it is possessed of great elasticity.

From the internal surface of the fibrous envelope, as well as from the sides of the septum, are given off a number of bands or cords which cross the interior of each crus in all directions, subdividing it into a number of separate compart-
ments, and giving the entire structure a spongy appearance. These bands and cords are called *trabeculae corporum cavernosum*, and consist of white fibrous tissue, elastic fibres, and plain muscular fibres. In them are continued numerous arteries and nerves.

The component fibres of which the trabeculae are composed are larger and stronger around the circumference than at the centre of the corpora cavernosa; they are also thicker behind than in front. The interspaces, on the contrary, are larger at the centre than at the circumference, their long diameter being directed transversely; they are largest anteriorly. They are called *cavernous spaces* and are occupied by venous blood, and are lined by a layer of flattened cells similar to the endothelial lining of veins (Fig. 1080).

The whole of the structure of the corpora cavernosa contained within the fibrous sheath consists, therefore, of a sponge-like tissue the areolar spaces of which freely communicate with each other and are filled with venous blood. The spaces may therefore be regarded as large cavernous veins.

The arteries bringing the blood to these spaces are the *arteries of the corpora cavernosa* and branches from the *dorsal artery of the penis*, which perforate the fibrous capsule, along the upper surface, especially near the forepart of the organ.

These arteries on entering the cavernous structure divide into branches which are supported and enclosed by the trabeculae. Some of these terminate in a capillary network, the branches of which open directly into the cavernous spaces (Fig. 1080); others assume a tendril-like appearance, and form convoluted and somewhat dilated vessels, which were named by Müller *helicine arteries* (*arteriae helicinae*). They project into the spaces, and from them are given off small capillary branches to supply the trabecular structure. They are bound down in the spaces by fine fibrous processes, and are more abundant in the back part of the corpora cavernosa.

The blood from the cavernous spaces is returned by a series of vessels, some of which emerge in considerable numbers from the base of the glans penis and converge on the dorsum of the organ to form the *deep dorsal vein*; others pass out on the upper surface of the corpora cavernosa and join the dorsal vein; some emerge from the under surface of the corpora cavernosa, and, receiving branches from the corpus spongiosum, wind around the sides of the penis to terminate in the dorsal vein; but the greater number pass out at the root of the penis and join the *prostatic plexus*.

The **Corpus Spongiosum** (*corpus cavernosum urethrae*) (Figs. 1075, 1077, and 1078).—The corpus spongiosum encloses the urethra, and is situated in the groove on the under surface of the corpora cavernosa penis. It commences posteriorly below the superficial layer of the triangular ligament of the urethra, between the diverging crura of the corpora cavernosa, where it forms a rounded enlargement, the *bulb of the urethra*, and terminates anteriorly in another expansion, the *glans penis* (Figs. 1074, 1075, 1077, and 1078), which overlaps the anterior rounded extremity of the corpora cavernosa. The central portion, or body of the corpus spongiosum, is cylindrical, and tapers slightly from behind forward.

The **Bulb of the Urethra** (*bulbus urethrae*) (Figs. 1073, 1077, and 1078) varies in size in different subjects; it receives a fibrous investment from the superficial layer of the triangular ligament, and is surrounded by the Accelerator urinae muscle. The urethra enters the bulb nearer its upper than its lower surface, being surrounded by a layer of erectile tissue, a thin prolongation of which is continued backward around the membranous and prostatic portions of the canal to the neck of the bladder, lying between the two layers of muscular tissue. The portion of the bulb below the urethra presents a partial division into two *lobes* (*hemisphaeria bulbi urethrae*), being marked externally by a linear raphé, whilst internally there projects, for a short distance, a thin *fibrous median septum* (*septum bulbi urethrae*), which is more distinct in early life.
Structure.—The corpus spongiosum consists of a strong fibrous envelope enclosing a trabecular structure, which contains in its meshes erectile tissue. The fibrous envelope is thinner, whiter in color, and more elastic than that of the corpora cavernosa of the penis. The trabeculae are more delicate, more nearly uniform in size, and the meshes between them smaller than in the corpora cavernosa, their long diameter, for the most part, corresponding with that of the penis. The external envelope or outer coat of the corpus spongiosum is formed partly of unstriped muscular fibre, and a layer of the same tissue immediately surrounds the canal of the urethra.

Ligaments of the Penis.—The suspensory ligament (ligamentum suspensorium penis) (Fig. 1076) is firm and fibrous. It passes from the front of the symphysis pubis to the tunica albuginea of the corpora cavernosa. The ligamentum fundiforme penis (Fig. 1073), formerly called the suspensory ligament, arises from the linea alba, sheath of the rectus, superficial fascia, and symphysis pubis, and surrounds the penis in a loop, being attached more distalward than is the suspensory ligament, and usually passes into the scrotum. It is composed of elastic tissue.

Vessels and Nerves of the Penis.—The arteries (Fig. 1081) of the penis come from branches of the internal pudic artery. The deep arteries of the penis give the chief supply to the erectile tissue of the corpora cavernosa, and the dorsal artery also sends branches to it; the artery of the bulb (p. 693) supplies the erectile tissue of the corpus spongiosum. The chief blood-supply of the glans is from the dorsal artery (p. 694). In the trabeculae the arteries are very small and often twisted. The twisted vessels are called helicine arteries. The small arteries open directly into the venous spaces. The veins of the penis empty directly into
THE PROSTATE PLEXUS OR INTO THE DEEP DORSAL VEIN, WHICH EMBUTES INTO THE PROSTATIC PLEXUS. ON EACH SIDE OF THE DEEP DORSAL VEIN IS A DORSAL ARTERY AND EXTERNAL TO EACH DORSAL ARTERY IS A DORSAL NERVE (FIG. 1083). THE SUPERFICIAL DORSAL VEIN (FIGS. 1082 AND 1083), RECEIVING SMALL VEINS FROM THE PREPUCE, PASSES BACK BENEATH THE SKIN, REACHES THE SYMPHYSIS AND DIVIDES INTO TWO BRANCHES, EACH OF WHICH PASSES TO THE CORRESPONDING SUPERFICIAL EXTERNAL PUBIC VEIN.

THE LYMPHATICS OF THIS REGION HAVE BEEN STUDIED CAREFULLY BY Poirier, Cunéo, and Delamare,¹ WHICH BOOK I HAVE FREELY USED.


THE NERVES ARE DERIVED FROM THE INTERNAL PUBIC NERVE AND THE PELVIC Plexus. ON THE GLANS AND BULB SOME FILAMENTS OF THE CUTANEOUS NERVES HAVE PACINIAN BODIES CONNECTED WITH THEM, AND, ACCORDING TO Krause, MANY OF THEM TERMINATE IN A PECULIAR FORM OF END-BULB.


¹ THE LYMPHATICS. BY POIRIER, CUNÉO, AND DELAMARE. TRANSLATED AND EDITED BY Cecil H. Leaf.

² Ibid.
THE TESTICLES (TESTES) AND THEIR COVERINGS (Figs. 1086, 1087).

The testicles are two glandular organs, which secrete the semen; they are situated in the scrotum, being suspended by the spermatic cords. At an early period of foetal life the testes are contained in the abdominal cavity, behind the peritoneum, but they subsequently descend into the scrotum.

DESCENT OF THE TESTIS (DESCENDUS TESTIS).

Each testis at an early period of foetal life is placed at the back part of the abdominal cavity, behind the peritoneum, in front and a little below the kidney. The anterior surface and sides are invested by peritoneum. At about the third month of intra-uterine life a peculiar structure, the gubernaculum testis, makes its appearance. This structure is at first a slender band which extends from the situation of the internal ring to the epididymis and body of the testicle, and is then continued upward in front of the kidney toward the Diaphragm. As development advances the peritoneum covering the testicle encloses it and forms a mesentery, the mesorchium, which also encloses the gubernaculum and forms two folds—one above the testicle, and the other below it. The one above the testicle is the plica vascularis, and contains ultimately the spermatic vessels; the one below, the plica gubernatrix, contains the lower part of the gubernaculum, which has now grown into a thick cord; it terminates below at the internal ring in a tube of peritoneum, the processus vaginalis, which now lies in the inguinal canal. The lower part of the gubernaculum by the fifth month has become a thick cord, whilst the upper part has disappeared. The lower part can now be seen to consist of a central core of unstriped muscle-fibre, and outside this of a firm layer of striped elements, connected, behind the peritoneum, with the abdominal wall. Later on, about the sixth month, the lower end of the gubernaculum can be traced into the inguinal canal, extending to the pubes, and, at a later period, to the bottom of the scrotum. The fold of peritoneum constituting the processus vaginalis projects itself downward into the inguinal canal, forming a gradually elongating depression or cul-de-sac, which eventually reaches the bottom of the scrotum. This cul-de-sac is now invaginated by the testicle, as the body of the fectus grows, for the gubernaculum does not grow commensurately with the growth of other parts, and therefore the testicle, being attached by the gubernaculum to the bottom of the
scrotum, is prevented from rising as the body grows, and is drawn first into the inguinal canal, and eventually into the scrotum. By the eighth month the testicle has reached the scrotum, preceded by the lengthened pouch of peritoneum, the processus vaginalis, which communicates by its upper extremity with the peritoneal cavity. Just before birth the upper part of the pouch usually becomes closed, and this obliteration extends gradually downward to within a short distance of the testis. The process of peritoneum surrounding the testis, which is now entirely cut off from the general peritoneal cavity, constitutes the tunica vaginalis.\(^1\)

Mr. Jacobson\(^2\) says that the attachments of the gubernaculum above are to the vas, the epididymis, and afterward to the testicle. The lower attachments of the gubernaculum, some of which are temporary, are the abdominal wall, pubes and root of the scrotum, Scarpa’s triangle, perineum and scrotum. The remains of the scrotal fibres constitute a so-called ligament of the scrotum or the mesorchium, which causes adhesion between the testicle and skin (Fig. 1086).

In the female, a small cord, corresponding to the gubernaculum in the male, descends to the inguinal region and ultimately forms the round ligament of the uterus. A pouch of peritoneum accompanies it along the inguinal canal, analogous to the processus vaginalis in the male; it is called the canal of Nuck.

**Surgical Anatomy.**—Abnormalities in the formation and in the descent of the testicle may occur. The testicle may fail to be developed, or it may be fully developed and the vasa deferentia may be undeveloped in whole or in part; or, again, both testicle and vasa deferentia may be fully developed, but the duct may not become connected to the gland. The testicle may fail in its descent (*cryptorchismus*) or it may descend into some abnormal position (*ectopia testis*). Thus it may be retained in the position where it was primarily developed, below the kidney; or it may descend to the internal abdominal ring, but fail to pass through this opening; it may be retained in the inguinal canal, which is perhaps the most common position; or it may pass through the external abdominal ring and remain just outside it, failing to pass to the bottom of the scrotum. On the other hand, it may get into some abnormal position; it may pass the scrotum and reach the perineum, or it may fail to enter the inguinal canal, and may find its way through the femoral ring into the crural canal, and present itself on the thigh at the saphenous opening. Ectopia testis is due to the absence, overdevelopment or malposition of some portion of the gubernaculum. There is still a third class of cases of abnormality in the position of the testicle, where the organ has descended in due course into the scrotum, but is misplaced. The most common form of this is where the testicle is *inverted*; that is to say, the organ is rotated, so that the epididymis is connected to the front of the scrotum, and the body, surrounded by the tunica vaginalis, is directed backward. In these cases the vasa deferentia is to be felt in the front of the cord. The condition is of importance in connection with hydrocele and hematocele, and the position of the testicle should always be carefully ascertained before performing any operation for these affections. Again, more rarely, the testicle may be *reversed*. This is a condition in which the top of the testicle, indicated by the globus major of the epididymis, is at the bottom of the scrotum, and the vasa deferentia comes off from the summit of the organ.

**The Coverings of the Testicle** (Fig. 1088).

The coverings of the testicle are the following:

<table>
<thead>
<tr>
<th>Skin</th>
<th>Scrotum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dartos</td>
<td>Intercolublar or External spermatic fascia.</td>
</tr>
<tr>
<td></td>
<td>Cremasteric fascia.</td>
</tr>
<tr>
<td></td>
<td>Infundibuliform or Fascia propria (Internal spermatic fascia).</td>
</tr>
<tr>
<td></td>
<td>Tunica vaginalis.</td>
</tr>
</tbody>
</table>

**The Testicular Bag or Scrotum** (Figs. 1086 and 1087).—The testicular bag or scrotum is a cutaneous pouch which contains the testes and part of the spermatic cords. It is divided on its surface into two lateral portions by a median line or

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1. The obliteration of the process of peritoneum which accompanies the cord, and is hence called the juxticular process, is often incomplete. See section on Inguinal Hernia.
2. Diseases of the Male Organs of Generation.
The coverings of the testicle

Raphé (raphe scroti), which is continued forward to the under surface of the penis and backward along the middle line of the perineum to the anus. Of these two lateral portions, the left is usually longer than the right, and corresponds with the usual greater length of the spermatic cord on the left side. Its external aspect varies under different circumstances: thus under the influence of warmth and in old and debilitated persons it becomes elongated and flaccid, but under the influence of cold and in the young and robust it is short, corrugated, and closely applied to the testes. The wrinkles in the scrotum are called rugae.

The scrotum consists of two layers, the **integument** and the **dartos**.

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**Fig. 1086.**—The scrotum. On the left side the cavity of the tunica vaginalis has been opened; on the right side only the layers superficial to the cremaster have been removed. (Testut.)

**The Integument.**—The integument is very thin, of a brownish color, and generally thrown into folds or rugae. It is provided with sebaceous follicles, the secretion of which has a peculiar odor, and is beset with thinly-scattered, crisp hairs, the roots of which are seen through the skin.

**The Dartos** (tunica dartos) (Figs. 1079 and 1086).—The dartos is a thin layer of loose tissue, endowed with contractility; it forms the proper tunic of the scrotum, is continuous around the base of the scrotum, with the two layers of the superficial fascia of the groin and perineum, and sends inward a distinct septum, the **septum of the scrotum** (septum scroti) (Fig. 1086), which divides it into two cavities for the two testes, the septum extending between the raphé and the under surface of the penis as far as its root.

The dartos is closely united to the skin externally, but connected with the
subjacent parts by delicate areolar tissue, upon which it glides with the greatest facility. The dartos is very vascular, and consists of a loose areolar tissue containing unstriped muscular fibre, but no fat. Its contractibility is slow, and excited by cold and mechanical stimuli, but not by electricity.

The Intercolumnar or Spermatic Fascia (Fig. 1086).—The intercolumnar fascia is a thin membrane derived from the margin of the pillars of the external abdominal ring, during the descent of the testis in the foetus, which is prolonged downward around the surface of the cord and testis. It is separated from the dartos by loose areolar tissue, which allows of considerable movement of the latter upon it, but is intimately connected with the succeeding layers.

The Cremasteric Fascia (fascia cremasterica) (Figs. 1086 and 1087).—The cremasteric fascia consists of scattered bundles of muscular fibres, the Cremaster muscle (m. cremaster) (Figs. 1086 and 1087) connected together into a continuous covering by intermediate areolar tissue. The muscular fibres are continuous with the lower border of the Internal oblique muscle.
The Infundibuliform Fascia (tunica vaginalis communis) [testis et funiculi spermatici] (Figs. 1086 and 1087).—The infundibuliform fascia is a thin membranous layer, which loosely invests the surface of the cord. It is a continuation downward of the fascia transversalis. Beneath it is a quantity of loose connective tissue which connects this layer of fascia with the spermatic cord and posterior parts of the testicle. This connective tissue is continuous above with the subserous areolar tissue of the abdomen. These two layers, the infundibuliform fascia and the tissue beneath
The male organs of generation

It, are known collectively as the fascia propria. The infundibuliform fascia completely encloses the testicle and epididymis and is fused with the parietal lamina of the tunica vaginalis propria testis.

The Tunica Vaginalis (tunica vaginalis propria testis).—The tunica vaginalis is described with the testis (p. 1480).

Vessels and Nerves.—The arteries supplying the coverings of the testis are: the superficial and deep external pudic, from the femoral; the superficial perineal branch of the internal pudic; and the cremasteric branch from the deep epigastric. The veins follow the course of the corresponding arteries. The lymphatics terminate in the inguinal glands. The nerves are: the ilio-inguinal branch of the lumbar plexus, the two superficial perineal branches of the internal pudic nerve, the inferior pudendal branch of the small sciatic nerve, and the genital branch of the genito-femoral nerve.

THE SPERMATIC CORD (Funiculus Spermaticus)
(Figs. 1086, 1087, 1090, 1091).

The spermatic cord extends from the internal abdominal ring, where the structures of which it is composed converge, to the back part of the testicle. In the abdominal wall the cord passes obliquely along the inguinal canal, lying at first beneath the Internal oblique muscle and upon the fascia transversalis; but nearer the pubes it rests upon Poupart’s ligament, having the aponeurosis of the External oblique in front of it and the conjoined tendon behind it. It then escapes at the external ring, and descends nearly vertically into the scrotum. The left cord is usually rather longer than the right, consequently the left testis generally hangs somewhat lower than its fellow.

Structure.—The spermatic cord contains the spermatic duct, the deferential artery and veins, the spermatic artery, the pampiniform plexus of veins, the spermatic plexus, and the deferential plexus of the sympathetic nerve, lymphatics, and the cord-like remnant of the funicular process of peritoneum called the ligament...
of Cloquet (Fig. 1090). All the above structures are held together by connective tissue. These structures are enshrouded by the infundibuliform process of the transversalis fascia (Fig. 1096 and p. 1074). This fascia is thin above and thicker below, and encloses the testicle and epididymis, as well as the cord, being firmly adherent to the parietal layer of the vaginal tunic of the testicle and with the posterior portion of the testicle and epididymis. Upon this fascia are the fibres of the Cremaster muscle, which spring from the internal oblique, and in this fascia are the cremasteric artery, the genital branch of the genito-femoral nerve, and external spermatic veins. This fascia is surrounded by the intercolumnar or spermatic fascia, which is distinct above, but not below.

**Vessels and Nerves of the Spermatic Cord.**—The arteries (Figs. 1089 and 1096) of the cord are: the spermatic, from the aorta; the artery of the vas deferens, from the superior vesical; the cremasteric, from the deep epigastrie.

The spermatic artery (a. spermatica interna) arises from the abdominal aorta below the renal artery, descends by the Psoas muscle, crosses the ureter and external iliac vessels, meets the vas deferens at the internal abdominal ring, escapes from the abdomen at the internal or deep abdominal ring, and lying in front of the vas deferens accompanies the other constituents of the spermatic cord along the inguinal canal and through the external abdominal ring into the scrotum. It then descends to the testicle, and, becoming tortuous, divides into several branches, two or three of which, the epididymal branches, accompany the vas deferens and supply the epididymis, anastomosing with the artery of the vas deferens and the cremasteric artery; others, the glandular branches, pierce the back of the tunica albuginea and supply the substance of the testis.

The artery of the vas deferens, a branch of the superior vesical, is a long slender vessel which accompanies the vas deferens, ramifying upon the coats of that duct, and anastomosing with the spermatic artery and the cremasteric artery near the testis.
The cremasteric artery (*a. spermatica externa*) is a branch of the deep epigastric artery. It accompanies the spermatic cord and supplies the Cremaster muscle and other coverings of the cord, anastomosing with the spermatic and deferential arteries.

The spermatic veins (Figs. 1089, 1090, 1091, and 1093) emerge from the back of the testis and receive tributaries from the epididymis; they unite and form a convoluted plexus, the pampiniform plexus (*plexus.pampiniformis*), which forms the chief mass of the cord; the vessels composing this plexus are very numerous, and ascend along the cord in front of the vas deferens; below the external or superficeal abdominal ring they unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the internal or deep abdominal ring, coalesce to form two veins. These again unite to form a single vein, which opens on the right side into the postcava at an acute angle, and on the left side into the renal vein at a right angle.

The lymphatic vessels of the scrotum terminate in the superficial inguinal glands. The lymphatics of the testicle join the lymphatics of the epididymis and of the visceral layer of the vaginal tunic of the testicle, and ascend in the spermatic cord. They reach the lumbar region along the spermatic blood-vessels and terminate in the juxta-aorta glands, and sometimes in the glands in front of the aorta. The lymphatics of the seminal duct pass to the *external iliac glands*.

The nerves are the spermatic plexus from the sympathetic, joined by filaments from the pelvic plexus which accompany the artery of the vas deferens.

The Ligament of the Scrotum.—See Fig. 1085 and p. 1472.

Surgical Anatomy.—The scrotum forms an admirable covering for the protection of the testicle. This body, lying suspended and loose in the cavity of the scrotum, and surrounded by
a serous membrane, is capable of great mobility, and can therefore easily slip about within the scrotum, and thus avoid injuries from blows or squeezes. The skin of the scrotum is very elastic and capable of great distention, and on account of the looseness and amount of subcutaneous tissue the scrotum becomes greatly enlarged in cases of edema, to which this part is especially liable on account of its dependent position. The scrotum is frequently the seat of epithelioma; this is no doubt due to the rugae on its surface, which favor the lodgement of dirt, and this, causing irritation, is the exciting cause of the disease. Cancer was especially common in chimney-sweeps from the lodgement of soot. The scrotum is also the part most frequently affected by elephantiasis.

On account of the looseness of the subcutaneous tissue considerable extravasations of blood may take place from very slight injuries. It is therefore generally recommended never to apply leeches to the scrotum, since they may lead to considerable ecchymosis, but rather to puncture one or more of the superficial veins of the scrotum in cases where local bloodletting from this part is judged to be desirable. The muscular fibre in the dartos causes contraction and considerable diminution in the size of a wound of the scrotum, as after the operation of castration, and is of assistance in keeping the edges together and covering the exposed parts.

The testicles are suspended in the scrotum by the spermatic cords. As the left spermatic cord is rather longer than the right one, the left testicle hangs somewhat lower than its fellow. Each gland is of an oval form, compressed laterally, and having an oblique position in the scrotum, the upper extremity (extremitas superior) being directed forward and a little outward, the lower extremity (extremitas inferior), backward and a little inward; the anterior convex border (margo anterior).
looks forward and downward; the posterior or straight border (margo posterior), to which the cord is attached, backward and upward.

The anterior border and lateral surfaces (facies lateralis et facies mediialis), as well as both extremities of the organ, are convex, free, smooth, and invested by the visceral layer of the tunica vaginalis. The posterior border, to which the cord is attached, receives only a partial investment from that membrane. Lying upon the outer edge of this posterior border is a long, narrow, flattened body, named, from its relation to the testis, the epididymis (ἄντειος, testis) (Figs. 1094 and 1095). The curve of the epididymis is convex outward and backward. It consists of a central portion or body (corpus epididymidis); an upper enlarged extremity, the head or globus major (caput epididymidis); and a lower pointed extremity, the tail or globus minor (cauda epididymidis). The globus major is directed inward and is intimately connected with the upper end of the testicle by means of its efferent ducts, and the globus minor is connected with its lower end by cellular tissue and a reflection of the tunica vaginalis. The globus minor bends suddenly and passes into the seminal duct, the direction of which is upward and backward. The outer surface and upper and lower ends of the epididymis are free and covered by serous membrane; the body is also completely invested by it, excepting along its posterior border, and between the body and the testicle is a pouch or cul-de-sac, named the digital fossa (sinus epididymidis). Above this fossa is a fold of the tunica vaginalis, which is called the ligamentum epididymidis superior, and below it is another fold, the ligamentum epididymidis inferior. The epididymis is connected to the back of the testis by a fold of the serous membrane. Attached to the upper end of the testis, close to the globus major, is a small body. It is oblong in shape and has a broad base. Attached to the globus major of the epididymis is another small body, which is pear-shaped and has a stalk. These bodies are believed to be the remains of the upper extremity of the Müllerian duct, and are termed the hydatids of Morgagni; some observers, however, regard the stalked hydatid as being a rudiment of the pronephros. The body with a broad base is the non-pedunculated hydatid (appendix testis [Morgagnii]) (Figs. 1086 and 1094);

the pear-shaped body is the pedunculated hydatid (appendix epididymidis). When the testicle is removed from the body, the position of the vas deferens, on the
posterior surface of the testicle and inner side of the epididymis, marks the side to which the gland has belonged.

**Size and Weight.**—The average dimensions of this gland are from one and a half to two inches in length, one inch in breadth, and an inch and a quarter in the antero-posterior diameter, and the weight varies from six to eight drachms, the left testicle being a little the larger.

**The Tunics of the Testicle.**—The testis is invested by three tunics—the tunica vaginalis, tunica albuginea, and tunica vasculosa. The Proper Sheath of the Testicle or the Tunica Vaginalis (tunica vaginalis propria testis) (Figs. 1084, 1086, 1087, 1088, and 1096) is the serous covering of the testicle and epididymis. It is a pouch of serous membrane, derived from the peritoneum (processus vaginalis peritonei) during the descent of the testis in the foetus from the abdomen into the scrotum. After its descent that portion of the pouch which extends from the internal ring to near the upper part of the gland, the **funicular process**, becomes obliterated, the lower portion remaining as a shut sac, which invests the outer surface of the testis, and is reflected on to the internal surface of the scrotum; hence it may be described as consisting of a visceral and parietal portion.

The **Visceral Portion** (lamina visceralis) of the tunica vaginalis propria covers the outer surface of the testis, as well as the epididymis, connecting the latter to the testis by means of a distinct fold. From the posterior border of the gland it is reflected on to the internal surface of the infundibuliform process of the transversalis fascia, and between the tunica and the fascia is a layer of unstriated muscle fibres, the **Internal cremaster muscle** (Fig. 1088).

The **Parietal Portion** (lamina parietalis) of the tunica vaginalis propria is the reflected portion. It is far more extensive than the visceral portion, extending upward for some distance in front and on the inner side of the cord, and reaching below the testis. The inner surface of the tunica vaginalis is free, smooth, and covered by a layer of endothelial cells. The interval between the visceral and parietal layers of this membrane constitutes the **cavity of the tunica vaginalis** and contains a small amount of serous fluid.

The obliterated portion of the pouch may generally be seen as a fibro-cellular thread, the **ligament of Cloquet** (rudimentum processus vaginalis) (Fig. 1090), lying in the loose areolar tissue around the spermatic cord; sometimes this may be traced as a distinct band from the upper end of the inguinal canal, where it is connected with the peritoneum, down to the tunica vaginalis; sometimes it gradually becomes lost on the spermatic cord. Occasionally no trace of it can be detected. In some cases it happens that the pouch of peritoneum does not become obliterated, but the sac of the peritoneum communicates with the tunica vaginalis. This may give rise to one of the varieties of oblique inguinal hernia; or in other cases the
pouch may contract, but not become entirely obliterated; it then forms a minute canal leading from the peritoneum to the tunica vaginalis.\footnote{1}

The **Tunica Albuginea** (Figs. 1088, 1095, and 1096).—The tunica albuginea is the fibrous covering of the testis. It is a dense fibrous membrane, of a bluish-white color, composed of bundles of white fibrous tissue, which interlace in every direction. Its outer surface is covered by the tunica vaginalis, except at the points of attachment of the epididymis to the testicle, and along its posterior border, where the spermatic vessels enter the gland. This membrane surrounds the glandular structure of the testicle, and at its posterior border forms a projection, triangular in shape and cellular in structure, which is reflected into the interior of the gland, forming an incomplete vertical septum, called the **mediastinum testis**.

The **Mediastinum Testis** (*corpus Highmori*) (Figs. 1088, 1095, and 1096) extends from the upper, nearly to the lower, extremity of the gland, and is wider above than below. From the front and sides of this septum numerous slender fibrous cords and imperfect septa, called the **trabeculae** (*septula testis*) (Fig. 1096), are given off, which radiate toward the surface of the organ, and are attached to the inner surface of the tunica albuginea. This scaffolding of connective tissue divides the **parenchyma** (*parenchyma testis*) of the organ into a number of incomplete spaces, which are somewhat cone-shaped, being broad at their bases at the surface of the gland, and becoming narrower as they converge to the mediastinum. The mediastinum supports the blood-vessels, lymphatics, and ducts of the testis in their passage to and from the substance of the gland, and contains numerous fine canals, into which open the very small tubules of the proper substance of the testicle.

The **Tunica Vasculosa** (Fig. 1088).—The tunica vasculosa is the vascular layer of the testis, and consists of a plexus of blood-vessels held together by a delicate areolar tissue. It covers the inner surface of the tunica albuginea and the different septa in the interior of the gland, and therefore forms an internal investment to all the spaces of which the gland is composed.

**Structure of the Testicle and Epididymis** (Fig. 1096).—The glandular structure of the testis consists of numerous **lobules** (*lobuli testis*). Their number, in a single testis, is estimated by Berres at 250, and by Krause at 400. They differ in size according to their position, those in the middle of the gland being larger and longer. The lobules are conical in shape, the base of each being directed toward the circumference of the organ, the apex toward the mediastinum. Each lobule is contained in one of the intervals between the fibrous cords and vascular processes which extend between the mediastinum testis and the tunica albuginea, and consists of from one to three or more minute convoluted tubes, which anastomose with each other, the **tubuli seminiferi contorti**. The contorted tubes unite at the apex of the lobules and form the **straight tubes** (*tubuli seminiferi recti*). The straight tubes pass into the mediastinum testis and form the network known as the **rete testis** of Haller (Fig. 1096). The rete testis is lined with flattened epithelium. The tubes are lined with columnar ciliated epithelium. The **efferent ducts** (*duetuli efferentes testis*) (Fig. 1096), about twelve to fifteen in number, arise from the rete. The contorted tubes may be separately unravelled by careful dissection under water, and may be seen to commence either by free caecal ends or by anastomotic loops. The total number of tubes is considered by Munro to be about 300 and the length of each about sixteen feet; by Lauth their number is estimated at 840, and their average length two feet and a quarter. The diameter varies from \( \frac{1}{5} \) to \( \frac{1}{6} \) of an inch. The tubuli are pale in color in early life, but in old age they acquire a deep-yellow tinge from containing much fatty matter. Each tube consists of a basement layer, formed

\footnote{1 It is recorded that in the post-mortem examination of Sir Astley Cooper a minute funicular canal was found on each side of the body. Sir Astley Cooper states that when a student he suffered from inguinal hernia; probably this was of the congenital variety, and the canal found after death was the remains of the one down which the hernia travelled (Lancet, 1824, vol. ii. p. 116).—Ed. of 15th English edition.
of epithelioid cells united edge to edge, outside of which are other layers of flattened cells arranged in interrupted laminae, which give to the tube an appearance of striation in cross-section. The cells of the outer layers gradually pass into the interstitial tissue. Within the basement-membrane are epithelial cells arranged in several irregular layers, which are not always clearly separated, but which may be arranged in three different groups. Among these cells may be seen the spermatozoids in different stages of development. 1. Lining the basement-membrane and forming the outer zone is a layer of cubical cells, with small nuclei; these are known as the lining cells or spermatogonia. The nucleus of some of them may be seen to be in the process of indirect division (karyokinetics), and in consequence of this daughter cells are formed, which constitute the second zone.

2. Within this first layer is to be seen a number of larger cells with clear nuclei, arranged in two or three layers; these are the intermediate cells or spermatocytes. Most of these cells are in a condition of karyokinetic division, and the cells which result from this division form those of the next layer, the spermatoblasts or spermatids. 3. The third layer of cells therefore consists of the spermatoblasts or spermatids, and each of these, without further subdivision, becomes a spermatozoid. They are ill-defined granular masses of protoplasm, of an elongated form, with a nucleus which becomes the head of the future spermatozoid. In addition to these three layers of cells others are seen, which are termed the supporting cells, or cells of Sertoli. They are elongated and columnar, and project inward from the basement-membrane toward the lumen of the tube. They give off numerous lateral branches, which form a reticulum for the support of the three groups of cells just described. As development of the spermatozoids proceeds the latter group themselves around the inner extremities of the supporting cells. The nuclear part of the spermatozoid, which is partly embedded in the supporting cell, is differentiated to form the head of the spermatozoid, while the cell protoplasm becomes lengthened out to form the middle piece and tail, the latter projecting into the lumen of the tube. Ultimately the heads are separated and the spermatozoids are set free.

**Spermatogenesis.**—The stages in the development of the spermatozoids are as follows: The spermatogonia become enlarged to form the spermatocytes, and each spermatocyte subdivides into two cells, and each of these again divides into two spermatids or young spermatozoids, so that the spermatocyte gives origin to four spermatozoids.

The process of spermatogenesis bears a close relation to that of maturation of the ovum. The spermatocyte is equivalent to the immature ovum. It undergoes subdivision, and ultimately gives origin to four spermatozoids, each of which contains, therefore, only one-fourth of the chromatin elements of the nucleus of the spermatocyte. In the process of maturation of the ovum its nucleus divides, one-half being extended as the first polar body. The remaining half of the nucleus again subdivides, one-half being extended as the second polar body. The portion of the nucleus which is retained to form the female pronucleus of the now matured ovum contains, therefore, only one-fourth of the chromatin elements of the original nucleus, and thus the spermatozoid and the matured ovum, so far as their nuclear elements are concerned, may be regarded as of the same morphological value.

The tubules are enclosed in a delicate plexus of capillary vessels, and are held together by an intertubular connective tissue, which presents large interstitial spaces lined by endothelium, which are believed to be the rootlets of lymphatic vessels of the testis.

The Aberrant Ducts of the Epididymis (ductuli aberrantes) are tortuous and end in blind extremities. The superior aberrant duct (ductus aberrans superior) is in the globus major and joins the rete testis. The inferior aberrant duct (ductus aberrans inferior) (Fig. 1096) is in the tail of the epididymis, and takes origin from the
duct of the epididymis or the seminal duct. It is a persistent canal of the Wolffian body. It extends up the cord for two or three inches and terminates by a blind extremity, which is occasionally bifurcated. It may be as much as fourteen inches in length. Its structure is similar to that of the seminal duct.

The Seminal Duct or Vas Deferens (ductus deferens) (Figs. 1089, 1090, 1091, 1096, 1097, and 1135).—The seminal duct or vas deferens, the excretory duct of the testis, is the continuation of the epididymis. Commencing at the lower part of the globus minor, it ascends along the posterior border of the testis and inner side of the epididymis, and along the back part of the spermatic cord, through the inguinal canal to the internal or deep abdominal ring. From the ring it curves around the outer side of the internal epigastric artery and vein, crosses the external iliac vessels, and descends into the pelvis at the side of the bladder; it arches backward and downward to its base, crossing over the obliterated hypogastric artery and to the inner side of the ureter. At the base of the bladder it lies between that viscus and the rectum, running along the inner border of the seminal vesicle. Behind the bladder it becomes enlarged and sacculated, forming the ampulla (ampulla ductus deferentis) (Fig. 1097), and then, becoming narrowed at the base of the prostate, unites with the duct of the seminal vesicle to form the ejaculatory duct (Fig. 1098). From the internal abdominal ring to the middle of the ampulla the seminal duct is beneath the peritoneum. The vas deferens offers a hard and cord-like sensation to the fingers; it is about two feet in length, of cylindrical form, and about a line and a quarter in diameter. Its walls are dense, measuring one-third of a line, and its canal is extremely small, measuring about half a line.

Structure.—The vas deferens consists of three coats: 1. An external or areolar coat (tunica adventitia). 2. A muscular coat (tunica muscularis), which in the greater part of the tube consists of two layers of unstriped muscular fibre: an inner layer of thin longitudinal fibres (stratum internum) existing only at the beginning, a thick layer of circular fibres (stratum medium), and a thick external layer of longitudinal fibres (stratum externum). 3. An internal or mucous coat (tunica mucosa), which is pale, and arranged in longitudinal folds; its epithelial cells are of the columnar variety.

Organ of Giraldes (paradidymis).—This term is applied to a small body of rounded shape in the lower end of the spermatic cord, in front of the blood-vessels. It consists of a small collection of minute vesicles and a small collection of convoluted tubules. These tubes are lined with columnar ciliated epithelium, and probably represents the remains of a part of the Wolffian body.

Surgical Anatomy.—Abnormalities in the descent and position of the testicle have been discussed (p. 1472). The testicle may require removal for malignant disease, tuberculous disease, cystic disease, in cases of large hernia testis, and in some instances of incompletely descended or misplaced testicles. The operation of double castration has also been, during the last few years, performed for enlargement of the prostate gland; for it has been found that removal of the testicles is followed by very rapid and often considerable diminution in the size of the prostate. The operation is, however, one of severity, and is frequently followed by death in these cases, performed, as it necessarily is, in old men. Reginald Harrison has proposed to substitute for it excision of a portion of each vas deferens (vasectomy). The operation of castration is a comparatively simple one. An incision is made into the cavity of the tunica vaginalis from the external ring to the bottom of the scrotum. The coverings are shelled off the organ, and the mesorchium, stretching between the back of the testicle and the scrotum, divided. The cord is then isolated, and an aneurism needle, armed with a double ligature, passed under it, as high as is thought necessary, and the cord tied in two places, and divided between the ligatures. Sometimes, in cases of malignant disease, it is desirable to open the inguinal canal and tie the cord as near the internal abdominal ring as possible.

A collection of serous fluid in the sac of the vaginal tunic of the testicle is known as an ordinary or testicular hydrocele. In congenital hydrocele a communication remains between the tunica vaginalis testis and the peritoneal cavity. This communication should have closed during development. In infantile hydrocele the tunica vaginalis and part of the funicular process are distended with fluid, but the funicular process is closed above and the cavity of the hydrocele
THE TESTICLES

The Semen and the Spermatozoids.—Semen consists of spermatozoids with liquids and solids. Part of the semen comes from the testicles, most of it from accessory glands—that is, from the glands of the seminal ducts, the seminal vesicles, the prostate gland, and Cowper’s glands. Semen is a viscid, whitish fluid, of alkaline reaction and characteristic odor. It contains water and about 18 per cent. of solid matter. In this solid matter are fat, cholesterin, lecithin, proteids, nuclein, xanthin, chlorides, sulphates, and phosphates of sodium and potassium. Böttcher’s crystals, which can be obtained from semen, are composed of phosphate of spermine. Spermine is a nitrogenous substance. The fluid portion of semen carries and probably nourishes the living cells known as spermatozoids.

The spermatozoids (Fig. 1097) are minute, thread-like bodies, which constitute the essential elements of the semen. Each consists of a head, a middle piece or body, and an elongated filament or tail. The head, on surface view, appears oval in shape, but if seen in profile it is narrow and pointed at its free end. It represents the modified nucleus of the spermatid, and consists chiefly of chromatin, and so stains readily with nuclear reagents; it is covered by a thin cap of protoplasm. The body is a short cylindrical or conical piece, intervening between the head and tail, and is therefore sometimes spoken of as the intermediate segment. The tail is about four times the combined lengths of the head and body; its terminal part is extremely fine, and is named the end-piece. Contained within the body and tail is an axial filament, surrounded, except in the end-piece, by a thin layer of protoplasm; this axial filament terminates just below the head in a rounded knob or button. In virtue of their tails, which act as propellers, the spermatozoids, in the fresh condition, are capable of free movement, and if placed in favorable surroundings (e. g., in the female passages) may retain their vitality for some days or even weeks.
THE SEMINAL VESICLES (VESICULAE SEMINALES) (Figs. 1098, 1099).

The seminal vesicles are two lobulated membranous pouches placed between the base of the bladder and the rectum, serving as reservoirs for the semen, and secreting a fluid to be added to the secretion of the testicles. Each sac is somewhat pyramidal in form, the broad end being directed backward and the narrow end forward toward the prostate. It measures about two and a half inches in length, about five lines in breadth, and two or three lines in thickness. They vary, however, in size, not only in different individuals, but also in the same individual on the two sides. The upper surface is in contact with the base of the bladder, extending from near the termination of the ureters to the base of the prostate gland. The under surface rests upon the rectum, from which it is separated by the recto-vesical fascia. Their posterior extremities diverge from each other. Their anterior extremities are pointed, and converge toward the base of the prostate gland, where each joins with the corresponding seminal duct to form the ejaculatory duct. Along the inner margin of each vesicle runs the enlarged and convoluted vas deferens. The inner border of the vesicle and the corresponding seminal duct form the lateral boundaries of a triangular space, limited behind by the recto-vesical peritoneal fold; the portion of the bladder included in this space rests on the rectum.

Each vesicle consists of a single tube, coiled upon itself and giving off several irregular caecal diverticula (Fig. 1098), the separate coils, as well as the diverticula, being connected together by fibrous tissue. When uncoiled this tube is about the diameter of a quill, and varies in length from four to six inches; it terminates posteriorly in a cul-de-sac; its anterior extremity becomes constricted into a narrow straight duct, the excretory duct (ductus excretorius) (Fig. 1099), which joins with the corresponding seminal duct, and forms the ejaculatory duct.
The Ejaculatory Ducts (*ductus ejaculatorii*) (Fig. 1099).—The ejaculatory ducts are two in number, one on each side. Each duct is formed by the junction of the duct of the seminal vesicle with the seminal duct. Each duct is about three-quarters of an inch in length; it commences at the base of the prostate, and runs forward and downward between the middle and lateral lobes of that gland, and along the side of the sinus pocularis, to terminate by a separate slit-like orifice close to or just within the margins of the sinus. The ducts diminish in size and also converge toward their termination.

Structure.—The seminal vesicles are composed of three coats: an *external* or areolar (*tunica adventitia*); a *middle* or muscular coat (*tunica muscularis*), which is thinner than in the seminal duct, and is arranged in two layers, an outer, longitudinal, and inner, circular; an *internal* or mucous coat (*tunica mucosa*), which is pale, of a whitish-brown color, and presents a delicate reticular structure, like that seen in the gall-bladder, but the meshes are finer. The epithelium is columnar.

The coats of the ejaculatory ducts are extremely thin. They are: an *outer fibrous layer*, which is almost entirely lost after the entrance of the duct into the prostate; a *layer of muscular fibres*, consisting of an outer thin circular and an inner longitudinal layer; and the *mucous membrane*.

Vessels and Nerves.—The *arteries* supplying the seminal vesicles are derived from the *middle and inferior vesical* and *middle haemorrhoidal*. The *veins* and *lymphatics* accompany the arteries. The lymphatics anastomose on the surface of the vesicle. The trunks from this network anastomose with the lymphatics of the bladder and prostate, and pass to the *external* and *internal iliac glands*. The *nerves* are derived from the *pelvic plexus*.

Surgical Anatomy.—The seminal vesicles are often the seat of an extension of the disease in cases of *tuberculosis* of the testicle, and should always be examined through the rectum before coming to a decision with regard to castration in this affection. The vesicles have been deliberately *extirpated* for local tuberculosis. In gonorrhoea the seminal vesicles may become acutely inflamed (*acute seminal vesiculitis*). *Chronic seminal vesiculitis* may follow the acute form or may arise insidiously during gonorrhoea.
THE FEMALE ORGANS OF GENERATION.

EXTERNAL ORGANS (PARTES GENITALES EXTERNAL MULIEBRES).

The external organs of generation in the female are: the mons Veneris, the labia majora and minora, the vestibule, the clitoris, the vaginal bulb, and the glands of Bartholin. The term vulva (pudendum muliebre), as generally applied, includes all of these parts. In examining the structures entering into the formation of the vulva we find the homologues of most of the structures which make up the male genitals.

THE LARGE LIPS OR LABIA MAJORA (LABIA MAJORA PUDENDI)

(Figs. 1101, 1102, 1103).

The labia majora are two prominent longitudinal cutaneous folds, narrow behind but fuller and larger toward the mons Veneris, and enclosing the pudendal slit (rami pudendi) or common urino-genital opening. Each labium majus (labium 94 (1480)
majus pudendi) has two surfaces, an outer, which is covered by pigmented skin with numerous sebaceous glands and strong, crisp hairs, and an inner, which is smooth and moist, and is continuous with the genito-urinary mucous tract. In the subcutaneous areolo-fatty tissue of each labium majus the round ligament of the uterus ends. The labia are joined with each other anteriorly by the mons Veneris or anterior comissure (commissura labiorum anterior). Posteriorly they appear to become lost in the neighboring integument, although sometimes connected by a slight transverse fold in front of the anus, the posterior comissure (commissura labiorum posterior) or posterior boundary of the vulvar orifice. The interval between the posterior comissure and the anus, about an inch in length, constitutes the obstetric perinaeum.

Blood-vessels, Nerves, and Lymphatics.—The arteries of the labia majora are derived from the superficial external pudic arteries and from perineal branches of the internal pudic arteries. Homologous with the scrotum, the nerve-supply is derived from branches of the ilio-inguinal, internal pudic, and perineal branches of the small sciatic. The lymphatics drain into the superficial inguinal and internal iliac lymph-nodes.

THE SMALL LIPS, NYMPHAE OR LABIA MINORA (LABIA MINORA PUDENDI) (Figs. 1101, 1102, 1103).

The labia minora, or nymphae, are two smaller, narrower longitudinal folds, with a delicate covering of modified skin, and usually hidden from view unless the labia majora are separated. They end posteriorly by gradually joining the labia
THE CLITORIS (Figs. 1102, 1103, 1105).

The clitoris is an erectile structure which is the morphologic homologue of the penis; unlike the penis, however, it is not traversed by the urethra. It is situated beneath the anterior commissure (or mons Veneris) partially hidden between the anterior extremities of the labia minora. It is composed of a body and two crura; the extremity of the body is surmounted by a small glans.

The body of the clitoris, composed of erectile tissue, is about an inch and a quarter in length, bent upon itself so that the angle opens downward. It tapers toward the glans, is enclosed by a dense fibrous coat, and is divided by an incomplete

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**Fig. 1104.**—Female pelvic organs in situ, seen from above. (Bardeleben.)

**Fig. 1105.**—Varieties of hymen. (Testut, after Rose.)
septum corporum cavernosum into two semi-cylindrical corpora cavernosa clitoridis, homologous with the corpora cavernosa of the male. A suspensory ligament passes from the pubic symphysis to the fibrous coat of the body of the clitoris. Each corpus cavernosum diverges from its fellow to form the crus clitoridis. Each crus is attached to the pubic arch (pubis and ischium) and covered by the Ischiocavernosus muscle (m. erector clitoridis).

To each crus of the clitoris goes a branch from the internal pudic artery, which branch is known as the deep artery of the clitoris. The dorsal arteries of the clitoris (arteriae dorsalis clitoridis) from the internal pudic send branches to the glans. The nerves of the clitoris consist of the dorsal nerves of the clitoris from the internal pudic nerve and sympathetic fibres from the hypogastric plexus.

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**Fig. 1106.**—The female external organs of generation dissected. (Spaltehola.)

The glans clitoridis is a minute mass of erectile tissue, surmounting the tapering apex of the body of the clitoris. It is covered by a very sensitive epithelium, and its erectile tissue, like that of the glans penis, is continuous with the erectile tissue of the bulbus vestibuli, the homologue of the corpus spongiosum of the male. The preputium clitoridis and the frenulum clitoridis have already been described (p. 1491) as divisions of the labia minora.

Arteries and Nerves of the Clitoris.—The body and the crura of the clitoris derive their blood-supply from the deep artery of the clitoris (arteria profunda clitoridis) from the internal pudic artery. Another branch of this artery, the dorsal artery of
the clitoris (arteria dorsalis clitoridis) supplies the glans. The nerve-supply is derived from the dorsal nerve of the clitoris, from the internal pudic, and from the hypogastric sympathetic plexus.

THE VAGINAL BULB (BULBUS VESTIBULI) (Fig. 1106).

The bulbus vestibuli may be regarded as the homologue of the bulb portions of the corpus spongiosum of the male. The principal morphological difference lies in the fact that the two halves are fused in the male, but remain separated in the female. The bulbus vestibuli consists of a mass of minute convoluted bloodvessels, of such plexiform arrangement as to be often called erectile tissue, arranged in two halves on either side of the vaginal and urethral orifices. Each half is thicker or more massive posteriorly, while anteriorly it is attenuated and joins its fellow of the opposite side to form the pars intermedia, continuous with the erectile tissue of the glans clitoridis. Each half of the bulbus vestibuli rests against the lateral wall of the vagina and lies superficial to the triangular ligament. Externally and inferiorly it is covered by the Bulbo-cavernous muscle.

Arteries and Nerves of the Bulbus Vestibuli.—The blood is supplied by the artery to the bulb (arteria bulbì vestibuli), a branch of the internal pudic artery. The nerve-supply is by branches of the hypogastric sympathetic plexus.

GLANDS OF BARTHOLIN (GLANDULA VESTIBULARIS MAJOR [BARTHOLINI]) (Fig. 1106).

On each side of the posterior part of the commencement of the vagina is a round or oblong body, of a reddish-yellow color, and of the size of a horse-bean, analogous to Cowper's gland in the male. It is called the gland of Bartholin, the gland of Duverney, the vulvo-vaginal gland or the suburethral gland. Bartholin's gland lies partly in the inferior or anterior leaf of the triangular ligament. The posterior portion of the bulbus vestibuli and the Bulbo-cavernous muscle partly cover it. Each gland opens by means of a long single duct immediately external to the hymen, in the angle or groove between it and the nympha (Fig. 1105).

INTERNAL ORGANS (PARTES GENITALES INTERNAE MULIEBRES).

The internal organs of generation are—the vagina, the uterus and its appendages, the Fallopian tubes, the ovaries and their ligaments.

THE VAGINA (Figs. 1100, 1103, 1109).

The vagina extends from the vulva to the uterus. It is situated in the cavity of the pelvis, behind the bladder and in front of the rectum. Its direction is curved upward and backward, at first in the line of the pelvic outlet, and afterward in that of the axis of the cavity of the pelvis. Its walls are ordinarily in contact, and its usual shape on transverse section is that of an H, the transverse limb being slightly curved forward or backward, whilst the lateral limbs are somewhat convex toward the median line. Its length is about two and a half inches along its anterior wall (partes anterior), and three and a half inches along its posterior wall (paries posterior). It is constricted at its commencement, and becomes dilated medially, and narrowed near its uterine extremity; it surrounds the vaginal portion of the cervix uteri, a short distance from the os, its attachment extending higher up on the posterior than on the anterior wall of the uterus (Fig. 1112).
The vaginal axis forms with the uterine axis an obtuse angle opening forward, and, as a rule, a little greater than a right angle (Fig. 1110). The fact that the attachment of the vagina to the cervix is above the external os causes the formation of a recess between the cervix and vaginal wall, known as the vaginal fornix \((fornix vaginae)\). This recess is deeper posteriorly than it is laterally or in front. The anterior portion of the fornix is called the anterior fornix (Fig. 1103). The posterior portion is called the posterior fornix (Fig. 1103). The right and left portions are called the right and left lateral fornices. The vagina opens into the uro-genital cleft, between the labia minora and back of the urethra and clitoris. It opens by the vaginal orifice \((orificium vaginae)\) (Fig. 1102). In the virgin the opening is partly closed by the hymen (p. 1492). After rupture of the hymen atrophied fragments of the torn membrane remain around the vaginal orifice, and are known as the carunculae myrtiformes \((carunculae hymenales)\).

**Relations** (Figs. 1100 and 1103).—The upper part of the anterior wall of the vagina is in relation with the base of the bladder, being separated from that viscus by lax connective tissue. Lower down the middle line of the anterior wall and closely joined to it is the urethra. The upper part of the posterior wall, near the middle line, is covered for a quarter of an inch or more with peritoneum, which forms the anterior wall of the depths of the recto-vaginal pouch of peritoneum or pouch of Douglas \((excavatio rectouterina [Douglas])\) (Fig. 1112), between the uterus and vagina and the rectum. The portion of the posterior wall below the level of the pouch of Douglas is placed close to the rectum, a layer of pelvic fascia intervening. As the vaginal orifice is neared, the rectum and vagina separate, and interposed between them is a mass of fibro-fatty tissue called the perinaeum or perineal body. Its sides are enclosed between the Levatores ani muscles. The ureter toward its termination (Fig. 1113) lies near the lateral wall of the vagina, passing at this point in a direction downward, inward, and slightly forward to reach the bladder. The vagina near its termination passes through the triangular ligament, and upon its sides are the bulbs of the vestibule, the glands of Bartholin, and the Bulbo-cavernous muscle.

**Structure.**—The vagina consists of an internal mucous lining, of a muscular coat, and between the two of a layer of erectile tissue.

**The Mucous Membrane** \((tunica mucosa)\) (Fig. 1109).—The mucous membrane is continuous above with that lining the uterus. Its inner surface presents, along the anterior and posterior walls, a longitudinal ridge or raphé, called the rugous columns of the vagina \((columna rugarum anterior et posterior)\). The anterior column extends downward as far as the external orifice of the urethra, forming the carina urethralis vaginae. Numerous transverse ridges or rugae \((rugae vaginales)\) extend outward from the raphé on either side. These rugae are divided by furrows of variable depth, giving to the mucous membrane the appearance of being studded over with conical projections or papillae; they are most numerous near the orifice of the vagina, especially in females before parturition. The epithelium covering the mucous membrane is of the squamous variety. The submucous tissue is very loose and contains numerous large veins, which by their anastomoses form a plexus, together with smooth muscular fibres from the muscular coat; it is regarded by Gussenbauer as an erectile tissue (see p. 1497). It contains a number of mucous crypts, but no true glands.

**The Muscular Coat** \((tunica muscularis)\).—The muscular coat consists of two layers: an external longitudinal, which is far the stronger, and an internal circular layer. The longitudinal fibres are continuous with the superficial muscular fibres of the uterus. The strongest fasciculi are those attached to the recto-vesical fascia on each side. The two layers are not distinctly separable from each other, but
are connected by oblique decussating fasciculi which pass from the one layer to the other. Above the triangular ligament the fibres are non-striated; in the region of the ligament they show striations. In addition to this the vagina at its lower end is surrounded by a band of striped muscular fibres, the sphincter vaginae (p. 463). External to the muscular coat is a layer of connective tissue containing a large plexus of blood-vessels.

The Erectile Tissue.—The erectile tissue consists of a layer of loose connective tissue situated between the mucous membrane and the muscular coat; embedded in it is a plexus of large veins, and numerous bundles of unstriped muscular fibres derived from the circular muscular layer. The arrangement of the veins is similar to that found in other erectile tissues.

Blood-vessels, Nerves, and Lymphatics.—The arteries of the vagina are branches of the vesico-vaginal artery; the vaginal branch of the uterine artery (p. 688), and branches of the internal pudic and middle haemorrhoidal. The veins form an abundant plexus around the wall of the vagina and pass to the internal iliac veins. The lymphatics (Fig. 1107) arise from two communicating networks, one of which is below the mucous membrane, the other in the muscular wall. There is a third network around the vaginal wall, from which the collectors arise. The trunks from the upper third of the vagina pass to the external iliac glands; those from the middle third pass to the internal iliac glands; those from the lower third terminate in the glands at the promontory of the sacrum or in the lateral sacral glands. The nerves come from the third and fourth sacral nerves and from the utero-vaginal and vesical plexuses of the sympathetic.

1 The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
THE WOMB OR UTERUS (Figs. 1100, 1103, 1104, 1108, 1113).

The uterus is the organ of gestation, receiving the fecundated ovum in its cavity, retaining and supporting it during the development of the foetus, and becoming the principal agent in its expulsion at the time of parturition. It is a hollow muscular organ. The non-pregnant uterus is contained in the cavity of the pelvis between the bladder and rectum (Figs. 1103 and 1104). It is rarely placed exactly in the mid-line, but inclines to one side or the other, more often to the left than to the right. The walls of the organ are extremely thick. The uterus is movable as a whole, and the body of the uterus is movable upon the neck. Its position varies with the condition of adjacent parts, especially the bladder and rectum. The cervix is more firmly fixed than the body and fundus, and hence the latter vary more in position than the former. Normally, in an erect individual, with the bladder and rectum empty, the external os is at the level of the upper surface of the pubic symphysis (Fig. 1100) and in frontal plane passing through the ischiatic spines. The long axis of the uterus is directed forward and upward (Fig. 1100), and is angled where the body and cervix join. Hence, normally, with the bladder empty, the uterus is antverted and anteflexed. When the bladder fills the anteverision and anteflexion are almost abolished. If the bladder is overdistended and the rectum is empty, the uterus is pushed strongly backward, so that its long axis corresponds to the long axis of the vagina; in other words, it is retroverted.

In the virgin state it is pear-shaped, flattened from before backward, and is retained in its position by the round and broad ligaments on each side, and projects into the upper end of the vagina below (Figs. 1108 and 1109). Its upper end, or base, is directed upward and forward; its lower end, or apex, downward and backward, in the line of the axis of the inlet of the pelvis. It therefore forms an angle with the vagina, since the direction of the vagina corresponds to the axis of the cavity and outlet of the pelvis. The non-pregnant adult uterus measures about three inches in length, two inches in breadth at its upper part, and nearly an inch in thickness, and it weighs from an ounce to an ounce and a half.

It consists of two parts (Fig. 1108): (1) An upper and larger portion, consisting of the body and fundus. This portion is flattened from before backward. (2) A lower, smaller, and cylindrical portion, the cervix.

![Diagram of the uterus](image-url)
The Fundus (fundus uteri) (Fig. 1108).—The fundus is the upper broad extremity of the uterus. If a line is drawn from the uterine opening of one Fallopian tube to the other, the portion above the line is the fundus. The fundus is directly continuous with the body.

The Body of the Uterus (corpus uteri) (Fig. 1108).—The body of the uterus is below and continuous with the fundus. In outline, when seen from in front or behind, it resembles a triangle, the base being above and the point being absent.

The anterior surface (facies vesicalis) passes on each side into the posterior surface (facies intestinalis) by the lateral border (margo lateralis).

The body gradually narrows from the fundus to the neck. Its anterior surface is so slightly rounded as to appear flattened. It is covered by peritoneum (Fig. 1108), which becomes separated from it at its union with the cervix, in order to form the utero-vesical pouch, which lies between the uterus and bladder (Fig. 1112). Its posterior surface is more rounded than the anterior, being convex transversely. It is
covered by peritoneum throughout (Fig. 1113), and separated from the rectum by some convolutions of the small intestine (Fig. 1102). The peritoneum which covers the posterior surface forms most of the anterior wall of Douglas' cul-de-sac (Figs. 866, 1112, and 1113, and p. 1258). Its lateral margins (Figs. 1108 and 1113) are concave, and each gives attachment to the Fallopian tube above, the round ligament below, and in front of this the ligament of the ovary; behind both of these structures, and from the side of the womb the broad ligament passes. The division between the body and the cervices is indicated externally by a slight constriction, and by the reflection of the peritoneum from the anterior surface of the uterus on to the bladder, and internally by a narrowing of the canal called the internal os (Fig. 1111).

**The Neck or Cervix Uteri** (Figs. 1108 and 1111).—The neck or cervix uteri is the lower constricted segment of the uterus; around its circumference is attached the upper end of the vagina (Figs. 1103, 1108, 1109, and 1112), which extends upward a greater distance behind than in front. The neck is spindle-shaped in those who have had no children, cylindrical in those who have had children.

**The Supravaginal Portion** (portio supravaginalis [cervicis]) (Figs. 1108 and 1112).—The supravaginal portion is not covered by peritoneum in front; a pad of cellular tissue is interposed between it and the bladder. Behind, the peritoneum is extended over it.

**The Vaginal Portion** (portio vaginalis [cervicis]) (Figs. 1103, 1108, 1109, and 1112).—The vaginal portion is the lower end projecting into the vagina. It is round or
elliptical, the long axis of the elliptical figure being transversely placed. On its surface is a small aperture, the external mouth of the womb, or os uteri, or external os (orificium externum uteri) (Figs. 1108, 1109, 1111, and 1112), generally circular in shape, but sometimes oval or almost linear. If a woman has borne children the opening is transverse and the margins are irregular. The margin of the opening is, in the absence of past parturition or disease, quite smooth. This aperture divides the vaginal portion of the cervix into two lips, an upper or posterior lip (labium posterius) and a lower or anterior lip (labium anterius). On each side of the cervix and upper portion of the vagina there is a space containing bloodvessels and filled with loose cellular tissue. This loose tissue passes upward between the layers of the broad ligament and is called parametrium. On each side of the cervix and three-quarters of an inch away is the terminal portion of the corresponding ureter.

**Folds and Ligaments.**—The ligaments of the uterus are eight in number. Some are simple folds of peritoneum; others contain connective tissue and muscle. The ligaments are as follows: one anterior, one posterior, two lateral or broad, two sacro-uterine—all these being formed of peritoneum—and, lastly, two round ligaments.
The **Anterior Ligament** or the **Utero-vesical Fold** or **Vesico-uterine Ligament** is reflected on to the bladder from the front of the uterus, at the junction of the cervix and body. It forms the **uterine pouch** *(excavatio vesicouterina)* (Figs. 1112 and 1113).

The **Posterior Ligament** or the **Recto-vaginal Fold** passes from the posterior wall of the uterus over the upper fourth of the vagina, and thence on to the rectum and sacrum. It thus forms a pouch, called the **recto-vaginal pouch** or **Douglas' pouch** (Figs. 866, 1112, and 1113), the boundaries of which are, in front, the posterior wall of the uterus, the supravaginal portion of the cervix, and the upper fourth of the vagina; behind, the rectum and sacrum; above, the small intestine; and, laterally, the folds of Douglas or recto-uterine folds, which contain the sacro-uterine ligaments.

The **Lateral or Broad Ligament** *(ligamentum latum uteri)* (Figs. 1104, 1114, and 1121) is a peritoneal fold which passes from each side of the uterus to the lateral wall of the pelvis as high as the external iliac vein. From this region comes the peritoneal fold called the **suspensory ligament of the ovary** (Fig. 1114). The two broad ligaments form a septum across the pelvis, which divides that cavity into two portions. In the anterior part are contained the bladder, urethra, and vagina; in the posterior part, the rectum. In the uterus normally placed the anterior surface of the broad ligament faces forward and downward, and the posterior surface faces upward and backward. The ligament is more nearly vertical at its pelvic insertion. The two layers of the broad ligament are mostly near to each other, to the side and below they separate and pass into the peritoneum of the lateral pelvic wall, the bladder and the rectum. Between the two layers of each broad ligament are contained—(1) the Fallopian tube superiorly; (2) the round ligament; (3) the ovary and its ligament; (4) the parovarium or organ of Rosenmüller, and the paro-ophoron; (5) loose connective tissue, which is called **parametrium**; (6) unstriped muscular fibre; and (7) blood-vessels and nerves. The Fallopian tube is in the free edge of the broad ligament, and is contained in a special fold, which is attached to the part of the ligament near the ovary, and is known by the name of the **mesosalpinx** (Figs. 1110, 1114, and 1121). If the mesosalpinx is spread out, it is seen to be roughly triangular; the base of the triangle is outward, the apex at the upper and outer angle of the uterus; the upper boundary is the Fallopian tube, and the lower boundary is the ovary and its ligament. Between the two layers of the mesosalpinx are the parovarium and the paro-ophoron. Between the fimbriated extremity of the tube and the lower attachment of the broad ligament is a concave rounded margin, called the **infundibulo-pelvic ligament** (Fig. 1120).
The ovary lies in a depression of the broad ligament called the ovarian bursa (bursa ovarii) (Figs. 1114 and 1121), and is joined to the ligament by a short fold, the mesovarium (Fig. 1121).

The mesovarium passes upward from the posterior surface of the broad ligament (Fig. 1114). Beneath the mesovarium is a larger and thicker portion of the broad ligament, called the mesometrium (Fig. 1114).

The Sacro-uterine or Utero-sacral Ligaments (plicae rectouterinae) are contained in the peritoneal folds of Douglas. They pass from the second and third bones of the sacrum, downward and forward on the lateral aspects of the rectum to be attached one on each side of the uterus at the junction of the supravaginal cervix and the body, this point corresponding internally to the position of the os internum. They contain fibrous tissue and unstriated muscle-fibre. Muscular fibres from the uterine wall to the rectal wall constitute the Recto-uterinus muscle (musculus rectouterinus). This muscle is part of the sacro-uterine ligaments.

A Round Ligament (ligamentum teres uteri) (Figs. 1104, 1113, 1116, and 1121) is attached on each side of the uterus. The two ligaments are rounded cords between four and five inches in length, each situated between the layers of the broad ligament in front of and below the Fallopian tube. Commencing at the superior angle of the uterus, this ligament passes forward, upward, and outward through the internal abdominal ring, along the inguinal canal, to the labium majus, in which it becomes lost. The round ligament consists principally of muscular tissue prolonged from the uterus; also of some fibrous and areolar tissue, besides blood-vessels and nerves, enclosed in a duplication of peritoneum, which in the foetus is prolonged in the form of a tubular process for a short distance into the inguinal canal. This process is called the canal of Nuck. It is generally obliterated in the adult, but sometimes remains pervious even in advanced life. It is analogous to the peritoneal pouch which precedes the descent of the testis.

The Cavity of the Uterus (cavum uteri) (Fig. 1111).—The cavity of the uterus is small in comparison with the size of the organ, because of the great thickness of the wall. That portion of the cavity which corresponds to the body is triangular, flattened from before backward, so that its anterior and posterior walls are closely approximated, and having its base directed upward toward the fundus. At each superior angle is a funnel-shaped cavity, which constitutes the remains of one division of the body of the uterus into two cornua, and at the bottom of each cavity is the minute orifice of the Fallopian tube. At the inferior angle of the uterine cavity is a small constricted opening, smaller and more nearly circular than the external os uteri, the internal orifice of the uterus or internal os uteri (orificium internum uteri) (Fig. 1111), which leads into the cavity of the cervix.

The Cavity of the Cervix or Cervical Canal (canalis cervicis uteri) (Fig. 1111).
—The cavity of the cervix or cervical canal extends from the internal os uteri to the external os uteri. It is somewhat fusiform, flattened from before backward, broader at the middle than at either extremity, and communicates below with the vagina. The wall of the canal presents, anteriorly and posteriorly, a longitudinal column, from which proceed a number of small oblique columns, giving the appearance of branches from the stem of a tree; and hence the name uterine arbor vitae (plicae palmatae) applied to it. These folds usually become very indistinct after the first labor.

Structure.—The uterus is composed of three coats: an external or serous coat, a middle or muscular coat, and an internal or mucous coat.

The Serous Coat or Perimetrium (tunica serosa) (Figs. 1103, 1108, 1112, and 1113).—The serous coat is derived from the peritoneum; it invests the fundus and the whole of the posterior surface of the uterus; but covers the anterior surface only as far as the junction of the body and cervix. In the lower fourth of the posterior surface the peritoneum, though covering the uterus, is not closely connected with
it, being separated from it by a layer of loose cellular tissue and some large veins. At the lateral margins of the uterus the serous coat passes on to the broad ligaments. The serous coat adheres closely to the uterus, and it is very difficult to separate it from the muscle.

The Muscular Coat (tunica muscularis) (Fig. 1111).—The muscular coat forms the chief bulk of the substance of the uterus. In the unimpregnated state it is dense, firm, of a grayish color, and cuts almost like cartilage. It is thick opposite the middle of the body and fundus, and thin at the orifices of the Fallopian tubes. It consists of bundles of unstripped muscular fibres, disposed in layers, intermixed with areolar tissue, blood-vessels, lymphatic vessels, and nerves. The muscular tissue is disposed in three layers—external, middle, and internal.

The external layer is placed beneath the peritoneum, disposed as a thin plane on the anterior and posterior surfaces. It consists of fibres which pass transversely across the fundus, and, converging at each superior angle of the uterus, are continued on the Fallopian tube, the round ligament, the ligament of the ovary; some passing at each side into the broad ligament, and others running backward from the cervix into the sacro-uterine ligaments. The fibres of the external portion of the outer layer (stratum subserosum) are longitudinal. The fibres of the inner portion of the outer layer (stratum supravascularare) are partly circular and partly longitudinal.

The middle layer of fibres (stratum vascularare), which is thickest, presents bundles of circular fibres closely connected with blood-vessels. In this layer are most of the blood-vessels. The circular fibres about the internal os form a distinct sphincter. Those which surround the orifices of the Fallopian tubes are arranged in the form of two hollow cones, the apices of which surround the orifices of the Fallopian tubes, their bases intermingling with one another on the middle of the body of the uterus.

The internal or deep layer (stratum mucosum) consists of longitudinal fibres. Some consider the deeper portion of the muscular tissue of the uterus to be the muscularis mucosas. But the deep portion of the muscular substance is continuous with the more superficial portion, and there is no submucous coat between the muscle and the mucous membrane. The deeper layer of muscular fibres of the uterus contains connective tissue and elastic fibres. The muscular tissue of the cervix contains more connective and elastic tissue than does the body of the uterus; hence, the cervix is harder and stiffer than the body.

The Mucous Membrane (tunica mucosa) (Fig. 1111).—The mucous membrane is thin, smooth, and closely adherent to the subjacent muscular tissue. It is continuous, through the fimbriated extremity of the Fallopian tubes, with the peritoneum, and through the os uteri with the lining of the vagina.

In the body of the uterus it is smooth, soft, of a pale-red color lined with columnar ciliated epithelium, and presents, when viewed with a lens, the orifices of numerous tubular follicles arranged perpendicularly to the surface. It is unprovided with any submucosa, but is intimately connected with the innermost layer of the muscular coat. In structure its corium differs from ordinary mucous membrane, consisting of an embryonic nucleated and highly cellular form of connective tissue, in which run numerous large lymphatics. In it are the tube-like uterine glands (glandulæ uterinae), which are of small size in the unimpregnated uterus, but shortly after impregnation become enlarged and elongated, presenting a contorted or waved appearance toward their closed extremities, which reach into the muscularis, and may be single or bifid. The uterine glands consist of a delicate membrane, lined with epithelium, which becomes ciliated toward the orifices.

In the cervix the mucous membrane is sharply differentiated from that of the uterine cavity. It is thrown into numerous oblique ridges, which diverge from an anterior and posterior longitudinal raphé, presenting an appearance which has
received the name of arbor vitae. In the upper two-thirds of the canal the mucous membrane is provided with numerous deep glandular follicles (glandulae cervicales uteri), which secrete a clear viscid alkaline mucus; and in addition, extending through the whole length of the canal, are a variable number of little cysts, presumably follicles, which have become occluded and distended with retained secretion. They are called the ovules of Naboth. The mucous membrane covering the lower half of the cervical canal presents numerous papillae. The epithelium of the upper two-thirds is cylindrical and ciliated, but below this it loses its cilia, and gradually changes to squamous epithelium close to the external os.

The Uterus at Different Ages.—The uterus of the foetus is in the abdominal cavity projecting above the brim of the pelvis. The cervix is considerably larger than the body. At birth the cervix is larger relatively than in the adult; there is no distinct internal os distinguishing the cavity of the body of the uterus from the cavity of the cervix, and “the arbor vitae extends throughout the whole length of the uterus.”

The growth of the uterus is slow until puberty is almost reached, when for a time the growth is rapid. The growth of the uterine body causes the mucous membrane of this part to lose its folds, hence the arbor vitae disappears from the body. In a woman who has had children the uterine cavity is larger than in a woman who has never borne a child. In advanced years the uterine wall becomes paler and hard and rigid from atrophic fibrous changes. A more distinct constriction separates the body and cervix. The internal os frequently and the external os occasionally are obliterated in old age.

Abnormalities.—Very rarely the uterine cavity is divided into two by a septum. Occasionally the condition known as bicornate uterus exists. In this condition each lateral angle is prolonged into a horn or cornu. The uterus is formed by the union of the two ducts of Müller, and failure of fusion of these ducts makes a double uterus or a bicornate uterus.

Changes at a Menstrual Period.—For several days before the menstrual flow begins the mucous membrane increases in thickness and vascularity and its surface is cast into folds. After these preparatory changes the superficial portions of the mucous membrane break down and are cast off, and bleeding begins. At the termination of menstruation the mucous membrane rapidly regenerates. At each menstrual period from 100 to 200 grammes of blood are discharged. The meaning of menstruation is uncertain. Pflüger believes the wall of the uterus is made raw, so that if an impregnated ovum arrives it will adhere. Reichert believes that menstruation means that no impregnated ovum has arrived in the womb, and hence no bed is needed for one.

Changes Induced by Pregnancy.—The muscular fibres hypertrophy enormously and become vastly longer and broader. There is a great increase in connective tissue, and new connective-tissue fibres pass between bundles of muscle. The peritoneal coat undergoes hyperplasia. It remains closely adherent to the uterus, except over the lower segment, from which region it can be easily stripped. The blood-vessels become large and tortuous. The nerves are increased in length and new filaments form. The lymphatics undergo hypertrophy and hyperplasia (Prof. Barton Cooke Hirst). The uterus becomes spherical, and after the fourth month ovoidal. Early in pregnancy the increase in weight causes the uterus to descend in the pelvis. After the third month it rises progressively, and during the ninth month the fundus reaches the epigastrium. “Before term (four weeks in primiparae, ten days or one week in multiparae) the fundus sinks again, as the presenting part and lower uterine segment become engaged in the pelvic cavity. This phenomenon is explained by contraction of the overstretched abdominal walls.”

The womb is acutely anteflexed during the first three months.
of pregnancy. After this period, as the womb rises, the anteflexion is diminished, but some degree remains, because the abdominal walls are too lax to hold the organ straight. The uterus passes somewhat to the right side and undergoes a rotation on its longitudinal axis, so that the anterior surface looks front and to the right. These changes in position are caused by fecal distention of the sigmoid. The intestines are above and back of the uterus. During the first four months the cervix softens and enlarges somewhat. The length of the cervical canal is not altered during pregnancy, and the canal does not dilate until labor begins. During pregnancy the cervical glands secrete thick mucus, which coagulates and occludes the cervical canal; the round ligaments become stronger, and the layers of the broad ligament are separated toward their inner portions by the enlarging womb.
After parturition the uterus nearly regains its former size, usually weighing something over one and a half ounces; but its cavity is larger than in the virgin state, the external orifice is more marked, its edges present a fissured surface, its vessels are very tortuous, and its muscular layers are more defined.

Vessels and Nerves (Fig. 1116).—The arteries of the uterus are the uterine, from the internal iliac, and the ovarian, from the aorta. They are remarkable for their tortuous course in the substance of the organ and for their frequent anastomoses. The uterine artery reaches the lower part of the uterus at the side and is, pro-

![Diagram of the uterus and its vessels](image)

Fig. 1118.—The lymphatics of the internal organs of generation in the female. (Poirier and Charpy.)

longed as a large artery to the body and fundus, which ascends between the layers of the broad ligament. The uterine artery gives off a smaller branch, the cervical, which descends to supply the cervix and sends cervico-vaginal branches to the vagina. The azygos arteries of the vagina come from the cervico-vaginal reinforced by branches of the vaginal arteries (Fig. 1121). A median longitudinal vessel is formed in front and behind, which descends in the vaginal wall. The termination of the ovarian artery meets the termination of the uterine artery, and forms an anastomotic trunk from which branches are given off to supply the uterus. Dr. Robinson, instead of describing the uterine and ovarian
arteries as two vessels, describes them as parts of one vessel, the *arteria uterina ovarica* (p. 689). The *veins* are of large size, and correspond with the arteries. In the impregnated uterus these vessels form the *uterine sinuses*, consisting of the lining membrane of the veins adhering to the walls of the canals channelled through the substance of the uterus. They terminate in the *uterine plexuses*, which empty into the *internal iliac veins*. The *lymphatics* (Figs. 1117 and 1118) originate from three networks, a muscular network, a peritoneal network, and a network in the stroma. The trunks from these networks Anastomose, and thus form another network beneath the peritoneum, and from the fourth network the collectors arise. The network of the cervix is continuous with that of the body. The collecting trunks from the cervical region number from five to eight. Some terminate in the *external iliac glands*, some in the *internal iliac glands*, some in the *lateral sacral glands*, or the glands of the promontory. The collecting trunks from the body terminate chiefly in the *juxta-aortic* or *pre-aortic glands*, but some terminate in the *external iliac glands*, and some in the *inguinal glands*. The *nerves* come chiefly from the *utero-vaginal plexus*, which continues into the *hypogastric plexus* and receives filaments from the *third* and *fourth sacral nerves*. The uterus also receives direct fibres from the *hypogastric plexus* and from the *vesical plexus*.

![Fig. 1119.—Relations between uterus, ureter, and uterine artery. (Schematic.)](image)

**Surgical Anatomy.** *Pelvic cellulitis* (*parametritis*) is inflammation of the pelvic cellular tissue. It is due to sepsis, and its usual antecedent is uterine sepsis. A laceration of the cervix may admit bacteria. An abscess may form. If it points in the vagina it should be incised through the vaginal wall. The uterus may require removal (*hysterectomy*) in cases of *malignant disease* or for *fibroid tumors*. *Carcinoma* is the most common form of malignant disease of the uterus, though *cases of sarcoma* do occur. Carcinoma may show itself either as a columnar carcinoma or as a squamous carcinoma; the former commencing either in the cervix or body of the uterus, the latter always commencing in the epithelial cells of the mucous membrane covering of the vaginal surface of the cervix. The columnar form may be treated in the early stage, before fixation has taken place, by removal of the uterus, either through the vagina or by means of abdominal section. The former operation is attended by the smaller death-rate. Vaginal hysterectomy may be performed in any case in which the uterus or the uterus and tumor are not too large to be withdrawn through the vagina. It is difficult in this operation to deal with adhesions and other complications in the upper part of the pelvis, and for this reason many surgeons prefer the abdominal operation. *Vaginal hysterectomy* is performed by placing the patient in the lithotomy position and introducing a large duckbill speculum into the vagina. The cervix is then seized with a vulsellum and pulled down as far as possible and the mucous membrane of the vagina incised around the cervix as near to it as the disease will allow, especially in front, where the ureters are in danger of being wounded. A pair of dressing forceps are then pushed through into Douglas's

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1 The Lymphatics. By Poirier, Cunéo, and Delamare. Translated and edited by Cecil H. Leaf.
pouch and opened sufficiently to allow of the introduction of the two forefingers, by means of which the opening is dilated laterally as far as the sacro-uterine ligaments. A somewhat similar proceeding is adopted in front, but here the bladder has to be separated from the anterior wall of the uterus for about an inch before the vesico-uterine fold of peritoneum can be reached. This is done by carefully burrowing upward with a director and stripping the tissues off the anterior uterine wall. When the vesico-uterine pouch has been opened and the opening dilated laterally, the uterus remains attached only by the broad ligaments, in which are contained the vessels that supply the uterus. Before division of the ligaments, these vessels have to be dealt with. The forefinger of the left hand is introduced into Douglas's pouch and an aneurism needle, armed with a long silk ligature, is inserted into the vesico-uterine pouch, and is pushed through the broad ligament of one side about an inch above its lower level and at some distance from the uterus. One end of the ligature is now pulled through the anterior opening, and in this way we have the lowest inch of the broad ligament, in which is contained the uterine artery, enclosed in a ligature. This is tied tightly, and the operation is repeated on the other side. The broad ligament is then divided on either side, between the ligature and the uterus, to the extent to which it has been constricted. By traction on the volsellum which grasps the cervix, the uterus can be pulled considerably farther down in the vagina, and a second inch of the broad ligament is treated in a similar way. This second ligature will embrace the pampiniform plexus of veins and, when the broad ligament has been divided on either side, it will be found that a third ligature can be made to pass over the Fallopian tube and top of the broad ligament, after the uterus has been dragged down as far as possible. After the third ligature has been tied and the structures between it and the uterus divided, this organ will be freed from all its connections and can be removed from the vagina. This canal is then sponged out and lightly dressed with gauze, no sutures being used. The gauze may be removed at the end of the second day. In squamous epitheliam, amputation of the cervix is done by some in those cases where the disease is recognized before it has invaded the walls of the vagina or the neighboring broad ligaments. The operation consists in removing a wedge-shaped piece of the uterus, including the cervix, through the vagina and attaching the cut surfaces of the stump to the anterior and posterior vaginal walls, so as to prevent retraction. In view, however, of the continuity of the lymphatic network of the cervix with the lymphatics of the body, the operation is insufficient and should be condemned. Complete abdominal hysterectomy is rarely necessary, except for malignant disease. In this operation the entire uterus is removed. The preliminary introduction of bougies into the ureters as practised by Kelly and Clark enables the surgeon to readily recognize the situations of these tubes. After the abdomen has been opened the uterine vessels are secured and the broad ligaments divided in a similar manner to that employed in vaginal hysterectomy, except that the proceeding is commenced from above. When the first two ligatures have been tied and the broad ligament divided, it will be found that the uterus can be raised out of the pelvis. A transverse incision is now made through the peritoneum, where it is reflected from the anterior surface of the uterus on to the back of the bladder and the serous membrane peeled from the surface of the uterus until the vagina is reached. The anterior wall of this canal is cut across. The uterus is now turned forward and the peritoneum at the bottom of Douglas's pouch incised transversely, and the posterior wall of the vagina cut across until it meets the incision on the anterior wall. The uterus is now almost free, and is held only by the lower part of the broad ligament on either side, containing the uterine artery. A third ligature is made to encircle this, and, after having been tied, the structures are divided between the ligature and the uterus. The organ can now be removed. The vagina is plugged with gauze, and the external wound closed in the usual way. The vagina acts as a drain, and therefore the opening into it is usually left unsutured. In some cases of uterine fibroid the abdomen is opened and the tumor is removed, but the uterus is not taken away. This operation is called myomectomy. This operation is suited only to solitary subperitoneal or interstitial tumors (Penrose).

The common operation for uterine fibroids is supravaginal amputation. The uterus is cut away and the cervical flaps are sutured. Before the technique of hysterectomy was perfected and before myomectomy was devised the favorite operation for uterine fibroids was salpingo-oophorectomy, and by it a large majority of cases operated upon were cured. When it succeeds a premature menopause is induced and the tumor shrinks. The operation is useless if a woman is past the menopause, and is apt to fail if the tumor is very soft or very large.

THE ADNEXA OR APPENDAGES OF THE UTERUS.

The appendages of the uterus are the Fallopian tubes, the ovaries and ovarian ligaments, and the round ligaments. They are placed in the following order: in front is the round ligament; the Fallopian tube occupies the upper margin of the broad ligament; the ovary and its ligament are behind and below both.
THE FALLOPIAN TUBE (TUBA UTERINA [FALLOPII])
(Figs. 1108, 1113, 1114, 1120, 1121).

The Fallopian tubes or oviducts convey the ova from the ovaries to the cavity of the uterus. They are two in number, one on each side, situated in the upper margin of the broad ligament, extending from each superior angle of the uterus to the sides of the pelvis. Each tube is about four inches and a quarter in length, and is placed in a fold of peritoneum, which is part of the broad ligament and is called the mesosalpinx (Fig. 1114). Each tube is described as consisting of four portions: (1) the isthmus (isthmus tubae uterinae) (Fig. 1120), or inner constricted third; (2) the ampulla (ampulla tubae uterinae) (Fig. 1120), or outer dilated portion, which curves over the ovary; and (3) the infundibulum (infundibulum tubae uterinae), the funnel-like expansion of the tube, at the bottom of which is the abdominal orifice or pavilion (ostium abdominale tubae uterinae) (Fig. 1120). The abdominal orifice has a small diameter (2 mm. when relaxed to its full extent). The margin of the infundibulum is rendered irregular by the presence of numerous small processes, the fimbriae (fimbriae tubae). This end of the tube is called the fimbriated extremity (Fig. 1120), because of these processes. The surfaces of the fimbriae looking into the cavity of the infundibulum are covered with mucous membrane continuous with the tubal mucous membrane. The outer surfaces are covered with peritoneum. One of the fimbriae is attached to the ovary and is called the ovarian fimbria (fimbria ovarica) (Fig. 1120). (4) The uterine portion of the tube (pars uterina) (Fig. 1111) is in the uterine wall. The opening into the uterus (ostium uterinum tubae) is even smaller than the abdominal opening, and will admit only a small bristle. The general direction of the Fallopian tube is outward, backward, and downward. In connection with the fimbriae of the Fallopian tube or with the broad ligament close to them there is frequently one or more small vesicles floating on a long stalk of peritoneum. These are termed the hydatids of Morgagni (appendices vesiculosi). They are representative of small portions of the upper extremity of the Wolffian duct.

Course Pursued by the Fallopian Tube (Figs. 1104 and 1120).—The tube on each side begins at the upper and outer angle of the uterus and passes outward in a horizontal direction toward the uterine extremity of the ovary. It then bends almost to a right angle and ascends close to the pelvic wall and in front of the anterior margin to the tubal extremity of the ovary. At this point it turns sharply downward and a little backward, and the inner surface of the infundibulum comes to lie upon the free margin and the posterior portion of the inner surface of the ovary. “The fimbria ovarica thus ascends in a recurrent direction to the extrem- itas tubaria.”

Structure.—The Fallopian tube consists of three coats—serous, muscular, and mucous.

The external or serous coat (tunica serosa) (Fig. 1115) is peritoneal. Beneath this lies the tunica adventitia, composed of lax connective tissue.

The middle or muscular coat (tunica muscularis) consists of an external longitudinal layer (stratum longitudinal), and an internal circular layer (stratum circulare) of muscular fibres continuous with those of the uterus.

The internal or mucous coat (tunica mucosa) is continuous with the mucous lining of the uterus and, at the free extremity of the tube, with the peritoneum. It is thrown into longitudinal folds (plicae tubariae), which in the outer, larger part of the tube or ampulla (plicae ampullares) are much more extensive than in the narrow canal of the isthmus (plicae isthmicae). The lining epithelium is columnar and ciliated. This form of epithelium is also found on the inner surface of the tube.

fimbriae, while on the outer or serous surfaces, of these processes the epithelium gradually merges into the endothelium of the peritoneum.

**Vessels and Nerves.**—The chief artery of the tube is the tubal branch of the uterine artery (ramus tubarius) (Fig. 1116). It also receives branches from the ovarian (Fig. 1116). Some of the tubal veins empty into the uterine veins, some into the ovarian veins. The lymphatics (Figs. 1117 and 1118) coming from the tube unite with the trunks coming from the uterus and ovary and terminate in the juxta-aortic glands. The nerves come from the same plexuses that send branches to the uterus and ovary.

**The Epo-ophoron, Parovarium or Organ of Rosenmüller** (Figs. 1110, 1111, and 1120) is placed in the mesosalpinx, between the ovary and tube. It consists of a number of epithelial-lined closed tubes. This structure can be readily seen if the mesosalpinx is stretched and held in front of the light. One of these tubes runs parallel to the Fallopian tube and is called Gärtners duct (ductus epoophori longitudinalis). A number of tubes (ductuli transversi) ascend from near the ovary and
each empties into Gärtners's duct at a right angle. Gärtners's duct is a portion of the Wolffian duct, which has persisted and is represented in the male by the canal of the epididymis. The tubules which join the duct "are derived from the mesonephros and represent the vasa efferentia and coni vasculosi of the testis, and probably also the ductuli aberrantes of the canal of the epididymis." (Cunningham.)

The Paro-ophoron is within the mesosalpinx, but is nearer to the uterus than is the epo-ophoron. It consists of several small tubules, which can be seen in an adult only by the aid of a pocket lens. They are visible to the naked eye in a child at birth. It represents the organ of Giraldes in the male and is derived from the mesonephros.

THE OVARY (OVARIA) (Figs. 1104, 1108, 1110, 1111, 1113, 1114, 1115, 1120, 1121).

The ovaries, the testes muliebres of Galen, are two in number and are analogous to the testes in the male. They are oval-shaped bodies of an elongated form, flattened from above downward, situated one on each side of the uterus, in the posterior layer of the broad ligament behind and below the Fallopian tube. Each ovary is connected by its anterior straight margin to the broad ligament; by its lower extremity to the uterus by a proper ligament, the ligament of the ovary (ligamentum ovarii proprium) (Fig. 1120); and by its upper end to the fimbriated extremity of the Fallopian tube by the ovarian fimbria (fimbria ovarica) (Fig. 1120), its mesal and lateral surfaces and posterior convex border are free (Fig. 1121). The ovaries are of a grayish-pink color, and present either a smooth or a puckered, uneven surface. They are each about an inch and a half in length, three-quarters of an inch in width, and about a third of an inch thick, and weigh from one to two drachms.

The exact position of the ovary has been the subject of considerable difference of opinion, and writers are in conflict as to what is to be regarded as the normal position. The fact appears to be that the ovary is differently placed in different individuals. The two ovaries are seldom placed in absolutely identical positions. Hasse has described the ovary as being situated with its long axis transverse, or almost transverse, to the pelvic cavity. Schultze, on the other hand, believes that its long axis is antero-posterior. Kölliker asserts that the truth lies between these views, and that the ovary is placed obliquely in the pelvis, its long axis lying parallel to the external iliac vessels, with its surface directed inward and outward, and its convex free border upward. His has made some important observations on this subject, and his views are largely accepted. He teaches that the uterus rarely lies symmetrically in the middle of the pelvic cavity, but is generally inclined to one or other side, most frequently to the left, in the proportion of three to two. The position of the two ovaries varies according to the inclination of the uterus. When the uterus is inclined to the left, the ovary of this side lies with its long axis vertical and with one side closely applied to the outer wall of the pelvis, while the ovary of the opposite side, being dragged upon by the inclination of the uterus, lies obliquely, its outer extremity being retained in close apposition to the side of the pelvis by the infundibulo-pelvic ligament. When, on the other hand, the uterus is inclined to the right, the position of the two ovaries is exactly reversed, the right being vertical and the left oblique. In whichever position the ovary is placed, the Fallopian tube forms a loop around it, the uterine half ascending obliquely over it, and the outer half, including the dilated extremity, descending and bulging freely behind it. From this extremity the fimbriae pass upward on to the ovary and closely embrace it.

Waldeyer1 states, as the result of the examination of fifty female subjects,

ranging from early childhood to advanced age, that the ovary "lies on the lateral pelvic wall and vertically when the woman takes the erect posture." Its tubal extremity is near the external iliac vein; its uterine end is directed downward, while the Fallopian tube overlies it so as to cover it on its medial face entirely or nearly so. Its convex margin looks downward and backward toward the pelvic cavity and rectum, while its straight margin or hilum lies laterally on the pelvic wall attached to the mesosalpinx. He also finds that it lies in a distinct but shallow groove (fossa ovarii) limited above by the hypogastric artery and below by the ureter, in such a manner that the ureter lies along the convex margin of the ovary, and the hypogastric artery passes near the hilum or straight margin.

The ovary possesses two poles or extremities: (1) An outer, superior or tubal extremity (extremitas tubaria ovarii). (2) An inner, inferior or uterine extremity (extremitas uterina ovarii). The ovary has two surfaces, an inner surface (facies medialis), which is also upper; an outer surface (facies lateralis), which is also lower. The posterior or free border (margo liber) is markedly convex. The anterior border (margo mesovaricus) is almost straight and is narrow. The anterior border is not free, but is joined to the posterior layer of the broad ligament by a peritoneal fold known as the mesovarium. There is a groove in the anterior border called the hilum (hilus ovarii), through which vessels and nerves to pass, and emerge from the ovary.

Supports and Connections of the Ovary.

From its upper extremity a peritoneal fold is continuous with the peritoneum over the iliac vessels and Psoas muscle. It is called the ovario-pelvic fold or the suspensory ligament (ligamentum suspensorium ovarii) (Fig. 1104). It is in reality a portion of the broad ligament, and within it are the ovarian vessels and nerves. The vessels (Fig. 1121) and nerves go to the anterior border of the ovary and are surrounded by a peritoneal sheath derived from the posterior layer of the broad ligament; it is thus evident that the anterior border of the ovary is connected to the posterior portion of the broad ligament by a very short mesentery, the mesovarium1 (Fig. 1114). The ligament of the ovary or ovarian ligament (Figs. 1104 and 1120) is a round, cord-like structure, composed chiefly of non-striated muscle-fibres, which passes between the two folds of the broad ligament from the lower extremity of the ovary to the lateral angle of the uterus. The ovarian fimbria (Fig. 1120), as previously stated, passes to the upper extremity of the ovary from the extremity of the Fallopian tube.

The Descent of the Ovary.

In the female there is a gubernaculum which affects a considerable change in the position of the ovary, though not so extensive a change as is effected upon the male testicle. The gubernaculum in the female, as it lies on either side in contact with the fundus of the uterus formed by the union of the Müllerian ducts, contracts adhesions to this organ and thus the ovary is prevented from descending below this level. The remains of the gubernaculum—that is to say, the part between the attachment of the cord to the uterus to its termination in the labium majus—ultimately forms the round ligament of the uterus. A pouch of peritoneum accompanies it along the inguinal canal, analogous to the funicular process in the male; it is called the canal of Nuck. In rare cases the gubernaculum fails to contract adhesions to the uterus, and then the ovary descends through the inguinal canal into the labium majus, extending down the canal of Nuck. Under these conditions, the position of the ovary resembles the position of the testicle in the male.

The Ovary at Different Ages.—The ovary of childhood is smooth and even. The rupture of Graafian follicles, repeated many times, causes the surface

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1 Prof. Cunningham's Text-book of Anatomy.
THE FEMALE ORGANS OF GENERATION

of the ovary to become pitted, puckered, fibrous, and uneven in old age. The surface of the ovary is grayish-red in color. The corpus luteum of a non-pregnant woman slowly degenerates and disappears. The corpus luteum of an impregnated woman enlarges during pregnancy.

**Structure** (Figs. 1114, 1115, 1122, and 1123).—The ovary consists of a number of Graafian follicles or vesicles embedded in the meshes of a stroma or framework, and invested by a serous covering derived from the peritoneum.

**Serous Covering.**—Though the investing membrane of the ovary is continuous with the peritoneum near the hilum of the ovary (the point of junction being indicated by a narrow white line), it differs essentially from the peritoneum, inasmuch as it is an epithelial structure and consists of a single layer of columnar epithelial cells, instead of the flattened endothelial cells of other parts of the membrane; this has been termed the **germinal epithelium of Waldeyer**, and gives to the surface of the ovary a dull-gray aspect instead of the shining smoothness of serous membranes generally.

**Stroma.**—The stroma is a peculiar soft tissue, abundantly supplied with blood-vessels, consisting for the most part of spindle-shaped cells, with a small amount of ordinary connective tissue. These cells have been regarded by some anatomists as unstriped muscle-cells, which, indeed, they most resemble (His); by others as connective-tissue cells (Waldeyer, Henle, and Kölliker). On the surface of the organ this tissue is much condensed, and forms a layer composed of short connective-tissue fibres, with fusiform cells between them. This was formerly regarded as a distinct fibrous covering, and was termed the **tunica albuginea**, but is nothing more than a condensed layer of the stroma of the ovary.

**Graafian Follicles or Vesicles** (folliculi oophori vesiculor [Graafi]) (Figs. 1122 and 1123).—Upon making a section of an ovary numerous round transparent vesicles of various sizes are to be seen; they are the **Graafian vesicles or ovisacs** containing the ova. Immediately beneath the superficial covering is a layer of stroma, in which are a large number of minute vesicles of uniform size, about \( \frac{1}{16} \) of an inch in diameter. These are the Graafian vesicles in their earliest condition, and the layer where they are found has been termed the **cortical layer**. They are especially numerous in the ovary of the young child. After puberty and during the whole of the child-bearing period large and mature, or almost mature, Graafian vesicles are also found in the cortical layer in small numbers, and also **corpora lutea**, the remains of vesicles which have burst and are undergoing atrophy and absorption. Beneath this superficial stratum other large and mature Graafian vesicles are found embedded in the ovarian stroma. These increase in size as they recede from the surface toward a highly vascular stroma in the centre of the organ, termed the **medullary substance** (zona vasculosa [Waldeyeri]). This stroma forms

![Diagram](image-url)
the tissue of the hilum by which the ovary is attached, and through which the blood-vessels enter; it does not contain any Graafian vesicles.

The larger Graafian follicles consist of an external fibro-vascular coat connected with the surrounding stroma of the ovary by a network of blood-vessels; and an internal coat, named the ovicapsule, which is lined by a layer of nucleated cells, called the membrana granulosa. The fluid contained in the interior of the vesicles is transparent and albuminous, and in it is suspended the ovum. In that part of the mature Graafian vesicle which is nearest the surface of the ovary the cells of the membrana granulosa are collected into a mass which projects into the cavity of the vesicle. This is termed the discus proligerus, and in this the ovum is embedded.

The ova are formed from the germinal epithelium on the surface of the ovary. This becomes thickened, and in it are seen some cells which are larger and more rounded than the rest; these are termed the primordial ova. The germinal epithelium grows downward in the form of tubes or columns, termed the egg tubes of Pflüger, into the ovarian stroma, which grows outward between the tubes, and ultimately cuts them off from the germinal epithelium. These tubes are further subdivided into rounded nests or groups, each containing a primordial ovum which undergoes further development and growth, while the surrounding cells of the nest form the epithelium of the Graafian follicle.

The development and maturation of the Graafian vesicles and ova continue uninterruptedly from puberty to the end of the fruitful period of woman’s life, while their formation commences before birth. Before puberty the ovaries are small, the Graafian vesicles contained in them are disposed in a comparatively thick layer in the cortical substance; here they present the appearance of a large number of minute closed vesicles, constituting the early condition of the Graafian vesicle; many, however, never attain full development, but shrink and disappear. At puberty the ovaries enlarge and become more vascular, the Graafian vesicles are developed in greater abundance, and their ova are capable of fecundation.

Discharge of the Ovum.—The Graafian vesicles, after gradually approaching the surface of the ovary, burst; the ovum and fluid contents of the vesicles are liberated, and escape on the exterior of the ovary, passing thence into the Fallopian tube. This is effected either by application of the tube to the ovary, or by a curling upward of the fimbriated extremity, so that the ovum is caught as it falls.

In the foetus the ovaries are situated, like the testes, in the lumbar region, near the kidneys. They may be distinguished from those bodies at an early period by their elongated and flattened form, and by their position, which is at first oblique and then nearly transverse. They gradually descend into the pelvis.

The Round Ligament (p. 1503).

Vessels and Nerves.—The arteries of the ovaries (Figs. 1116 and 1121) are the ovarian from the aorta, corresponding to the spermatic arteries in the male. The ovarian artery on each side enters the pelvis in the fold of broad ligament known as the suspensory ligament of the ovary and enters the attached border, or hilum, of the ovary. The ovarian vessels anastomose about the hilum with branches of the uterine artery. The veins follow the course of the arteries; they form a plexus near the ovary, the pampiniform plexus, corresponding to a like structure near the male testicle. The lymphatics (Figs. 1117 and 1118) terminate in the glands to the corresponding side of the aorta, and they anastomose in their course with trunks from the uterine fundus and Fallopian tube. The nerves come from the ovarian plexus, which is a continuation of the renal plexus along the ovarian artery, and from the aortic plexus.

Surgical Anatomy of the Appendages.—Extra-uterine pregnancy most commonly occurs in the ampulla of the tube. The product of the conception may escape through the ostium abdominale or the walls of the tube may rupture, a violent hemorrhage resulting.
Pelvic peritonitis is a not uncommon sequence of tubal disease. Salpingitis is inflammation of the mucous coat of the tube—interstitial salpingitis of the middle coat, perosalpingitis of the peritoneal coat.

If inflammation closes the uterine and the abdominal ends of the tube, mucus gathers and distends the tube (hydrosalpinx). If purulent matter gathers, the condition is known as pyosalpinx.

An ovary may fail to descend and remain well above the pelvic brim; it may prolapse into Douglas's pouch; it may enter the sac of a hernia; it may inflame; a tumor or cyst may arise from it. A solid tumor of the ovary may be a fibroma, a sarcoma, or a carcinoma. "Cysts may originate in any part of the tubo-ovarian structure; as the cortical, medullary, or parenchymatous portions of the ovary; in the structure between the tube and ovary known as the Rosenmüller organ or parovarian structures; and in the hydatid of Morgagni."1 Cysts may be simple, proliferating, or dermoid; unicocular or multicocular. Glandular proliferous cysts, papillary proliferous cysts, dermoid cysts, and parovarian cysts may attain a large or even an enormous size. The operation for the removal of an ovarian cyst is one of the most successful of the major procedures of surgery.

THE MAMMARY GLAND (MAMMA) (Figs. 1124, 1125, 1126, 1127).

The breasts, mammary glands or mammae secrete the milk, and are accessory glands of the generative system. They develop fully in the female, but remain permanently rudimentary in the male. There are two of these glands, and they are situated in the superficial fascia of the anterior portion of the thorax. Between the two glands and in front of the sternum is a groove, the bosom.

Description of a Well-developed Breast.—Each gland appears as a hemispherical body projecting from the front of the thorax beneath the skin and lying over a portion of the Pectoralis major muscle and a smaller portion of the Serratus magnus muscle. The hemispherical projection extends usually from the margin of the sternum to the axilla and from the level of the second rib to the level of the sixth rib, or from the third rib to the seventh rib, but this does not represent the real size of the gland. The gland is much larger than this, being rendered so by tails or prolongations of breast tissue, which will be described later (p. 1517).

The Nipple (papilla mammae) (Figs. 1124, 1125, 1126, and 1127).—The nipple projects from a little below and to the median side of the summit of the hemisphere at or above the level of the fifth rib, and is covered with thin skin. The right nipple may not exactly correspond in situation and direction to the left nipple. The nipple varies considerably in height and shape. In the virgin it is usually cylindrical and is directed forward and slightly upward and outward. The apex of the nipple is rendered rough by fissures (Fig. 1124), it exhibits a depression in which are the openings of the milk ducts (Fig. 1126), and its circumference is thrown into concentric ridges (Fig. 1126). The nipple is surrounded by a darker circular wrinkled area, the areola (areola mammae) (Figs. 1124 and 1125), in which are sweat-glands and on which are twelve or fifteen small rounded elevations. These elevations are caused by cutaneous sebaceous glands which in structure represent a transition between sebaceous and mammary glands. They are probably rudimentary portions of the mammary gland and are known as the glands of Montgomery (glandulae areolares) (Fig. 1126). The color of the nipple and areola varies with the complexion of the individual. In brunettes it is darker than in blondes. The usual color of the nipple in a young woman is rosypink, the areola being of a darker shade. During the early months of pregnancy the nipple and areola become dark brown in color, the areola becomes larger in circumference, and the glands of Montgomery increase in size (Fig. 1127). The nipple contains non-striated muscle and mechanical irritation or sexual excitement makes it stiff and erect. The skin covering the breast is clear, soft, and delicate, and subcutaneous veins are often visible. The skin of the nipple and areola is particularly delicate.

Variations in the Mammae.—Before puberty the glands are small, of the infantile type, grow slowly, and differ but slightly from the male organs. The nipple is small and flat and pale. At puberty the increase in the size of the breast is rapid and considerable, due to growth of gland tissue and of subcutaneous fat. During pregnancy the breasts enlarge greatly and remain very large throughout lactation. This enlargement is due to new gland tissue and increased vascularity. Numerous blue veins are visible in the skin, the areola darkens, and the glands of Montgomery enlarge (Fig. 1127). During lactation the associated lymphatic glands may enlarge (A. Marmaduke Shield). After the termination of lactation the breasts diminish in size. They do not become as small as the virgin breast, are apt to lose their hemispherical outlines, and cease to be soft. They droop as flaccid pendulous masses, the subcutaneous fat is largely gone, and the outlines of the lobular breast tissue can be seen and felt. The nipple is long and hangs down like a teat. At the menopause the breast usually shrinks. In some cases, however, it actually increases in size. In such a case, although the gland atrophies, there is an extensive deposit of fat. In old age the glands undergo atrophy and largely disappear, the skin is flabby and thrown into wrinkles, and the breasts contain very little glandular structure, and are hard from the presence of fibrous tissue. The nipples become pigmented and corrugated. Women vary greatly in the development of the breasts. In some women they are large, firm, and well proportioned; in others they are small, flat, or atrophy occurs in the course of certain bodily diseases, as phthisis, and certain mental diseases, as melancholia. If the ovaries are ill-developed the breasts remain flat and small. In newly married women, even though pregnancy does not exist, the breasts often develop decidedly and rapidly. The outline and direction of the breast and also of the nipple may be altered by corsets. The left mamma is usually somewhat larger than the right.

![Dissection of the lower half of the female breast during the period of lactation. (From Luschka.)](image)

One gland or both glands may be entirely absent, the nipple being also absent. One or both glands may be absent, one or both nipples being present. When there is only one nipple, it is apt to be the left. The term polymazia (mammae accessoriae multiebris) means the presence of supernumerary breasts, with or without
nipples. Polytheilia means the presence of supernumerary nipples, the associated glandular structure being rudimentary. There may be one, two, or several supernumerary breasts, and when more than one exists, are usually asymmetrical. If one is functionally active, it enlarges during pregnancy and furnishes milk.

Supernumerary mammae may secrete milk or may be without function. The most common situation is on the part of the chest below and to the inner side of the normally placed gland. They may also exist in the axilla, the abdomen, the groin, the back, and the thigh. Many cases of supposed supernumerary glands have been really instances in which moles, warts, or sebaceous cysts have been mistaken for breast tissue, but some cases are undoubted.

Prolongations of Mammary Tissue.—As previously stated, the outlines of the breasts are not regular, but here and there tails, prolongations, or cusps come off from and are true portions of the gland. Two or even more prolongations pass to the edge of the sternum; others pass toward the axilla, the clavicle, and the origin of the external oblique muscle from the ribs. Underneath the mammary gland prolongations of mammary tissue penetrate the pectoral fascia (Heidenhain). If one of the glandular cusps is of considerable size it is called an outlying lobule.

Structure of Mammary Gland and Nipple (Figs. 1124 and 1125).—The glands of the breast (corpus mammae) rest by a smooth posterior surface upon the loose pectoral fascia, which fastens the breast to the muscle beneath, but so loosely that the breast is movable. The mamma consists of gland-tissue; of fibrous tissue, connecting its lobes, of fatty tissue in the intervals between the lobes, of retinacula, and of skin. The gland-tissue, when freed from fibrous tissue and fat, is of a pale reddish color, firm in texture, in general circular in form, with prolongations here and there, flattened from before backward, thicker in the centre than at the circumference, and presenting several inequalities on its surface, especially in front. On the anterior surface there are many irregular elevated processes with deep spaces between them. From the summits of the elevations connective-tissue strands (retinacula curts) pass to the true skin. The glandular structure consists of numerous lobes (lobi mammae), and these are composed of lobules (lobuli mammae), connected together by areolar tissue, blood-vessels, and ducts. The smallest lobules consist of a cluster of rounded alveoli (Fig. 1124), which open into the smallest branches of the excretory ducts; these ducts, uniting, form larger ducts, which terminate in single canals. Each canal is called a lactiferous, galactophorous or mammillary duct (ductus lactiferus) (Fig. 1124). Each lobe possesses one lactiferous duct. This passes to the apex of the lobe and then into the nipple. The lactiferous ducts are white and cord-like, and contrast with the yellowish-red tissue of the gland itself. The number of excretory ducts varies from fifteen to twenty. They converge toward the areola, beneath which each duct forms a spindle-shaped dilatation, the ampulla (sinus lactiferans) (Fig. 1124). The ampullae serve as reservoirs for the milk. At the base of the nipple the ducts become contracted and pursue a straight course to its summit, perforating it by separate orifices considerably narrower than the ducts themselves. Each orifice (porus lactiferus) is the orifice of a tube which drains an individual lobe. The ducts are composed of areolar tissue, with longitudinal and transverse elastic fibres; muscular fibres are entirely absent; their mucous lining is continuous, at the point of the nipple, with the integument. The epithelium of the mammary gland differs according to the state of activity of the organ. In the gland of a woman who is not pregnant or nursing the alveoli are very small and solid, being filled with a mass of granular polyhedral cells. During pregnancy the alveoli enlarge and the cells undergo rapid multiplication. At the commencement of lactation the cells in the centre of an alveolus undergo fatty degeneration, and are eliminated in the first milk as colostrum-corpuscles. The peripheral cells of the alveolus remain, and form a single layer of granular, short columnar cells lining the limit-
ing membrana propria. The single nucleus of each cell divides and forms two. In the protoplasm, especially, in the end of the cells toward the alveolus,

![Diagram of the mammary gland]

Fig. 1125.—Right breast in sagittal section, inner surface of outer segment. (Testut.)

drops of fat appear, and the nucleus toward this end of the cell also becomes fatty.

![Diagram of nipple and areola]

Fig. 1126.—Nipple and areola of a virgin. (Testut.)

Fig. 1127.—Nipple and areolae of a pregnant woman. (Testut.)

The end of the cell toward the alveolus breaks down, and the liberated material constitutes “the albuminous ingredients of the milk, while the drops of fat become the milk-globules. The portion of the cell which remains forms new
The female organs of generation

Cytoplasm, and the same process is repeated over and over again. The cells also secrete water and the salts which are found in the milk.1

The fibrous tissue (Fig. 1125) invests the entire surface of the breast, and sends down septa between its lobes, connecting them together.

The fatty tissue (Figs. 1124 and 1125) surrounds the surface of the gland and occupies the interval between its lobes. It usually exists in considerable abundance, and determines the form and size of the gland. There is no fat immediately beneath the areola and nipple.

Vessels and Nerves.—The arteries supplying the mammary gland are derived from the perforating branches of the internal mammary, long thoracic branches of the axillary, and branches from the intercostals. The veins describe an anastomotic circle around the base of the nipple, called by Haller the circulus venosus. From this large branches transmit the blood to the circumference of the gland and end in the axillary and internal mammary veins. The lymphatics of the mammary gland (Figs. 1128 and 1129) and mammary region have been previously described (pp. 810 and 811). The nerves are derived from the fourth, fifth, and sixth intercostal nerves, and sympathetic filaments from the dorsal cord pass to the breast along the branches of the intercostal nerves.

Surgical Anatomy.—Occasionally the mammary gland undergoes enormous hypertrophy. This may occur at any age, even in the virgin. The physiological enlargement of puberty may become excessive or the physiological enlargement of pregnancy and lactation may continue and increase after the termination of lactation. The chief elements in the enlargement are fat and connective tissue, and it is doubtful if there is extensive reproduction of glandular tissue.

Abscess of the breast may occur at any age, but is most common by far in nursing women. The portals are opened to infection by a crack in the nipple and bacteria are carried inward by the lymph-vessels. In some cases the pus gathers beneath the skin (supra-mammary abscess), in others in the breast tissue (intra-mammary abscess). In rare cases pus gathers beneath the breast (retro-mammary abscess). In intra-mammary abscess the pus burrows through the

1 Human Physiology. By Joseph Howard Raymond.
fibrous septa or fascia and forms numerous channels, and such a channel is constricted at the point where it passes through fascia or a fibrous septum, as an hour-glass is constricted.

In every patient suffering from abscess the nipple should be examined for a sore or crack, and the area when found should be treated antiseptically. A supra-mammary abscess should be opened by an incision radiating from the nipple.

In intra-mammary abscess follow the advice of Sheild: open the abscess by an incision radiating from the nipple, insert the index finger, and when possible pass it to the bottom of the abscess and carry the tip from the depths of the abscess to as near the surface as possible. At this point make a counter opening. The finger breaks down septa which cause constriction and thus converts the tracking sinuses into one large cavity. Drain by tubes.

A retro-mammary abscess is opened by an incision, following the outline of the breast at the thoraco-mammary junction, the finger being pushed through the incision and up under the gland.

Tuberculosis of the breast may occur, and if it does, cold abscess is apt to form. The best treatment is removal of the gland and the associated lymph glands.

Chronic mastitis is a condition of mammary fibrosis, most common in neurotic single women, and apt to be associated with ovarian or uterine disease.

Malignant dermatitis or Paget's disease of the nipple is a chronic condition consisting of epithelial proliferation, induration, desquamation, and ulceration, and it is apt to be followed by epithelioma.

Chancre of the nipple is occasionally met with.

Secondary and tertiary syphilitic lesions are seen upon the skin of the breast, the nipple, and the areola.

Cysts and tumors are common in the breast.

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Fig. 1129.—Lymphatics of the breast and axillary glands. (Poirier and Charpy.)

There may be cystic degeneration of the gland in women near the menopause (involution cysts); a lacted cyst; a hydatid cyst; an adenoma may become cystic. The nipple may suffer from epithelioma, myoma, myxoma, angioma, papilloma, or fibroma.

The innocent tumors of the breast are fibro-adenoma, cystic adenoma, myxoma, and angioma. The skin of the breast may suffer from any form of growth or cyst which could arise from the skin of another part. Malignant tumors of the glandular structure are ten times as frequent as innocent tumors. Sarcoma is rare; carcinoma is very common.

Carcinoma of the breast has occupied much of the attention of surgeons during recent years. The old operation was uniformly followed by recurrence. The modern radical operation has been evolved from the studies of Moore, the younger Gross, Heidenhain, Stiles, Banks, Halsted, and others. The modern operation always removes at least the skin and subcutaneous tissue over the hemispherical portion of the breast, the outlying lobules of the breast, the pectoral fascia,

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1 Diseases of the Breast. By A. Marmaduke Sheild.

96
and the sternal portion of the great Pectoral muscle, the lymphatic tracts from the breast, the lymphatic glands and cellular tissue from the axilla, and from beneath the latissimus dorsi muscle. The pectoral fascia and the sternal portion of the great Pectoral muscle must come away in every case, because breast tissue may pass through the fascia. The entire breast must be removed, because even in a recent case the entire breast is regarded as infected. The clavicular portion of the great Pectoral muscle is anatomically distinct from the sternal portion and its removal is not imperative. Some operators remove the lesser Pectoral muscle. To leave it is of no value to the arm, and it frequently causes an annoying rigid band anterior to the axilla. To take it away gives ready access to the axillary vessels at a desirable point above. The sheath of the axillary vein should be removed with the glands and cellular tissue of the axilla. The glands receiving lymph from the cancerous area must be removed, of course. In view of the fact that in an undetermined percentage of cases a lymph tract passes direct to the subclavian glands, it is evident that these glands may become infected by this route instead of, as is more usual, secondarily to axillary infection; hence it seems wiser in every case to remove the cellular tissue and glands from the subclavian triangle. All of these structures should be removed as one piece, in order to avoid cutting across lymph tracts and flooding the wound with carcinoma cells which might adhere, grow, and reproduce cancer.

Halsted's operation is the method adopted by most surgeons. The wound cannot be completely closed, and the raw spot is covered at once or later with Thiersch skin grafts. (For surgical considerations regarding the lymphatics in mammary carcinoma see page 811.)

The Male Breast (mamma virilis).—The male breast is a small flat structure, consisting chiefly of connective tissue, but containing some branched tubules. Under normal circumstances it remains permanently of the infantile type. It possesses a nipple which is much smaller than that of the female breast, and which usually lies over the fourth intercostal space, but may lie over the fourth or fifth rib. The nipples of the two sides are rarely placed quite symmetrically. Accessory glands and accessory nipples are as common among males as females. The male breast may exhibit some evidence of temporary functional activity at birth and at puberty. Cases have been recorded of actual lactation by the male breast.

Surgical Anatomy.—The male breasts may undergo enormous hypertrophy (gynaecomazia). In these cases the penis is often small and the testicles may be atrophied. The breasts may be absent in the male. Disease of the male breast is not nearly so frequent as disease of the female breast. The organ may be the seat of syphilis, tuberculosis, acute or chronic mastitis, abscess or tumor. A number of cases of cancer of the male breast have been recorded.
THE SURGICAL ANATOMY OF INGUINAL HERNIA AND FEMORAL HERNIA.

Dissection (Fig. 287).—For dissection of the parts concerned in inguinal hernia a male subject, free from fat, should always be selected. The body should be placed in the supine position, the abdomen and pelvis raised by means of blocks placed beneath them, and the lower extremities rotated outward, so as to make the parts as tense as possible. If the abdominal walls are flaccid, the cavity of the abdomen should be inflated through an aperture made at the umbilicus. An incision should be made along the middle line from a little below the umbilicus to the symphysis pubis, and continued along the front of the scrotum, and a second incision from the anterior superior spine of the ilium to just below the umbilicus. These incisions should divide the integument, and the triangular-shaped flap included between them should be reflected downward and outward, when the superficial fascia will be exposed.

The Superficial Fascia of the Abdomen (p. 434).—This, over the greater part of the abdominal wall, consists of a single layer of fascia, which contains a variable amount of fat; but as it approaches the groin it is easily divisible into two layers, between which are found the superficial vessels and nerves and the superficial inguinal lymphatic glands.

The Superficial Layer of the Superficial Fascia or the Fascia of Camper is thick, areolar in texture, containing adipose tissue in its meshes, the quantity of which varies in different subjects. Below, it passes over Poupart's ligament, and is continuous with the outer layer of the superficial fascia of the thigh. In the male this fascia is continued over the penis and over the outer surface of the cord to the scrotum, where it helps to form the dartos. As it passes to the penis, and over the cord to the scrotum it changes its character, becoming thin, destitute of adipose tissue, and of a pale reddish color; and in the scrotum it acquires some involuntary muscular fibres. From the scrotum it may be traced backward, to be continuous with the superficial fascia of the perineum. In the female this fascia is continued into the labia majora.

The hypogastric branch of the ilio-hypogastric nerve perforates the aponeurosis of the External oblique muscle about an inch above and a little to the outer side of the external abdominal ring, and is distributed to the integument of the hypogastric region.

The ilio-inguinal nerve escapes at the external abdominal ring, and is distributed to the integument of the upper and inner part of the thigh, to the scrotum in the male and to the labium in the female.

The superficial epigastric artery arises from the femoral about half an inch below Poupart's ligament, and, passing through the saphenous opening in the fascia lata, ascends on to the abdomen, in the superficial fascia covering the External oblique muscle, nearly as high as the umbilicus. It distributes branches to the superficial inguinal lymphatic glands, the superficial fascia, and the integument, anastomosing with branches of the deep epigastric and internal mammary arteries.

The superficial circumflex iliac artery, the smallest of the cutaneous branches, arises close to the preceding, and, piercing the fascia lata, runs outward, parallel with Poupart's ligament, as far as the crest of the ilium, dividing into branches which supply the superficial inguinal lymphatic glands, the superficial fascia, and
the integument, anastomosing with the deep circumflex iliac and with the gluteal and external circumflex arteries.

Fig. 1130.—Right external abdominal ring and saphenous opening in the male. (Spalteholz.)

Fig. 1131.—Right inguinal canal in the male. Second layer viewed from in front. (Spalteholz.)
The superficial external pudic (superior) artery arises from the inner side of the femoral artery close to the preceding vessels, and, after passing through the saphenous opening, courses inward across the spermatic cord, to be distributed to the integument on the lower part of the abdomen, the penis and scrotum in the male, and the labium in the female, anastomosing with branches of the internal pudic.

The Superficial Veins.—The veins accompanying these superficial vessels are usually much larger than the arteries; they terminate in the internal saphenous vein.

The superficial inguinal lymphatic glands are placed immediately beneath the integument, are of large size, and vary from ten to twenty in number (p. 791).

The Deep Layer of the Superficial Fascia, the Fascia of Scarpa or the Fascia of Cooper (p. 435) is thinner and more membranous in character than the superficial layer. In the middle line it is intimately adherent to the linea alba; above, it is continuous with the superficial fascia over the rest of the trunk; below, it blends with the fascia lata of the thigh a little below Poupart's ligament; below and internally, in the male, it is continued over the penis and over the outer surface of the cord to the scrotum, where it helps to form the dartos. From the scrotum it may be traced backward to be continuous with the base of the triangular ligament of the urethra. In the female it is continuous with the labia majora.

The scrotum is a cutaneous pouch which contains the testes and part of the spermatic cords, and into which an inguinal hernia frequently descends.

The Aponeurosis of the External Oblique Muscle (Fig. 1130).—This is a thin but strong membranous aponeurosis, the fibres of which are directed obliquely downward and inward. That portion of the aponeurosis which extends between
the anterior superior spine of the ilium and the spine of the os pubis is a broad band, folded inward and continuous below with the fascia lata; it is called Poupart's ligament (Figs. 288, 1130, 1133, 1134, 1135, 1141, and 1142). The portion which is reflected from Poupart's ligament at the spine of the os pubis, along the pectineal line, is called Gimbernat's ligament (Fig. 296, 338, 1130, 1141, and 1142). A thin fibrous band extends from the inner end of Poupart's ligament and Gimbernat's ligament upward and inward behind the inner pillar of the external ring to the anterior layer of the rectus sheath. The fibres diverge as they ascend. This band is known as the triangular fascia or Colles's fascia or the triangular ligament of Colles (Figs. 1132 and 1136).

The External or Superficial Abdominal Ring (anulus inguinalis subcutaneus) (Figs. 288 and 1130).—Just above and to the outer side of the crest of the os pubis an interval is seen in the aponeurosis of the External oblique, called the external abdominal ring. This aperture is oblique in direction, somewhat triangular in form, and corresponds with the course of the fibres of the aponeurosis. It usually measures from base to apex about an inch, and transversely about half an inch. It is bounded below by the crest of the os pubis; above, by a series of curved fibres, the intercolumnar fibres, which pass across the upper angle of the ring, so as to increase its strength; and on either side by the margins of the opening in the aponeurosis, which are called the columns or pillars of the ring.

The External Pillar, which at the same time is inferior (crus inferius), from the obliquity of its direction, is the stronger; it is formed by that portion of Poupart's ligament which is inserted into the spine of the os pubis; it is curved, so as to form a kind of groove, upon which the spermatic cord rests.

The Internal or Superior Pillar (crus superius) is a broad, thin, flat band, which is attached to the front of the body of the os pubis, interlacing with its fellow of the opposite side in front of the symphysis pubis, that of the right side being superficial.

The external abdominal ring gives passage to the spermatic cord in the male and round ligament in the female; it is much larger in men than in women, on account of the large size of the spermatic cord, hence the great frequency of inguinal hernia in men.

The Intercolumnar Fibres (fibrae intercruales) (Fig. 1130) are a series of curved tendinous fibres which arch across the lower part of the aponeurosis of the External oblique. They have received their name from stretching across between the two pillars of the external ring; they increase the strength of the lower part of the aponeurosis and prevent the divergence of the pillars from one another. They are thickest below, where they arise from Poupart's ligament, and they are inserted into the linea alba, describing a curve, with the convexity downward. They are much thicker and stronger at the outer angle of the external ring than internally, and are more strongly developed in the male than in the female. These intercolumnar fibres, as they pass across the external abdominal ring, are themselves connected together by delicate fibrous tissue, thus forming a fascia which, as it is attached to the pillars of the ring, covers it in, and is called the intercolumnar fascia. This intercolumnar fascia is continued downward as a tubular prolongation around the outer surface of the cord and testis, and encloses them in a distinct sheet; hence, it is also called the external spermatic fascia. The sac of an inguinal hernia in passing through the external abdominal ring receives an investment from the intercolumnar fascia.

If the finger is introduced a short distance into the external ring and the limb is then extended and rotated outward, the aponeurosis of the External oblique, together with the iliac portion of the fascia lata, will be felt to become tense and the external ring much contracted; if the limb is, on the contrary, flexed upon the pelvis and rotated inward, this aponeurosis will become lax, and the external ring
sufficiently enlarged to admit the finger with comparative ease; hence the patient should always be put in the latter position when the taxis is applied for the reduction of an inguinal hernia, in order that the abdominal walls may be relaxed as much as possible.

The aponeurosis of the External oblique should be removed by dividing it across in the same direction as the external incisions, and reflecting it downward and outward; great care is requisite in separating it from the aponeurosis of the muscle beneath. The lower part of the Internal oblique and the Cremaster are then exposed, together with the inguinal canal, which contains the spermatic cord (Fig. 1133). The mode of insertion of Poupart's and Gimbernat's ligaments into the os pubis should also be examined.

**Poupart's Ligament** (ligamentum inguinale [Pouparti]) (Figs. 288, 1130, 1133, 1134, 1135, 1141, and 1142) or the crural arch is the lower border of the aponeurosis of the External oblique muscle, which extends from the anterior superior spine of the ilium to the spine of the os pubis. From this latter point it is reflected outward to be attached to the pectineal line for about half an inch, forming Gimbernat's ligament. Its general direction is curved downward toward the thigh, where it is continuous with the fascia lata. Its outer half is rounded and oblique in direction; its inner half gradually widens at its attachment to the os pubis, is more horizontal in direction, and lies beneath the spermatic cord.

**Gimbernat's Ligament** (ligamentum lacunare [Gimbernati]) (Figs. 288, 293, 338, 1130, 1141, and 1142) is that portion of the aponeurosis of the External oblique muscle which is reflected upward and outward from the spine of the os pubis to be inserted into the pectineal line. It is about half an inch in length, larger in the male than in the female, almost horizontal in direction in the erect posture, and of a triangular form, with the base directed outward. Its base or outer margin is concave, thin, and sharp, and lies in contact with the femoral sheath, forming the inner boundary of the femoral ring (Fig. 1141). Its apex corresponds to the spine of the os pubis. Its posterior margin is attached to the pectineal line, and is continuous with the pubic portion of the fascia lata. Its anterior margin is continuous with Poupart's ligament.

The **Triangular Fascia of the Abdomen, Colles's Fascia** or the **Triangular Ligament of Colles** (ligamentum inguinale reflexum [Collesi]) (Figs. 1132, 1133, and 1136) is a band of tendinous fibres, of a triangular shape, which is attached by its apex to the inner end of Poupart's ligament and to Gimbernat's ligament. It passes inward beneath the spermatic cord, and expands into a somewhat fan-shaped fascia, lying behind the inner pillar of the external abdominal ring and in front of the conjoined tendon, and interlaces with the ligament of the other side at the linea alba in the anterior layer of the sheath of the Rectus muscle.
The Ligament of Cooper.—See Fig. 296 and p. 439.

The Internal Oblique Muscle (Figs. 1131, 1132, and 1133) has been previously described (p. 439). The part which is now exposed is partly muscular and partly tendinous in structure. Those fibres which arise from Poupart's ligament, few in number and paler in color than the rest, arch downward and inward across the spermatic cord, and, becoming tendinous, are inserted, conjointly with those of the Transversalis, into the crest of the os pubis and pectineal line, forming what is known as the conjoined tendon of the Internal oblique and Transversalis (Figs. 1133 and 1134). This tendon is inserted immediately behind the inguinal canal and external abdominal ring, serving to protect what would otherwise be a weak point in the abdominal wall. The conjoined tendon is sometimes divided into an outer and an inner portion, the former being called the ligament of Hesseltbach (ligamentum interfoveolare) (Fig. 291), and the latter the ligament of Henle (Fig. 291). Sometimes the conjoined tendon is insufficient to resist the pressure from within, and is carried forward in front of the protrusion through the external ring, forming one of the coverings of direct inguinal hernia, or the hernia forces its way through the fibres of the conjoined tendon.

The Cremaster (Figs. 1131 and 1133) is derived from the lower margin of the Internal oblique, of which muscle it is in reality a portion. It is a thin muscular layer composed of a number of fasciculi. It arises by a thick external bundle of fibres from the upper portion of Poupart's ligament, being connected with the Internal oblique muscle and also occasionally with the Transversalis. It arises also by a thin inner bundle of fibres from the anterior layer of the rectus sheath.

The thick bundle of origin is on the lateral surface; the thin bundle is on the medial surface of the spermatic cord. The Cremaster passes along with the spermatic cord, and descends with it through the external ring. Upon the front and sides of the cord both bundles spread out upon the vaginal tunic of the testicle and epididymis, and form a series of loops which differ in thickness and length in different subjects. These loops are united together by areolar tissue, and form a thin covering over the cord and testis, the cremasteric fascia (fascia cremasterica).

It will be observed that the Cremaster is a separated portion of the Internal oblique. This fact affords an easy explanation of the manner in which the testicle and cord are invested by this muscle. At an early period of foetal life the testis is placed at the lower and back part of the abdominal cavity, but during its descent toward the scrotum, which takes place before birth, it passes beneath the arched border of the Internal oblique. In its passage beneath this muscle some fibres are derived from its lower part, which accompany the testicle and cord into the scrotum.

It occasionally happens that the loops of the Cremaster surround the cord, some lying behind as well as in front. It is probable that under these circumstances the testis in its descent passes through, instead of beneath, the fibres of the Internal oblique.

In the descent of an oblique inguinal hernia, which takes the same course as the spermatic cord, the Cremaster muscle forms one of its coverings. This muscle becomes largely developed in cases of hydrocele and large old scrotal herniae. No such muscle exists in the female, but an analogous structure is developed in those cases where an oblique inguinal hernia descends beneath the margin of the Internal oblique.

The Internal oblique should be detached from Poupart's ligament, separated from the Transversalis to the same extent as in the previous incisions, and reflected inward on to the sheath of the Rectus (Fig. 1134). The deep circumflex iliac vessels, which lie between these two muscles, form a valuable guide to their separation.
The Transversalis Muscle (Figs. 1132 and 1134) has been previously described (p. 444). The part which is now exposed is partly muscular and partly tendinous in structure; it arises from the outer third of Poupart's ligament, its fibres curve downward and inward, and are inserted, together with those of the Internal oblique, into the lower part of the linea alba, into the crest of the os pubis and the pectineal line, forming what is known as the conjoined tendon of the Internal oblique and Transversalis (Figs. 1133 and 1134). The falx aponeurotica [inguinalis] is a collection of fibres of tendinous consistence in the inner side of the Transversalis insertion. Between the lower border of this muscle and Poupart's ligament a space is left in which is seen the transversalis fascia.

The Inguinal or Spermatic Canal (canalis inguinalis) (Figs. 1131, 1132, and 1134) contains the spermatic cord in the male and the round ligament in the female. It is an oblique canal, about an inch and a half in length, directed downward and inward and placed parallel with, and a little above, Poupart's ligament. It commences above at the internal or deep abdominal ring, which is the point where the cord enters the inguinal canal, and terminates below at the external or superficial ring. It is bounded, in front, by the integument and superficial fascia, by the aponeurosis of the External oblique throughout its whole length, and by the Internal oblique for its outer third; behind, by the triangular fascia, the conjoined tendon of the Internal oblique and Transversalis, transversalis fascia, and the subperitoneal fat and peritoneum; above, by the arched fibres of the Internal oblique and Transversalis; below, by the union of the transversalis fascia with Poupart's ligament. That form of hernia in which the intestine follows the course of the spermatic cord along the inguinal canal is called oblique inguinal hernia.

On the posterior wall of the inguinal canal is seen the band of fibres known as the ligament of Hesselbach (ligamentum interfoveolare [Hesselbachi]) (Fig. 291). It is placed in front of the deep epigastric artery. The fibres come from the external portion of the lower fibres of the conjoined tendon (Fig. 1133) and pass

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**Fig. 1134.**—Inguinal hernia. Dissection showing the Transversalis muscle, the transversalis fascia, and the internal abdominal ring.
downward for a distance, some of them then passing outward and upward, some of them downward and inward to the inner surface of Poupart's ligament.

The Transversalis Fascia (Figs. 296, 1134, and 1142) is a thin aponeurotic membrane which lies between the inner surface of the Transversalis muscle and the peritoneum. It forms part of the general layer of fascia which lines the interior of the abdominal and pelvic cavities, and is directly continuous with the iliac and pelvic fasciae.

In the inguinal region the transversalis fascia is thick and dense in structure, and joined by fibres from the aponeurosis of the Transversalis muscle; but it becomes thin and cellular as it ascends to the Diaphragm. Below, it has the following attachments; external to the femoral vessels it is connected to the posterior margin of Poupart’s ligament, and is there continuous with the iliac fascia. Internal to the vessels it is thin, and attached to the os pubis and pectineal line behind the conjoined tendon, with which it is united; and, corresponding to the points where the femoral vessels pass into the thigh, this fascia descends in front of them, forming the anterior wall of the femoral sheath. The spermatic cord in the male and the round ligament in the female pass through this fascia; the point where they pass through is called the internal or deep abdominal ring. This opening is not visible externally, owing to a prolongation of the transversalis fascia on the structures forming the infundibuliform fascia.

The Internal or Deep Abdominal Ring (annulus inguinalis abdominalis) (Figs. 296 and 1134) is situated in the transversalis fascia, midway between the anterior superior spine of the ilium and symphysis pubis, and about half an inch above Poupart’s ligament. It is of an oval form, its long diameter being directed upward and downward; it varies in size in different subjects, and is much larger in the male than in the female. It is bounded above and externally by the arched fibres of the Transversalis muscle, below and internally by the deep epigastric vessels. It transmits the spermatic cord in the male and the round ligament in the female. From its circumference, a thin, funnel-shaped membrane, the infundibuliform fascia, is continued around the cord and testis, enclosing them in a distinct pouch (Fig. 1134). When the sac of an oblique inguinal hernia passes through the internal or deep abdominal ring, the infundibuliform fascia constitutes one of its coverings.

The Subperitoneal Areolar Tissue or the Fascia Propria of Cooper.—Between the transversalis fascia and the peritoneum is a quantity of loose areolar tissue. In some subjects it is of considerable thickness and loaded with adipose tissue. Opposite the internal ring it is continued around the surface of the cord, forming a loose sheath for it.

The Deep Epigastric Artery (Figs. 291 and 1135) arises from the external iliac artery a few lines above Poupart’s ligament. It at first descends to reach this ligament, and then ascends obliquely along the inner margin of the internal or deep abdominal ring, lying between the transversalis fascia and the peritoneum, and passing upward pierces the transversalis fascia and enters the sheath of the Rectus muscle by passing over the semilunar fold of Douglas. Consequently the deep epigastric artery bears a very important relation to the internal abdominal ring as it passes obliquely upward and inward from its origin from the external iliac. In this part of its course it lies along the lower and inner margin of the internal ring and beneath the commencement of the spermatic cord. At its commencement it is crossed by the vas deferens in the male and by the round ligament in the female.

The Peritoneum (Fig. 1135), corresponding to the inner surface of the internal ring, presents a well-marked depression, the depth of which varies in different subjects. A thin fibrous band is continued from it along the front of the cord for a variable distance, and becomes ultimately lost, the ligament of Cloquet. This is the remains of the pouch of peritoneum which, in the foetus, precedes
the cord and testis into the scrotum, the obliteration of which commences soon after birth. In some cases the fibrous band can only be traced a short distance, but occasionally it may be followed, as a fine cord, as far as the upper end of the tunica vaginalis. Sometimes the tube of peritoneum is closed only at intervals and presents a sacculated appearance, or a single pouch may extend along the whole length of the cord, which may be closed above, or the pouch may be directly continuous with the peritoneum by an opening at its upper part.

In the female fetus the peritoneum is also prolonged in the form of a tubular process for a short distance into the inguinal canal. This process is called the canal of Nuck. It is generally obliterated in the adult, but sometimes it remains pervious even in advanced life.

In order to understand the relation of the peritoneum to inguinal hernia, it is necessary to view the anterior abdominal wall from its internal aspect, when it will be seen as shown in Fig. 1135. Between the upper margin of the front of the pelvis and the umbilicus, the peritoneum, when viewed from behind, will be seen to be raised into five vertical folds, with intervening depressions, by more or less prominent bands which converge to the umbilicus. One of these is situated in the median line, and is caused by the urachus, the remnant of the allantois; it extends from the summit of the bladder to the umbilicus. The fold of peritoneum covering it is known as the fold of the urachus or the plica urachi (plica umbilicalis media). On either side of this is a prominent band, caused by the obliterated hypogastric artery, which extends from the side of the bladder obliquely upward and inward to the umbilicus. This is covered by a fold of peritoneum which is known as the
hypogastric fold or the plica hypogastrica \((\text{plica umbilicalis lateralis})\). To either side of these three cords is the deep epigastric artery, which ascends obliquely upward and inward from a point midway between the symphysis pubis and the anterior superior spine of the ilium to the semilunar fold of Douglas, in front of which it disappears. It is covered by a fold of peritoneum which is known as the plica epigastrica. Between these raised folds are depressions of the peritoneum, constituting so-called fossae. The most internal, between the plica urachi and the plica hypogastrica, is known as the internal inguinal fossa \((\text{fovea supravesicalis})\). The middle one is situated between the plica hypogastrica and the plica epigastrica, and is termed the middle inguinal fossa \((\text{fovea inguinalis mesialis})\). The external one is external to the plica epigastrica, and is known as the external inguinal fossa \((\text{fovea inguinalis lateralis})\). Occasionally the deep epigastric artery corresponds in position to the obliterated hypogastric artery, and then there is but one fold on each side of the middle line, and the two external fossae are merged into one. In the usual condition of the parts the floor of the external inguinal fossa corresponds to the internal abdominal ring, and into this fossa an oblique inguinal hernia descends. To the inner side of the plica epigastrica are the two internal fossae, and through either of these a direct hernia may descend, as will be explained in the sequel (p. 1535). The whole of this space, that is to say, the space between the deep epigastric artery, the margin of the Rectus and Poupart’s ligament, is commonly known as Hesselbach’s triangle. These three depressions or fossae are situated above the level of Poupart’s ligament, and in addition to them is another below the ligament, corresponding to the position of the femoral ring, and into which a femoral hernia descends.

**INGUINAL HERNIA.**

Inguinal hernia is that form of protrusion which makes its way through the abdomen in the inguinal region.

There are two principal varieties of inguinal hernia—external or oblique, and internal or direct.

External or oblique inguinal hernia, the more frequent of the two, takes the same course as the spermatic cord. It is called external from the neck of the sac being on the outer or iliac side of the deep epigastric artery.

Internal or direct inguinal hernia does not follow the same course as the cord, but protrudes through the abdominal wall on the inner or pubic side of the deep epigastric artery.

**Oblique Inguinal Hernia.**

In oblique inguinal hernia (Fig. 1135) the intestine or omentum escapes from the abdominal cavity at the internal ring. Before it is a pouch of peritoneum, which forms the hernial sac (Fig. 1137, A). This pouch of peritoneum is invested by the subserous areolar tissue, and is enclosed in the infundibuliform process of the transversalis fascia, which it receives as it enters the inguinal canal. In passing along the inguinal canal the hernia displaces upward the arched fibres of the Transversalis and Internal oblique muscles, and is imperfectly surrounded by the fibres of the Cremaster muscles, the coat being completed by the cremasteric fascia. It then passes along the front of the cord, and escapes from the inguinal canal at the external ring, receiving an investment from the intercolumnar fascia. Lastly, it descends into the scrotum, receiving coverings from the superficial fascia and the integument.

The coverings of this form of hernia, after it has passed through the external ring, are, from without inward, the integument, superficial fascia, intercolumnar...
OBVERSE INGUINAL HERNIA

This form of hernia lies in front of the vessels of the spermatic cord and seldom extends below the testis, on account of the intimate adhesion of the coverings of the cord to the tunica vaginalis (Fig. 1137, A).

The seat of stricture in a strangulated oblique inguinal hernia is either at the external ring, in the inguinal canal, caused by the fibres of the Internal oblique or Transversalis; or at the internal ring, most frequently in the latter situation. If it is situated at the external ring, the division of a few fibres at one point of its circumference is all that is necessary for the replacement of the hernia. If in the inguinal canal or at the internal ring, it may be necessary to divide the

aponeurosis of the External oblique so as to lay open the inguinal canal. In dividing the stricture the direction of the incision should be upward.

When the hernia passes along the inguinal canal and escapes from the external ring into the scrotum, the condition is called complete oblique inguinal or scrotal hernia (Fig. 1137, A). If the hernia does not escape from the external ring, but is retained in the inguinal canal, the condition is called incomplete inguinal hernia or bubonocele. In each of these cases the coverings which invest the intestine or omentum will depend upon the extent to which it descends in the inguinal canal.

There are some other varieties of oblique inguinal hernia depending upon congenital defects in the processus vaginalis. The testicle in its descent from the abdomen into the scrotum is preceded by a pouch of peritoneum, which about
the period of birth becomes shut off from the general peritoneal cavity by a closure of that portion of the pouch which extends from the internal abdominal ring to

![Diagram of hernia types](image)

near the upper part of the testicle, the lower portion of the pouch remaining persistent as the tunica vaginalis. It would appear that this closure commences at
two points—viz., at the internal abdominal ring and at the top of the epididymis—and gradually extends until, in the normal condition, the whole of the intervening portion is converted into a fibrous cord. From failure in the completion of this process variations in the relation of the hernial protrusion to the testicle and tunica vaginalis are produced, which constitute distinct varieties of inguinal hernia, and which have received separate names and are of surgical importance. These are congenital, infantile, encysted, and hernia of the funicular process.

**Congenital Hernia** (Fig. 1137, B).—Where the congenital pouch of peritoneum which precedes the cord and testis in its descent remains patent throughout and is unclosed at any point, the cavity of the tunica vaginalis communicates directly with the cavity of the peritoneum. The intestine descends along this pouch into the cavity of the tunica vaginalis, which constitutes the sac of the hernia, and the gut lies in contact with the testicle.

**Infantile and Encysted Hernia.**—Where the congenital pouch of peritoneum is occluded at the internal ring only, but remains patent throughout the rest of its extent, two varieties of oblique inguinal hernia may be produced, which have received the names of infantile and encysted hernia. In the **infantile form** (Fig. 1137, C) the septum which closed the congenital sac above and the peritoneum in its immediate neighborhood yields and forms a sac, which descends behind the tunica vaginalis, so that in front of the bowel there are three layers of peritoneum, the two layers of the tunica vaginalis and the layer of the proper hernial sac. In the **encysted form** (Fig. 1137, D) yielding occurs in the same position as in the infantile form—namely, at the occluded spot in the pouch—and a sac forms which projects into and not behind the tunica vaginalis, as in the infantile form, and thus it constitutes a sac within a sac, so that in front of the bowel there are two layers of peritoneum—one layer of the tunica vaginalis and one of true hernial sac.

**Hernia into the Funicular Process** (Fig. 1137, E).—Where the congenital pouch of peritoneum is occluded at the lower point only—that is, just above the testicle—the intestine descends into the pouch of peritoneum as far as the testicle, but is prevented from entering the sac of the tunica vaginalis by the septum which has formed between it and the pouch, so that it resembles the congenital form in all respects, except that, instead of enveloping the testicle, that body can be felt below the rupture.

**Direct Inguinal Hernia.**

In direct inguinal hernia the protrusion makes its way through some part of the abdominal wall internal to the epigastric artery.

At the lower part of the abdominal wall is a triangular space, **Hesselbach's triangle**, bounded externally by the deep epigastric artery, internally by the margin of the Rectus muscle, below by Poupart's ligament (Fig. 1135). The conjoined tendon is stretched across the inner two-thirds of this space, the remaining portion of the space having only the subperitoneal areolar tissue and the transversalis fascia between the peritoneum and the aponeurosis of the External oblique muscle.

In some cases the hernial protrusion escapes from the abdomen on the outer side of the conjoined tendon, pushing before it the peritoneum, the subserous areolar tissue, and the transversalis fascia. It then enters the inguinal canal, passing along nearly its whole length, and finally emerges from the external ring, receiving an investment from the intercolumnar fascia. The coverings of this form of hernia are precisely similar to those investing the oblique form, with the insignificant difference that the infundibuliform fascia is replaced by a portion derived from the general layer of the transversalis fascia.

In other cases—and this is the more frequent variety—the hernia is either forced through the fibres of the conjoined tendon or the tendon is gradually distended in
front of it so as to form a complete investment for it. The intestine then enters the lower end of the inguinal canal, escapes at the external ring lying on the inner side of the cord, and receives additional coverings from the superficial fascia and the integument. This form of hernia has the same coverings as the oblique variety, excepting that the conjoined tendon is substituted for the Cremaster, and the infundibuliform fascia is replaced by a portion derived from the general layer of the transversalis fascia.

The difference between the position of the neck of the sac in these two forms of direct inguinal hernia has been referred, with some probability, to a difference in the relative positions of the obliterated hypogastric artery and the deep epigastric artery. When the course of the obliterated hypogastric artery corresponds pretty nearly with that of the deep epigastric the projection of these arteries toward the cavity of the abdomen produces two fossae in the peritoneum. The bottom of the external fossa of the peritoneum corresponds to the position of the internal abdominal ring, and a hernia which distends and pushes out the peritoneum lining this fossa is an oblique hernia. When, on the other hand, the obliterated hypogastric artery lies considerably to the inner side of the deep epigastric artery, corresponding to the outer margin of the conjoined tendon, it divides the triangle of Hesselbach into two parts, so that three depressions will be seen on the inner surface of the lower part of the abdominal wall—viz., an external one on the outer side of the deep epigastric artery; a middle one, between the deep epigastric and the obliterated hypogastric arteries; and an internal one, on the inner side of the obliterated hypogastric artery (pp. 1531 and 1532). In such a case a hernia may distend and push out the peritoneum forming the bottom of either fossa. These fossae are the inguinal fossae. When the hernia distends and pushes out the peritoneum forming the bottom of the external fossa, it is an oblique or external inguinal hernia.

When the hernia distends and pushes out the peritoneum forming the bottom of either the middle or the internal fossa, it is a direct or internal hernia.

The anatomical difference between these two forms of direct or internal inguinal hernia is that, when the hernia protrudes through the middle fossa—that is, the fossa between the deep epigastric and the obliterated hypogastric arteries—it will enter the upper part of the inguinal canal; consequently its coverings will be the same as those of an oblique hernia, with the insignificant difference that the infundibuliform fascia is replaced by a portion derived from the general layer of the transversalis fascia, whereas when the hernia protrudes through the internal fossa it is either forced through the fibres of the conjoined tendon or the tendon is gradually distended in front of it so as to form a complete investment for it. The intestine then enters the lower part of the inguinal canal, and escapes from the external abdominal ring lying on the inner side of the cord.

This form of hernia has the same coverings as the oblique variety, excepting that the conjoined tendon is substituted for the Cremaster, and the infundibuliform fascia is replaced by a portion derived from the general layer of the fascia transversalis.

The seat of stricture in strangulation in both varieties of direct hernia is most frequently at the neck of the sac or at the external ring. In that form of hernia which perforates the conjoined tendon it not infrequently occurs at the edges of the fissure through which the gut passes. In dividing the stricture the incision should in all cases be directed upward.1

If the hernial protrusion passes into the inguinal canal, but does not escape

1 In all cases of inguinal hernia, whether oblique or direct, it is proper to divide the stricture directly upward: the reason of this is obvious, for by cutting in this direction the incision is made parallel to the deep epigastric artery—either external to it in the oblique variety, or internal to it in the direct form of hernia—and thus all chance of wounding the vessel is avoided. If the incision was made outward, the artery might be divided if the hernia was direct; and if made inward, the vessel would stand an equal chance of injury if the case was one of oblique inguinal hernia.—Ed. of 15th English edition.
from the external abdominal ring, it forms what is called **incomplete direct hernia**. This form of hernia is usually of small size, and in corpulent persons is very difficult of detection.

Direct inguinal hernia is of much less frequent occurrence than the oblique, their comparative frequency being, according to Cloquet, as one to five. It occurs far more frequently in men than in women, on account of the larger size of the external ring in the former sex. It differs from the oblique in its smaller size and globular form, dependent most probably on the resistance offered to its progress by the transversalis fascia and conjoined tendon. It differs also in its position, being placed over the os pubis and not in the course of the inguinal canal. The deep epigastric artery runs on the outer or iliac side of the neck of the sac, and the spermatic cord along its external and posterior side, not directly behind it, as in oblique inguinal hernia.

### FEMORAL HERNIA.

The dissection of the parts comprised in the anatomy of femoral hernia should be performed, if possible, upon a female subject free from fat. The subject should lie upon the back; a block is first placed under the pelvis, the thigh everted, and the knees slightly bent and retained in this position. An incision should then be made from the anterior superior spinous process of the ilium along Poupart’s ligament to the symphysis pubis; a second incision should be carried transversely across the thigh about six inches beneath the preceding; and these are to be connected together by a vertical one carried along the inner side of the thigh (Fig. 338). These several incisions should divide merely the integument; this is to be reflected outward, when the superficial fascia will be exposed.

The **Superficial Fascia** forms a continuous layer over the whole of the thigh, consisting of areolar tissue, containing in its meshes much fat, and capable of being separated into two or more layers, between which are found the superficial vessels and nerves. It varies in thickness in different parts of the limb. In the groin it is thick, and the two layers are separated from one another by the superficial inguinal lymphatic glands, the internal saphenous vein, and several smaller vessels. One of these layers, the superficial, is continuous with the superficial fascia of the abdomen.

The superficial layer should be detached by dividing it across in the same direction as the external incisions; its removal will be facilitated by commencing at the lower and inner angle of the space, detaching it at first from the front of the internal saphenous vein, and dissecting it off from the anterior surface of that vessel and its tributaries; it should then be reflected outward in the same manner as the integument. The cutaneous vessels and nerves and superficial inguinal glands are then exposed, lying upon the deep layer of the superficial fascia. These are the internal saphenous vein and the superficial epigastric, superficial circumflex iliac, and superficial external pudic vessels, as well as numerous lymphatics, ascending with the saphenous vein to the inguinal glands.

The **internal or long saphenous vein** (Figs. 1138, 1139, and 1140) ascends along the inner side of the thigh, and, passing through the saphenous opening in the fascia lata, terminates in the femoral vein about an inch and a half below Poupart’s ligament (Fig. 1130). This vein receives at the saphenous opening the superficial epigastric, the superficial circumflex iliac, and the superficial external pudic veins. The **superficial external pudic artery** (superior) **arises** from the inner side of the femoral artery, and, after passing through the saphenous opening, courses inward across the spermatic cord, to be distributed to the integument on the lower part of the abdomen, the penis and scrotum in the male and the labium in the female, Anastomosing with branches of the internal pudic.

The **superficial epigastric artery** arises from the femoral about half an inch below Poupart’s ligament, and, passing through the saphenous opening in the fascia lata, ascends on to the abdomen, in the superficial fascia covering the External oblique muscle, nearly as high as the umbilicus. It distributes branches
to the superficial inguinal lymphatic glands, the superficial fascia, and the integument, anastomosing with branches of the deep epigastric and internal mammary arteries.

The **superficial circumflex iliac artery**, the smallest of the cutaneous branches, arises close to the preceding, and, piercing the fascia lata, runs outward, parallel with Poupart’s ligament, as far as the crest of the ilium, dividing into branches which supply the superficial inguinal lymphatic glands, the superficial fascia, and the integument of the groin, anastomosing with the deep circumflex iliac, and with the gluteal and external circumflex arteries.

**The Superficial Veins** (Fig. 1138).—The veins accompanying these superficial arteries are usually much larger than the arteries; they terminate in the internal or long saphenous vein at the saphenous opening.

**The superficial inguinal lymphatic glands.**—See p. 791.

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**Fig. 1138.**—Femoral hernia. Superficial dissection.

The **ilio-inguinal nerve** arises from the first lumbar nerve. It escapes at the external abdominal ring, and is distributed to the integument of the upper and inner part of the thigh—to the scrotum in the male and to the labium in the female. The size of this nerve is in inverse proportion to that of the ilio-hypogastric nerve. Occasionally it is very small, and ends by joining the ilio-hypogastric; in such cases a branch of the ilio-hypogastric takes the place of the ilio-inguinal, or the latter nerve may be altogether absent. The **crural branch of the genitofemoral nerve** passes along the inner margin of the Psoas muscle, beneath Poupart’s ligament, into the thigh, entering the sheath of the femoral vessels, and lying
superficial and a little external to the femoral artery. It pierces the anterior layer of the sheath of the vessels, and, becoming superficial by passing through the fascia lata, it supplies the skin of the anterior aspect of the thigh as far as midway between the pelvis and knee. On the front of the thigh it communicates with the outer branch of the middle cutaneous nerve, derived from the femoral.

The **Deep Layer of the Superficial Fascia** is a very thin fibrous layer, best marked on the inner side of the long saphenous vein and below Poupart’s ligament. It is placed beneath the subcutaneous vessels and nerves, and upon the surface of the fascia lata, to which it is intimately adherent at the lower margin of Poupart’s ligament. It covers the saphenous opening in the fascia lata, is closely united to its circumference, and is connected to the sheath of the femoral vessels corresponding to its under surface. The portion of fascia covering this aperture is perforated by the internal saphenous vein and by numerous blood- and lymphatic vessels; hence it has been termed the *cribriform fascia*, the openings for these vessels having been likened to the holes in a sieve. The cribriform fascia adheres closely both to the superficial fascia and to the fascia lata, so that it is described by some anatomists as a part of the fascia lata, but it is usually considered (as in this work) as belonging to the superficial fascia. It is not till the cribriform fascia has been cleared away that the saphenous opening is seen, so that this opening does not in ordinary cases exist naturally, but is the result of dissection (p. 515). A femoral hernia in passing through the saphenous opening receives the cribriform fascia as one of its coverings.

Fig. 1139.—Femoral hernia, showing fascia lata and saphenous opening.
The deep layer of superficial fascia, together with the criciform fascia, having been removed, the fascia lata is exposed.

The Fascia Lata has been already described with the muscles of the front of the thigh (p. 515). At the upper and inner part of the thigh, a little below Poupart's ligament, a large oval-shaped aperture is observed after the superficial fascia has been cleared away; it transmits the internal saphenous vein and other smaller vessels, and is called the saphenous opening (Fig. 1130). In order the more correctly to consider the mode of formation of this aperture, the fascia lata in this part of the thigh is described as consisting of two portions, an iliac portion and a pubic portion.

The iliac portion (Fig. 1139) is all that part of the fascia lata on the outer side of the saphenous opening. It is attached externally to the crest of the ilium and its anterior superior spine; to the whole length of Poupart's ligament; and to the pectineal line in conjunction with Gimbernat's ligament. From the spine of the os pubis it is reflected downward and outward, forming an arched margin, the outer boundary or falciform process or superior cornu (cornu superius) (Fig. 1139) of the saphenous opening. This margin overlies and is adherent to the anterior layer of the sheath of the femoral vessels; to its edge is attached the criciform fascia, and below it is continuous with the pubic portion of the fascia lata.

The pubic portion of the fascia lata or the pectineal fascia (Fig. 1139) is situated at the inner side of the saphenous opening; at the lower margin of this aperture it is continuous with the iliac portion; traced upward, it covers the surface of the Pectineus, Adductor longus, and Gracilis muscles; and, passing behind the

![Image of Femoral Hernia](image-url)
sheath of the femoral vessels, to which it is loosely united, is continuous with the sheath of the Psoas and Iliacus muscles, and is attached above to the iliopsoas the fascia covering the iliopsoas muscle. From the description it may be observed that the iliac portion of the fascia lata passes in front of the femoral vessels and the pubic portion behind them, so that an apparent aperture consequently exists between the two, through which the internal saphenous vein joins the femoral vein.

The **Saphenous Opening** (fossa ovalis) (Figs. 1130, 1138, 1139, and 1140) is an oval-shaped aperture measuring about an inch and a half in length and half an inch in width. It is situated at the upper and inner parts of the front of the thigh, below Poupart’s ligament, and is directed obliquely downward and outward. It is covered by the **cribriform fascia** (fascia cribrosa), a portion of the deep layer of the superficial fascia of the thigh, and which extends from the falciform margin to the pubic portion of the fascia lata or the pectineal fascia.

The **outer margin** of the saphenous opening is of a semilunar form, thin, strong, sharply defined, and lies on a plane considerably anterior to the inner margin. If this edge is traced upward, it will be seen to form a curved elongated process, the falciform process or **superior cornu** (Fig. 1139), which ascends in front of the femoral vessels, and, curving inward, is attached to Poupart’s ligament and to the spine of the os pubis and pectineal line, where it is continuous with the pubic portion. If traced downward, it is found continuous with another curved margin, the concavity of which is directed upward and inward; this is the inferior cornu of the saphenous opening, and is blended with the pubic portion of the fascia lata covering the Pectineus muscle.

The **inner boundary of the opening** (Figs. 1130 and 1139) is on a plane posterior to the outer margin and behind the level of the femoral vessels; it is much less prominent and defined than the outer, from being stretched over the subjacent Pectineus muscle. It is through the saphenous opening that a femoral hernia passes after descending along the crural canal.

If the finger is introduced into the saphenous opening while the limb is moved in different directions, the aperture will be found to be greatly constricted on extending the limb or rotating it outward, and to be relaxed on flexing the limb and inverting it; hence the necessity for placing the limb in the latter position in employing the two for the reduction of a femoral hernia.

The iliac portion of the fascia lata, but not its falciform process, should now be removed by detaching it from the lower margin of Poupart’s ligament, carefully dissecting it from the subjacent structures, and turning it inward, when the sheath of the femoral vessels is exposed, descending beneath Poupart’s ligament (Fig. 1140).

**Poupart’s Ligament** (ligamentum inguinale [Poupart]) (Figs. 288, 1130, 1133, 1134, 1136, 1139, 1140, 1141, and 1142) is the lower border of the aponeurosis of the External oblique muscle, which extends from the anterior superior spine of the ilium to the spine of the os pubis. From this latter point it is reflected outward, to be attached to the pectineal line for about half an inch, forming **Gimbernat’s ligament**. Its general direction is curved downward toward the thigh, where it is continuous with the fascia lata. Its outer half is rounded and oblique in direction. Its inner half gradually widens at its attachment to the os pubis, is more horizontal in direction, and lies beneath the spermatic cord. Nearly the whole of the space included between Poupart’s ligament and the innominate bone is filled in by the parts which descend from the abdomen into the thigh (Figs. 296, 338, and 1141). The outer half of the space (lacuna musculorum) is occupied by the Iliacus and Psoas muscles, together with the external cutaneous and femoral nerves. The pubic half of the space (lacuna vasorum) is occupied by the femoral vessels included in their sheath, a small oval-shaped interval existing between the femoral vein and the inner wall of the sheath,
which is occupied merely by a little loose areolar tissue, a few lymphatic vessels, and occasionally by a small lymphatic gland; this is the femoral ring, through which the gut descends in femoral hernia. The part of Poupart’s ligament in front of the femoral or crural ring is called the **superficial crural arch**.

**Gimbernat’s Ligament** (ligamentum lacunare [Gimbernati]) (Figs. 296, 338, 1130, 1141, and 1142) is that part of the aponeurosis of the External oblique muscle which is reflected backward and outward from the spine of the os pubis, to be inserted into the pectineal line. It is about half an inch in length, larger in the male than in the female, almost horizontal in direction in the erect posture, and of a triangular form, with the base directed outward. Its **base or outer margin** is concave, thin, and sharp, and lies in contact with the femoral sheath. Its **apex** corresponds to the spine of the os pubis. Its **posterior margin** is attached to the pectineal line, and is continuous with the pubic portion of the fascia lata. Its **anterior margin** is continuous with Poupart’s ligament.

**Femoral Sheath** (Fig. 1141).—The femoral or **crural sheath** is a continuation downward of the fasciae that line the abdomen, the **transversalis fascia** passing down in front of the femoral vessels, and the **iliac fascia** descending behind them; these fasciae are directly continuous on the iliac side of the femoral artery, but a small space exists between the femoral vein and the point where they are continuous on the pubic side of that vessel, which constitutes the **femoral or crural canal** (Fig. 1130). The femoral sheath is closely adherent to the contained vessels about an inch below the saphenous opening, being blended with the areolar sheath of the vessels, but opposite Poupart’s ligament it is much larger than is required to contain them; hence the funnel-shaped form which it presents. The outer border of the sheath...
FEMORAL HERNIA

is perforated by the femoral nerve. Its inner border is pierced by the internal saphenous vein and numerous lymphatic vessels. In front it is covered by the iliac portion of the fascia lata; and behind it is the pubic portion of the same fascia.

If the anterior wall of the sheath is removed (Fig. 1130), the femoral artery and vein are seen lying side by side, a thin septum separating the two vessels, while another septum may be seen lying just internal to the vein, and cutting off a small space between the vein and the inner wall of the sheath. The septa are stretched between the anterior and posterior walls of the sheath, so that each vessel is enclosed in a separate compartment. The interval left between the vein and the inner wall of the sheath is not filled up by any structure, excepting a little loose areolar tissue, a few lymphatic vessels, and occasionally by a small lymphatic gland; this is the femoral or crural canal (Fig. 1130), through which the intestine descends in femoral hernia.

Deep Crural Arch.—Passing across the front of the femoral sheath on the abdominal side of Poupart's ligament, and closely connected with it, is a thickened band of fibres of the transversalis fascia, called the deep crural arch. It is apparently a thickening of the transversalis fascia, joining externally to the centre of Poupart's ligament, and arching across the front of the crural sheath, to be inserted by a broad attachment into the pectineal line behind the conjoined tendon. In some subjects this structure is not very prominently marked, and not infrequently it is altogether wanting. The superficial crural arch is the portion of Poupart's ligament in front of the femoral ring.

The Femoral or Crural Canal (canalis femoralis) (Figs. 296, 338, and 1130) is the narrow interval between the femoral vein and the inner wall of the femoral sheath. It exists as a distinct canal only when the sheath has been separated from the vein by dissection or by the pressure of a hernia or tumor. Its length is from a quarter to half an inch, and it extends from the femoral ring to the upper part of the saphenous opening.

Its anterior wall is very narrow, and formed by a continuation downward of the transversalis fascia, under Poupart's ligament, covered by the falciform process of the fascia lata.

Its posterior wall is formed by a continuation downward of the iliac fascia covering the pubic portion of the fascia lata.

Its outer wall is formed by the fibrous septum separating it from the inner side of the femoral vein.

Its inner wall is formed by the junction of the processes of the transversalis and iliac fasciae, which form the inner side of the femoral sheath, and lies in contact at its commencement with the outer edge of Gimbernat's ligament.

This canal has two orifices—an upper one, the femoral or crural ring, closed by the septum crurale; and a lower one, the saphenous opening, closed by the cribiform fascia.

The femoral or crural ring (annulus femoralis) (Figs. 1130, 1141, and 1142) is the upper opening of the femoral canal, and leads into the cavity of the abdomen. It is bounded in front by Poupart's ligament and the deep crural arch; behind, by the os pubis, covered by the Pectineus muscle and the pubic portion of the fascia lata; internally, by the base of Gimbernat's ligament, the conjoined tendon, the transversalis fascia, and the deep crural arch; externally, by the fibrous septum lying on the inner side of the femoral vein. The femoral ring is of an oval form; its long diameter, directed transversely, measures about half an inch, and it is larger in the female than in the male, which is one of the reasons of the greater frequency of femoral hernia in the former sex.

Position of Parts around the Ring.—The spermatic cord in the male and round ligament in the female lie immediately above the anterior margin of the
THE SURGICAL ANATOMY OF HERNIA

femoral ring, and may be divided in an operation for femoral hernia if the incision for the relief of the stricture is not of limited extent. In the female this is of little importance, but in the male the spermatic artery and vas deferens may be divided.

The femoral vein lies on the outer side of the ring.

The deep epigastric artery in its passage upward and inward from the external iliac artery passes across the upper and outer angle of the crural ring, and is consequently in danger of being wounded if the stricture is divided in a direction upward and outward.

The communicating branch between the deep epigastric and obturator lies in front of the ring.

The circumference of the ring is thus seen to be bounded by vessels in every part, excepting internally and behind (Fig. 1142). It is in the former position that the stricture is divided in cases of strangulated femoral hernia.

The obturator artery (p. 689), when it arises by a common trunk with the deep epigastric (p. 690), which occurs once in every three subjects and a half, bears a very important relation to the crural ring. In most cases it descends on the

inner side of the external iliac vein to the obturator foramen, and will consequently lie on the outer side of the crural ring, where there is no danger of its being wounded in the operation for dividing the stricture in femoral hernia (Fig. 429 A, p. 690). Occasionally, however, the obturator artery curves along the free margin of Gimbernat’s ligament in its passage to the obturator foramen; it would consequently skirt along the greater part of the circumference of the crural ring, and could hardly avoid being wounded in the operation (Fig. 429 B, p. 690).

The Crural Septum or Septum Crurale (septum femorale musculus) (Fig. 296).—The femoral ring is closed by a thin process of transversalis fascia containing fat and called, by J. Cloquet, the septum crurale. This serves as a barrier to the protrusion of a hernia through this part. Its upper surface is slightly concave, and supports a small lymphatic gland (Fig. 1142), by which it is separated from the subserous areolar tissue and peritoneum. Its under surface is turned toward the femoral canal. The septum crurale is perforated by numerous apertures for the passage of lymphatic vessels connecting the deep inguinal lymphatic glands with those surrounding the external iliac artery.

![Fig. 1142.—Hernia. The relations of the femoral and internal abdominal rings, seen from within the abdomen. Right side.](image-url)
The size of the femoral canal, the degree of tension of its orifices, and consequently the degree of constriction of a hernia, vary according to the position of the limb. If the leg and thigh are extended, abducted, or everted, the femoral canal and its orifices are rendered tense from the traction on these parts by Poupart's ligament and the fascia lata, as may be ascertained by passing the finger along the canal. If, on the contrary, the thigh is flexed upon the pelvis, and at the same time adducted and rotated inward, the femoral canal and its orifices become considerably relaxed; for this reason the limb should always be placed in the latter position when the application of the taxis is made in attempting the reduction of a femoral hernia.

The subperitoneal areolar tissue is continuous with the subserous areolar tissue of surrounding parts. It is usually thickest and most fibrous where the iliac vessels leave the abdominal cavity. It covers over the femoral ring, the small interval on the inner side of the femoral vein. In some subjects it contains a considerable amount of adipose tissue. In such cases, where it is protruded forward in front of the sac of a femoral hernia, it may be mistaken for a portion of omentum. The peritoneum lining the portion of the abdominal wall between Poupart's ligament and the brim of the pelvis is similar to that lining any other portion of the abdominal wall, being very thin. Here there is no natural aperture for the escape of intestine.

Descent of the Hernia.—From the preceding description it follows that the femoral ring must be a weak point in the abdominal wall; hence it is that when violent or long-continued pressure is made upon the abdominal viscera a portion of intestine may be forced into it, constituting a femoral hernia; and the changes in the tissues of the abdomen which are produced by pregnancy, together with the larger size of this aperture in the female, serve to explain the frequency of this form of hernia in women.

When a portion of the intestine passes through the femoral ring, a pouch of peritoneum lies before it, which forms what is called the hernial sac; it is covered by the subserous areolar tissue, receives an investment from the septum crurale, and descends vertically along the crural canal in the inner compartment of the sheath of the femoral vessels as far as the saphenous opening; at this point it changes its course, being prevented from extending farther down the sheath on account of the narrowing of the sheath and its close contact with the vessels, and also from the close attachment of the superficial fascia and crural sheath to the lower part of the circumference of the saphenous opening; the hernia is consequently directed forward, pushing before it the cribriform fascia, and then curves upward on to the fallopian process of the fascia lata and lower part of the tendon of the External oblique, being covered by the superficial fascia and integument. While the hernia is contained in the femoral canal it is usually of small size, owing to the resisting nature of the surrounding parts; but when it has escaped from the saphenous opening into the loose areolar tissue of the groin, it becomes considerably enlarged. The direction taken by a femoral hernia in its descent is at first downward, then forward and upward; this should be borne in mind, as in the application of the taxis for the reduction of a femoral hernia pressure should be directed in the reverse order.

Coverings of the Complete Hernia.—The coverings of a femoral hernia, from within outward, are—peritoneum, subserous areolar tissue, the septum crurale, crural sheath, cribriform fascia, superficial fascia, and integument.¹

¹ Sir Astley Cooper has described an investment for femoral hernia, under the name of "fascia propria," lying immediately external to the peritoneal sac, but frequently separated from it by more or less adipose tissue. Surgically, it is important to remember the existence (at any rate, the occasional existence) of this layer, on account of the ease with which an inexperienced operator may mistake the fascia for the peritoneal sac and the contained fat for omentum. Anatomically, this fascia appears identical with what is called in the text "subserous areolar tissue," the areolar tissue being thickened and caused to assume a membranous appearance by the pressure of the hernia.—En. of 15th English edition.
Varieties of Femoral Hernia.—If the hernia descends along the femoral canal only as far as the saphenous opening, and does not escape from this aperture, the condition is called incomplete femoral hernia. The small size of the protrusion in this form of hernia, which is due to the firm and resisting nature of the canal in which it is contained, renders it an exceedingly dangerous variety, from the extreme difficulty of detecting the existence of the swelling, especially in corpulent subjects. The coverings of an incomplete femoral hernia, named from without inward, are as follows: the integument, superficial fascia, iliac portion of fascia lata, crural sheath, septum crurale, subserous areolar tissue, and peritoneum. When, however, the hernia protrudes through the saphenous opening and directs itself forward and upward, it forms a complete femoral hernia, the coverings of which have been given (p. 1533). Occasionally the hernial sac descends on the iliac side of the femoral vessels or in front of these vessels, or even sometimes behind them.

The seat of stricture in a strangulated femoral hernia varies; it may be in the peritoneum at the neck of the hernial sac; in the greater number of cases it would appear to be at the point of junction of the falciform process of the fascia lata with the lunated edge of Gimbernat's ligament, or at the margin of the saphenous opening in the thigh. The stricture should in every case be divided in an inward direction, or upward and inward, and the extent of the necessary cut in the majority of cases is about two or three lines. By these means all vessels or other structures of importance in relation with the neck of the hernial sac will be avoided.
SURGICAL ANATOMY OF THE PERINÆUM.

Dissection.—The student should select a well-developed muscular subject, free from fat, and the dissection should be commenced early, in order that the parts may be examined in as recent a state as possible. A staff having been introduced into the bladder and the subject placed in the position shown in Fig. 1143, the scrotum should be raised upward, and retained in that position, and the rectum moderately distended with tow.

The Perinæum corresponds to the inferior aperture or outlet of the pelvis. Its deep boundaries are, in front, the pubic arch and subpubic ligament; behind, the tip of the coccyx; and on each side, the rami of the os pubis and ischium, the tuberosities of the ischium, and great sacro-sciatic ligaments. The space included by these boundaries is somewhat lozenge-shaped, and is limited on the surface of the body by the scrotum in front, by the buttocks behind, and on each side by the inner side of the thigh. A line drawn transversely between the anterior parts of the tuberosities of the ischium, on each side, in front of the anus, divides this space into two portions. The anterior portion contains the penis and urethra, and is called the perinæum proper or genito-urinary region. The posterior portion contains the termination of the rectum, and is called the ischio-rectal or anal region.

ISCHIO-RECTAL REGION.

The ischio-rectal region contains the termination of the rectum and a deep fossa, filled with fat, on each side of the intestine, between it and the tuberosity of the ischium; this is called the ischio-rectal fossa.

The ischio-rectal region presents in the middle line the aperture of the anus; around this orifice the integument is thrown into numerous folds, which are obliterated on distention of the anus. The integument is of a dark color, continuous with the mucous membrane of the rectum, and is provided with numerous
Dissection (Fig. 1143).—Make an incision through the integument, along the median line, from the base of the scrotum to the anterior extremity of the anus: carry it around the margins of this aperture to its posterior extremity, and continue it backward to about an inch behind the tip of the coccyx. A transverse incision should now be carried across the base of the scrotum, joining the anterior extremity of the preceding; a second, carried in the same direction, should be made in front of the anus; and a third at the posterior extremity of the first incision. These incisions should be sufficiently extensive to enable the dissector to raise the integument from the inner side of the thighs. The flaps of skin corresponding to the ischio-rectal region should now be removed. In dissecting the integument from this region great care is required, otherwise the Corrugator cutis ani and External sphincter will be removed, as they are intimately adherent to the skin.

The **Superficial Fascia** is exposed on the removal of the skin; it is very thick, areolar in texture, and contains much fat in its meshes. In it are found ramifying two or three branches of the perforating cutaneous nerve; these turn around the inferior border of the Gluteus maximus and are distributed to the integument around the anus.

In this region, and connected with the lower end of the rectum, are four muscles: the Corrugator cutis ani; the two Sphincters, External and Internal; and the Levator ani.

These muscles have been already described (p. 451).

The **Ischio-rectal Fossa** (fossa ischiorectalis) (Figs. 299 and 303) is situated between the end of the rectum and the ischial tuberosity. It is triangular in shape; its base, directed to the surface of the body, is formed by the integument of the ischio-rectal region; its apex, directed upward, corresponds to the point of division of the obturator fascia and the thin membrane given off from it, which covers the outer surface of the Levator ani (ischio-rectal or anal fascia). Its dimensions are about an inch in breadth at the base and about two inches in depth, being deeper behind than in front. It is bounded, internally, by the Sphincter ani, Levator ani, and Coccygeus muscles; externally, by the tuberosity of the ischium and the obturator fascia, which covers the inner surface of the Obturator internus muscle; in front, it is limited by the line of junction of the superficial fascia with the base of the triangular ligament; and behind, by the margin of the Gluteus maximus muscle and the great sacro-sciatic ligament. This space is filled with a large mass of adipose tissue, which explains the frequency with which abscesses in the neighborhood of the rectum burrow to a considerable depth.

If the subject has been injected, on placing the finger on the outer wall of this fossa the internal pudic artery, with its accompanying veins and the two divisions of the nerve, will be felt about an inch and a half above the margin of the ischial tuberosity, but approaching nearer the surface as they pass forward along the inner margin of the pubic arch. These structures are enclosed in a sheath, the [fascial canal or canal of Alcock](Figs. 303 and 1148), formed by the obturator fascia, the pudic nerve lying below the artery and the dorsal nerve of the penis above it. Crossing the space transversely, about its centre are the inferior hemorrhoidal vessels and nerves, which are distributed to the integument of the anus and to the muscles of the lower end of the rectum. These vessels are occasionally of large size, and may give rise to troublesome hemorrhage when divided in the operation of lithotomy or in that for fistula in ano. At the back part of this space, near the coccyx, may be seen a branch of the fourth sacral nerve, and at the forepart of the space the superficial perineal vessels and nerves can be seen for a short distance.
THE PERINEUM PROPER IN THE MALE.

The perineal space is of a triangular form; its deep boundaries are limited, laterally, by the rami of the pubic bones and ischia, meeting in front at the pubic arch; behind, by an imaginary transverse line extending between the anterior parts of the tuberosities of the ischia. The lateral boundaries are, in the adult, from three inches to three inches and a half in length, and the base from two to three inches and a half in breadth, the average extent of the space being two inches and three-quarters.

The variations in the diameter of this space are of extreme interest in connection with the operation of lithotomy and the extraction of a stone from the cavity of the bladder. In those cases where the tuberosities of the ischia are near together it would be necessary to make the incisions in the lateral operation of lithotomy less oblique than if the tuberosities were widely separated, and the perineal space consequently wider. The perineum is subdivided by the median raphe into two equal parts. Of these, the left is the one in which the operation of lithotomy is performed.

In the middle line the perineum is convex, and corresponds to the bulb of the urethra. The skin covering it is of a dark color, thin, freely movable upon the subjacent parts, and covered with sharp crisp hairs, which should be removed before the dissection of the part is commenced. In front of the anus a prominent line commences, the raphe, continuous in front with the raphe of the scrotum. The skin of the raphe is adherent to the deep layer of the superficial fascia.

Upon removing the skin and the superficial layer of the superficial fascia, in the manner shown in Fig. 1143, a plane of fascia will be exposed, covering in the triangular space and stretching across from one ischio-pubic ramus to the other. This is the deep layer of the superficial fascia or fascia of Colles (fascia superficialis perinaei). It has already been described (p. 458). It is a layer of considerable strength, and encloses and covers a space in which are contained muscles, vessels, and nerves. It is continuous in front with the fascia of the penis and the dartos of the scrotum; on each side it is firmly attached to the margin of the ischio-pubic ramus and to the tuberosity of the ischium; and posteriorly it curves down behind the Transversalis perinaei muscles to join the base of the triangular ligament.

It is between this layer of fascia and the triangular ligament of the urethra that extravasation of urine most frequently takes place in cases of rupture of the urethra. The triangular ligament of the urethra (p. 461) is attached to the ischio-pubic rami, and in front to the subpubic ligament. It is clear, therefore, that when extravasation of fluid takes place between these two layers, it cannot pass backward, because the two layers are continuous with each other around the Transversi perinaei muscles; it cannot extend laterally, on account of the connection of both these layers to the rami of the os pubis and ischium; it cannot find its way into the pelvis because the opening into this cavity is closed by the triangular ligament, and, therefore, so long as these two layers remain intact, the only direction in which the fluid can make its way is forward into the areolar tissue of the scrotum and penis, and then on to the anterior wall of the abdomen.

When the deep layer of the superficial fascia is removed (Fig. 1144), a space is exposed, between this fascia and the triangular ligament, in which are contained the superficial perineal vessels and nerves and some of the muscles connected with the penis and urethra—viz., in the middle line, the Accelerator urinae; on each side, the Erector penis; and behind, the transversus perinaei; together with the crura of the corpora cavernosa and the bulb of the corpus spongiosum. Here also is seen the central tendinous point of the perineum. This is a fibrous point in the middle line of the perineum between the urethra and the rectum, being about half an inch in front of the anus. At this point four muscles converge and are attached—viz., the External sphincter ani, the Accelerator urinae, and the two Transversi perinaei
muscles; so that by the contraction of these muscles, which extend in opposite directions, it serves as a fixed point of support.

The Accelerator urinae, the Erector penis, and the Superficial transversus perinaei muscles have been already described (p. 459). They form a triangular space (Fig. 1144), bounded, internally, by the Accelerator urinae; externally, by the Erector penis; and behind, by the Transversus perinaei. The floor of this space is formed by the triangular ligament of the urethra; and running from behind forward in it are the superficial perineal vessels and nerves, and the transverse perineal artery coursing along the posterior boundary of the space, on the Transversus perinaei muscle.

The Accelerator urinae and Erector penis should now be removed, when the triangular ligament of the urethra will be exposed, stretching across the front of the outlet of the pelvis. The urethra is seen perforating its centre, just behind the bulb; and on each side is the crus penis, connecting the corpus cavernosum with the rami of the ischium and os pubis.

The Triangular Ligament or the Deep Perineal Fascia (trigonum urogenitale or diaphragma urogenitale) (Figs. 308, 309, and 1145), which has been already described (p. 461), consists of two layers, the inferior anterior or superficial layer (fascia trigoni urogenitalis inferior) of which is now exposed. It is united to the superior or deep layer behind, but is separated in front by a subfascial space in which are contained certain structures.

The inferior layer of the triangular ligament (Figs. 304 and 309) consists of a strong fibrous membrane, the fibres of which are disposed transversely, which stretches across from one ischio-pubic ramus to the other and completely fills in the pubic arch; it is attached in front to the subpubic ligament, except just in the centre, where a small interspace is left for the dorsal vein of the penis. In the erect position of the body it is almost horizontal. It is perforated by the urethra in the middle line, and on each side of the urethral opening by the ducts of Cowper's glands and by the arteries of the bulb; in front, and external to this, by the artery
of the corpus cavernosum, immediately before this vessel enters the crus penis. Near its apex the ligament is perforated by the termination of the pudic artery and by the dorsal nerve of the penis. The apex of the triangular ligament is known as the transverse perineal ligament. The crura penis are exposed, lying superficial to this ligament. They will be seen to be attached by blunt-pointed processes to the rami of the os pubis and ischium, in front of the tuberosities, and passing forward and inward, joining to form the body of the penis. In the middle line the bulb and corpus spongiosum are exposed by the removal of the Accelerator urinae muscle.

If the inferior layer of the triangular ligament is detached on either side, the deep perineal interspace will be exposed and the following parts will be seen between it and the deep layer of the ligament: the subpubic ligament in front, close to the symphysis pubis; the dorsal vein of the penis; the membranous portion of the urethra and the Compressor urethrae muscle; Cowper’s glands and their ducts; the pudic vessels and the dorsal nerve of the penis; the artery and nerve of the bulb and a plexus of veins.

![Diagram](image_url)

Fig. 1145.—Deep perineal fascia. On the left side the anterior layer has been removed.

The superior, deep, or posterior layer of the triangular ligament or deep perineal fascia (fascia trigoni urogenitalis superior) (Fig. 304) is derived from the obturator fascia, and is continuous with it along the pubic arch. Behind, it joins with the inferior layer of the triangular ligament, and is continuous with the anal fascia. Above it is the prostate gland (Fig. 1146), supported by the anterior fibres of the Levator ani, which act as a sling for the gland and form the Levator prostatae muscle. The superior layer of the triangular ligament is continuous around the anterior free edge of this muscle with the layer of recto-vesical fascia covering the prostate gland. The superior layer of the triangular ligament is perforated by the urethra. Between the two layers of the triangular ligament are situated the membranous part of the urethra, enveloped by the Compressor urethrae muscle (Fig. 309); the ducts of Cowper’s glands; the arteries to the bulb; the pudic vessels and the dorsal nerve of the penis. The membranous part of the urethra is about three-quarters of an inch in length, and passes downward and
forward behind the symphysis pubis, from which it is distant about an inch. It is the narrowest part of the tube, and is enveloped, as has already been stated, by the Compressor urethrae muscle.

The Compressor urethrae has already been described (p. 460). In addition to this muscle, and immediately beneath it, circular muscular fibres surround the membranous portion of the urethra from the bulb in front to the prostate behind, and are continuous with the muscular fibres of the bladder. These fibres are involuntary.

Cowper's glands (Figs. 302, 1145, and 1146) are situated immediately below the membranous portion of the urethra, close behind the bulb, and below the artery of the bulb.

The Pudic Vessels (Figs. 1145 and 1146) and Dorsal Nerve of the Penis (Fig. 309) are placed along the inner margin of the pubic arch (p. 1548).

The Artery of the Bulb (Figs. 1145 and 1146, and p. 692) passes transversely inward, from the internal pudic artery (p. 690) along the base of the triangular ligament, between its two layers, accompanied by a branch of the pudic nerve. If the superior layer of the triangular ligament is removed and the crus penis of one side detached from the bone, the under or perineal surface of the Levator ani muscle, covered by the anal fascia, is brought fully into view (Figs. 301, 302, and 303). This muscle, with the triangular ligament in front and the Coccygeus and Pyriformis behind, closes the outlet of the pelvis.

The Levator ani and Coccygeus muscles have already been described (p. 453).

Position of the Viscera at the Outlet of the Pelvis.—Divide the central tendinous point of the perineum, separate the rectum from its connections by dividing the fibres of the Levator ani, which descend upon the sides of the prostate gland, and draw the gut backward toward the coccyx, when the under surface of the prostate gland, the neck and base of the bladder, the vesicule seminales, and the vasa deferentia will be exposed.

The Prostate Gland (p. 1141) is a pale, firm, glandular body which is placed immediately below the neck of the bladder, around the commencement of the
urethra. It is placed in the pelvic cavity, behind the lower part of the symphysis pubis, above the superior layer of the triangular ligament, and rests upon the rectum, through which it may be distinctly felt, especially when enlarged. In shape and size it resembles a chestnut. Its base is directed upward toward the neck of the bladder. Its apex is directed downward to the deeper layer of the triangular ligament, which it touches.

Its posterior surface is smooth, marked by a slight longitudinal furrow, and rests on the second part of the rectum, to which it is connected by areolar tissue. Its anterior surface is flattened, marked by a slight longitudinal furrow, and placed about three-quarters of an inch below the pubic symphysis. It measures about an inch and a half in its transverse diameter at the base, an inch in its anteroposterior diameter, and three-quarters of an inch in depth. Hence the greatest extent of incision that can be made in it without dividing its substance completely across is obliquely backward and outward. This is the direction in which the incision is made in it in the lateral operation of lithotomy. The prostate has a sheath derived from the recto-vesical fascia (p. 1459).

Above the prostate a small triangular portion of the bladder is seen (Fig. 1147), bounded, in front and below, by the prostate gland; above, by the recto-vesical fold of the peritoneum; on each side, by the seminal vesicle and the vas deferens. It is separated from direct contact with the rectum by the recto-vesical fascia. The relation of this portion of the bladder to the rectum is of extreme interest to the surgeon. In cases of retention of urine this portion of the organ is found projecting into the rectum, between three and four inches from the margin of the anus, and may be easily perforated without injury to any important parts. This portion of the bladder was consequently selected in the old days for the performance of the now obsolete operation of tapping the bladder.

**Surgical Anatomy.** **Median Lithotomy.**—As the incision is in the raphé, the hemorrhage is trivial, and there is but slight risk of injuring the pelvic fascia. But the operation gives little room for manipulation and is inadmissible in children, because in them dilatation of the wound may tear the bladder loose from the urethra. A risk of median lithotomy is division of the artery of the bulb.

In median lithotomy a grooved staff is introduced, the groove being median. The knife is introduced in the mid-line, just in front of the anal margin, and hits the staff near the apex of the prostate; the entire length of the membranous urethra is cut as the instrument is withdrawn.

**Parts Divided.**—Skin, superficial fascia, sphincter ani muscle, central tendon of the perineum, inferior leaf of the triangular ligament, membranous urethra, and the Compressor urethrae muscle.

**Lateral Lithotomy.**—The operation is performed on the left side of the perineum, as this is most convenient for the right hand of the operator. A grooved staff having been introduced into the bladder, the first incision is commenced midway between the anus and the back of the scrotum (i.e., in an ordinary adult perineum about an inch and a half in front of the anus) a little on the left side of the raphé, and is carried obliquely backward and outward to midway between the anus and tuberosity of the left ischium. The incision divides the integument and superficial fascia, the inferior hemorrhoidal vessels and nerves, and the superficial and transverse perineal vessels. If the forefinger of the left hand is thrust upward and forward into the wound, pressing at the same time the rectum inward and backward, the staff may be felt in the membranous portion of the urethra. The finger is fixed upon the staff, and the structures covering the staff are divided with the point of the knife, which must be directed along the groove toward the bladder, the edge of the knife being turned outward and backward, dividing in its course the membranous portion of the urethra and part of the left lobe of the prostate gland to the extent of about an inch. The knife is then withdrawn, and the forefinger of the left hand passed along the staff into the bladder. The position of the stone having been ascertained, the staff is to be withdrawn, and the forceps is introduced over the finger into the bladder. If the stone is very large, the opposite side of the prostate may need to be notched before the forceps is introduced; the finger is now withdrawn, and the blades of the forceps opened and made to grasp the stone, which must be extracted by slow and cautious undulating movements.

**Parts Divided in the Operation.**—The various structures divided in this operation are as follows: the integument, superficial fascia, inferior hemorrhoidal vessels and nerves, and prob-
ably the superficial perineal vessels and nerves, the posterior fibres of the Accelerator urinæ muscle, the Transversus perinæi muscle and artery, the triangular ligament, the anterior fibres of the Levator ani muscle, part of the Compressor urethrae muscle, the membranous and prostatic portions of the urethra, and part of the prostate gland.

Parts to be Avoided in the Operation.—In making the necessary incisions in the perineum for the extraction of a calculus the following parts should be avoided: The primary incision should not be made too near the middle line, for fear of wounding the bulb of the corpus spongiosum or the rectum; nor too far externally, otherwise the internal pudic artery may be implicated as it ascends along the inner border of the pubic arch. If the incisions are carried too far forward, the artery of the bulb may be divided; if carried too far backward, the entire breadth of the prostate and neck of the bladder may be cut through, which allows the urine to become infiltrated behind the pelvic fascia into the loose areolar tissue between the bladder and rectum, instead of escaping externally; diffuse inflammation is consequently set up, and peritonitis, from the close proximity of the recto-vesical peritoneal fold, is the result. If, on the contrary, only the anterior part of the prostate is divided, the urine makes its way externally, and there is less danger of infiltration taking place.

During the operation it is of great importance that the finger should be passed into the bladder before the staff is removed; if this is neglected, and if the incision made in the prostate and neck of the bladder is too small, great difficulty may be experienced in introducing the finger afterward; and in the child, where the connections of the bladder to the surrounding parts are very loose, the force made in the attempt is sufficient to displace the bladder upward into the abdomen, out of the reach of the operator. Such a proceeding has not unfrequently occurred, producing the most embarrassing results and total failure of the operation.

It is necessary to bear in mind that the arteries in the perineum occasionally take an abnormal course. Thus the artery of the bulb, when it arises, as sometimes happens, from the pudic opposite the tuber ischii, is liable in its passage forward to the bulb to be wounded in the operation of lithotomy. The accessory pudic may be divided near the posterior border of the prostate gland, if this gland is completely cut across; and if the prostatic veins are of large size, and give rise, when divided, to troublesome hemorrhage. In men advanced in years the prostatic veins are very apt to be enlarged.

Extravasation of Urine.—Extravasation most commonly occurs from urethral rupture, between Colles's fascia and the triangular ligament of the urethra (extravasation in front of the triangular ligament). The adherence of these two fascial layers posteriorly prevents the urine from passing backward. The urine cannot find a way laterally, because both layers on each side are attached to the rami of the pubes and ischium. It cannot reach the pelvis, because the triangular ligament bars the way. It can only go forward if the two fascial layers remain intact, and consequently the urine passes into the areolar tissue of the serotum beneath the superficial fascia of the penis and of the anterior abdominal wall.

Pus and blood would pursue the same course in this space. Effusions in this space causes much pain, because the space contains the three long serotum nerves.

In rupture of the urethra between the two layers of the triangular ligament, the urine remains in this situation as long as fascia remains intact. If suppuration occurs, destruction of fascia liberates the urine.

In rupture behind the superior layer of the triangular ligament (extravasation back of the triangular ligament), the urine passes into the ischio-rectal fossa and upward and backward into the pelvis.

THE FEMALE PERINÆUM.

The female perinæum presents certain differences from that of the male, in consequence of the whole of the structures which constitute it being perforated in the middle line by the vulvo-vaginal passage.

The Superficial Fascia, as in the male, consists of two layers, of which the superficial one is continuous with the superficial fascia over the rest of the body, and the deep layer, corresponding to the fascia of Colles in the male, is, like it, attached to the ischio-rectal rami, and in front is continued forward through the labia majora to the inguinal region. It is of less extent than in the male, in consequence of being perforated by the aperture of the vulva.

On removing this fascia the muscles of the female perinæum, which have already been described (p. 463), are exposed (Figs. 310 and 1147). The Sphincter vaginae, corresponding to the Accelerator urinæ in the male, consists of an atten-
uated plane of fibres, forming an orbicular muscle around the orifice of the vagina, instead of being united in a median raphé, as in the male. The Erector clitoridis is proportionately reduced in size, but differs in no other respect from the erector penis, and the Transversus perinaei is similar to the muscle of the same name in the male.

The triangular ligament (Fig. 1147) is not strongly marked as in the male. It transmits the urethra and the tube of the vagina.

The Compressor Urethrae corresponds with the Compressor urethrae in the male. It arises from the ischio-pubic ramus, and, passing inward, its anterior fibres blend with the muscle of the opposite side, in front of the urethra; its middle fibres, the most numerous, are inserted into the side of the vagina, and the posterior fibres join the central point of the perineum.

The distribution of the internal pudic artery is the same as in the male (p.1552), and the pudic nerve has also a similar arrangement, the dorsal nerve being, however, very small and supplying the clitoris.

The corpus spongiosum is divided into two lateral halves, which are represented by the bulbi vestibuli and partes intermediales.

The Perineal Body fills up the interval between the lower part of the vagina and the rectum. Its base is covered by the skin lying between the anus and
vagina on what is called the perineum. Its anterior surface lies behind the posterior vaginal wall, and its posterior surface lies in front of the anterior rectal wall and the anus. It measures about an inch and a quarter from before backward, and laterally extends from one tuberosity of the ischium to the other. In it are situated the muscles belonging to the external organs of generation. Through its centre runs the transverse perineal septum, which is of great strength in women, and forms on either side, behind the posterior commissure, a hard, ill-defined body, consisting of connective tissue, with much yellow elastic tissue and interlacing bundles of involuntary muscular fibres, in which the voluntary muscles of the perineum are inserted.

**THE PELVIC FASCIA (FASCIA PELVIS) (Figs. 303 and 1149).**

The pelvic fascia strengthens the floor of the pelvis, fastens pelvic structures together, and supports the nerves, blood-vessels, and lymphatics. It is connected above with the transversalis fascia and the iliac fascia. It is at first a thin membrane and covers the inner surface of the pelvis, being attached to the brim for a short distance at the side of the cavity and to the inner surface of the bone around the attachment of the Obturator internus. At the posterior portion of this muscle it is continued backward as a very thin membrane in front of the Pyriformis muscle to the front of the sacrum. In front, as it descends, it gives off the parietal layer of the pelvic fascia, which continues as the obturator fascia. It then becomes thicker and covers the inner and upper surface of the Diaphragm of the pelvis as far as the white line (arcus tendineus fasciae pelvis). The portion covering the superior and upper surface of the pelvic Diaphragm is the inner sheath of the Levator ani muscle and is called the visceral layer of the pelvic fascia or the recto-vesical fascia (fascia diaphragmatic pelvis superior). The white line is a rough band of fascial thickening, seen in the pelvic fascia of each side. It indicates the line of separation between the pelvic cavity and the ischio-rectal fossa. It passes from the lower
portion of the symphysis pubis outward and backward to the spine of the ischium. It makes the attachment of the Levator ani muscle to the pelvic fascia. At the white line the chief mass of the pelvic fascia passes upon the pelvic viscera and is known as the **fascia endo-pelvica**. It covers portions of the vagina, rectum, and urinary bladder, becomes thinner and thinner, and is gradually lost. Other bands of fascia begin at the white line, descend on the inner surface of the recto-vesical fascia, and in the male pass to the tip of the prostate and become the prostatic fascia. Between the anterior ends of the two white lines the level of the fascia is lower, and it forms a fossa, bounded on the sides in the male by the **pubo-prostacic ligaments** (ligamenta puboprostatica lateralia), and in the female by the **pubo-vesical ligaments** (ligamenta pubovesicalia lateralia). These ligaments are called the **lateral true ligaments of the bladder**. In the base of this fossa in the male runs the **anterior true ligament of the bladder** or the **pubo-prostacic ligament** (ligamentum puboprostaticum).

![Diagram of pelvic viscera of the male subject](image)

FIG. 1149.—Side view of the pelvic viscera of the male subject, showing the pelvic and perineal fasciae.

**medium**, and in the female the **anterior true vesical ligament** (ligamentum pubovesicale medium). These ligaments arise from the lowest portion of the symphysis and pass to the urinary bladder and prostate in the male, and urinary bladder and urethra in the female (Spalteholz). The outer surface of the pelvic Diaphragm is covered by the **anal fascia** or the **ischio-rectal fascia** (fascia diaphragmatis pelvis inferior). It is the lower or outer sheath of the Levator ani muscle, and is derived from the obturator fascia. The space between the obturator fascia and the anal fascia is pyramidal and is called the **ischio-rectal fossa** (fossa ischiorectalis).

The pelvic fascia does not completely invest the bladder, although the neck and lateral walls lie upon the Levator ani muscles, and the lateral true ligaments and the anterior ligament ascend upon the sides and front of the bladder and are lost upon the fibrous coat of that viscus. The sides and anterior wall have a fascial investment. The **sheath of the prostate** has already been discussed (p. 1459). It is
continuous with the recto-vesical fascia and the anterior true ligament of the bladder.

The pelvic fascia is composed, according to Hughes, of: 1. The fibrous capsules of the pelvic viscera. 2. The sheaths of the Levator ani and Coccygei muscles (recto-vesical and anal fasciae). 3. The sheath of the Obturator internus (obturator fascia). 4. Sheath of the Compressor urethrae muscle (the triangular ligament). 5. The sheath of the pelvic aspect of the Pyriformis muscle. The sacral plexus is outside this sheath, the internal iliac vessels inside of it. As previously stated, the pelvic fascia gives off the obturator fascia and the recto-vesical fascia.

The Obturator Fascia (fascia obturatoria) descends and covers the Obturator internus muscle. It is a direct continuation of the parietal pelvic fascia below the white line above mentioned, and is attached to the pelvic arch, the ischial tuberosities, and to the margin of the great sacro-sciatic ligaments. This fascia forms a canal for the pudic vessels and nerve in their passage forward to the perineum, and gives off a thin membrane which covers the perineal aspect of the Levator ani muscle, and is called the anal or ischio-rectal fascia. It forms the inner boundary of the ischio-rectal fossa. From its attachment to the rami of the os pubis and ischium a process is given off which is continuous with a similar process from the opposite side, so as to close the front part of the outlet of the pelvis, forming the deep layer of the triangular ligament.

The Recto-vesical Fascia or the Visceral Layer of the Pelvic Fascia (fascia endopelvica) descends into the pelvis upon the upper surface of the Levator ani muscle, and invests the prostate, bladder, and rectum. From the inner surface of the symphysis pubis a short rounded band is continued, on each side of the middle line, to the upper surface of the prostate and neck of the bladder, forming the pubo-prostatic or anterior true ligaments of the bladder. At the side this fascia is connected to the side of the prostate, enclosing this gland and the vesico-prostatic plexus of veins, and is continued on to the side of the bladder, forming the lateral true ligaments of the organ. Another prolongation invests the seminal vesicle, and passes across between the bladder and rectum, being continuous with the same fascia of the opposite side. Another thin prolongation is reflected around the surface of the lower end of the rectum. The Levator ani muscle arises from the point of division of the pelvic fascia, the visceral layer of the fascia descending upon and being intimately adherent to the upper surface of the muscle, while the under surface of the muscle is covered by a thin layer derived from the obturator fascia, called the ischio-rectal or anal fascia. In the female the vagina perforates the recto-vesical fascia and receives a prolongation from it.

1 A Manual of Practical Anatomy. By Prof. Alfred W. Hughes; edited and completed by Dr. Arthur Keith.
CHRONOLOGICAL TABLE
OF
THE DEVELOPMENT OF THE FETUS.

(FROM BEAUNIS AND BOUCHARD.)

First Week.—During this period the ovum is in the Fallopian tube. Having been fertilized in the upper part of the tube, it slowly passes down, undergoing segmentation, and reaches the uterus probably about the end of the first week. During this time it does not undergo much increase in size.

Second Week.—The ovum rapidly increases in size and becomes imbedded in the decidua, so that it is completely enclosed in the decidua reflexa by the end of this period. An ovum believed to be of the thirteenth day after conception is described by Reichert. There was no appearance of any embryonic structure. The equatorial margins of the ovum were beset with villi, but the surface in contact with the uterine wall and the one opposite to it were bare. In another ovum, described by His, believed to be of about the fourteenth day, there was a distinct indication of an embryo. There was a medullary groove bounded by folds. In front of this a slightly prominent ridge, the rudimentary heart. The amnion was formed and the embryo was attached by a stalk, the allantois, to the inner surface of the chorion. It may be said, therefore, that these parts, the amnion and the allantois, and the first rudiments of the embryo, the medullary groove, and the heart, are formed at the end of the second week.

Third Week.—By the end of the third week the flexures of the embryo have taken place, so that it is strongly curved. The protvertebral disks, which begin to be formed early in the third week, present their full complement. In the nervous system the primary divisions of the brain are visible, and the primitive ocular and auditory vesicles are already formed. The primary circulation is established. The alimentary canal presents a straight tube communicating with the yolk-sac. The branchial arches are formed. The limbs have appeared as short buds. The Wolfian bodies are visible.

Fourth Week.—The umbilical vesicle has attained its full development. The caudal extremity projects. The upper and the lower limbs and the cloacal aperture appear. The heart separates into a right and left heart. The special ganglia and anterior roots of the spinal nerves, the olfactory fossae, the lungs and the pancreas can be made out.

Fifth Week.—The allantois is vascular in its whole extent. The first traces of the hands and feet can be seen. The primitive aorta divides into aorta and pulmonary artery. The duct of Müller and genital gland are visible. The ossification of the clavicle and the lower jaw commences. The cartilage of Meckel occupies the first post-oral arch.

Sixth Week.—The activity of the umbilical vesicle ceases. The pharyngeal clefts disappear. The vertebral column, primitive cranium, and ribs assume the cartilaginous condition. The posterior roots of the nerves, the membranes of the nervous centres, the bladder, kidney, tongue, larynx, thyroid body, the germ of teeth, and the genital tubercle and folds are apparent.

Seventh Week.—The muscles begin to be perceptible. The points of ossification of the ribs, scapula, shaft of humerus, femur, tibia, patellae, and upper jaw appear.

Eighth Week.—The distinction of arm and forearm, and of thigh and leg, is apparent, as well as the interdigital clefts. The capsule of the lens and pupillary membrane, the interventricular and commencement of the interauricular septum, the salivary glands, the spleen, and suprarenal capsules are distinguishable. The larynx begins to become cartilaginous. All the vertebral bodies are cartilaginous. The points of ossification for the ulna, radius, fibula, and ilium make their appearance. The two halves of the hard palate unite. The sympathetic nerves are now for the first time to be discerned.

1 [Eternod (Anat. Anzeiger, Band xv., 1898) described an ovum which he reconstructed. It had a precise history, from which he concluded that it must have belonged to the end of the second or the beginning of the third week. Including the villi it measured 10 × 8.2 × 6 mm. It was flattened on its embryonal side, and the embryo measured 1.8 mm. The amnion was completely formed and the allantois existed as a long canal. The vitelline circulation was established and the villi of the chorion were beginning to be vascularized. The blastopore still opened into the amniotic cavity, with the primitive groove behind it and the rudimentary groove in front. The notochord was closing in and all three layers of the blastoderm were distinct, except around the blastopore, where they formed an undivided mass.—Ed. of 15th English edition.]
Ninth Week.—The corpus striatum and the pericardium are first apparent. The ovary and testicle can be distinguished from each other. The genital furrow appears. The osseous nuclei of the bodies and arches of the vertebrae, of the frontal, vomer, and malar bones of the shafts of the metacarpal and metatarsal bones, and of the phalanges appear. The union of the hard palate is completed. The gall-bladder is seen.

Third Month.—The formation of the fetal placenta advances rapidly. The projection of the caudal extremity disappears. It is possible to distinguish the male and female organs from each other. The cloacal aperture is divided into two parts. The cartilaginous arches on the dorsal region of the spine close. The points of ossification for the occipital, sphenoid, lachrymal, nasal, squamous portion of temporal and ischium appear, as well as the orbital centre of the superior maxillary. The pons Varolii and fissure of Sylvius can be made out. The eyelids, the hair, and the nails begin to form. The mammary gland, the epiglottis, and prostate are beginning to develop. The union of the testicle with the canals of the Wolffian body takes place.

Fourth Month.—The closure of the cartilaginous arches of the spine is complete. Osseous points for the first sacral vertebra and os pubis appear. The ossification of the maxilla and meus takes place. The corpus callosum, the membrana lamina spiralis, the cartilage of the Eustachian tube, and the tympanic ring are seen. Fat is first developed in the subcutaneous cellular tissue. The tonsils are seen, and the closure of the genital furrow and the formation of the scrotum and prepuce take place.

Fifth Month.—The two layers of the decidua begin to coalesce. Osseous nuclei of the axis and odontoid process, of the lateral points of the first sacral vertebra, of the median points of the second, and of the lateral masses of the ethmoid make their appearance. Ossification of the stapes and the petrous bone and ossification of the germs of the teeth take place. The germs of the permanent teeth and the organ of Corti appear. The eruption of hair on the head commences. The sudoriferous glands, Brunner’s glands, the follicles of the tonsil and base of the tongue, and the lymphatic glands appear at this period. The differentiation between the uterus and vagina becomes apparent.

Sixth Month.—The points of ossification for the anterior root of the transverse process of the seventh cervical vertebra, the lateral points of the second sacral vertebra, the median points of the third, the manubrium sterni, and the os calcis appear. The sacro-vertebral angle forms. The cerebral hemispheres cover the cerebellum. The papillae of the skin, the sebaceous glands, and Peyer’s patches make their appearance. The free border of the nail projects from the corium of the dermis. The walls of the uterus thicken.

Seventh Month.—The additional points of the first sacral vertebra, the lateral points of the third, the median point of the fourth, the first osseous point of the body of the sternum, and the osseous point for the astragalus appear. Meckel’s cartilage disappears. The cerebral convolutions, the island of Reil, and the tubercula quadrigemina are apparent. The pupillary membrane atrophies. The testicle passes into the vaginal process of the peritoneum.

Eighth Month.—Additional points for the second sacral vertebra, lateral points for the fourth and median points for the fifth sacral vertebrae, can be seen.

Ninth Month.—Additional points for the third sacral vertebra, lateral points for the fifth, osseous points for the middle turbinate bone, for the body and great cornu of the hyoid, for the second and third pieces of the body of the sternum, and for the lower end of the femur appear. Ossification of the bony lamina spiralis and axis of the cochlea takes place. The eyelids open, and the testicles are in the scrotum.
INDEX

Angle of skull, 147
of sternum, 157
subscapular, 173
Angular artery, 609
convolution, 931
gyre, 931
pinnate external, 50, 140
internal, 80, 140
vein, 726
Ankle bone, 246
bursa of, 546
Anterior joint articulations of, 340
ligaments of, 349
surface form of, 353
surgical anatomy of, 353
Annular ligament of ankle, anterior, 541
external, 545
internal, 545
of radius and ulnar, 316
of tibia, 1171
of wrist, anterior, 493
posterior, 495
plexus, 1121
Annulus clavarius, 1125
ovalis, 569
Ano-coecygeal body of Symington, 1324
Ansa hypoglossi, 1077
lenticularis, 914, 957
peduncularis, 914, 957
of Viesens, 1096
Ante-cubital glands, 787
Anterior angle of ribs, 163
annular ligament of ankle, 544
of wrist, 493
atlanto-axial ligament, 276
talo-axoid ligament, 276
auricular artery, 613
nerves, 1052
bicipital ridge, 181
branches of superior cervical ganglion, 1080
cardiac plexus, 1090
carpal arch, 661
do ulnar, 665
cerebral artery, 628
ehanced of eye, 1139
ehydro-sternal ligament, 290
ehydro-xiphoïd ligament, 290
ehroid artery, 630
ehroid arteries, 627
ehroïd process, 131
common ligament, 271
communicating artery of ulna, 664
condyloid foramen, 73, 133, 136
fossa, 136
corony plexus, 1090
costo-vertebral ligament, 286
costo-xiphoïd ligament, 290
crescentic lobe of cerebellum, 897
crucial ligament, 339
crural nerve. See Femoral nerve.
dep deep cervical vein, 733
dental canal, 107
divisions of cervical nerves, 988
do of coccygeal nerves, 1023
do of lumbar nerves, 1015
do of thoracic nerves, 1010
diverticulal canal, 82, 100
cells, 101
foramen, 82, 130, 141
sinuses, 101
extremity of ribs, 162
facial vein, 726
femoral region, muscles of, 514
fontanelle, 78, 103
Anterior fossa of skull, 130
gluteal line, 216
humeral region, muscles of, 476
inferior cerebellar artery, 642
spinous process of ilium, 217
intercostal arteries, 646
veins, 752
internal frontal artery, 628
interosseous artery of ulnar, 664
nerve, 1004
intersternal ligament, 292
interstromarcheonic line, 225
jugular vein, 728
ligament of Helmholtz, 1170
of malleus, 1170
of wrist, 320
longitudinal ligament, 271
spinal veins, 754
marginal fasciculus, 854
median vein, 736
mediastinal glands, 808
mediasinum, 1396
mellusular velum, 901
meningeal artery, 623
naraes, 112, 1108
nasal spine, 111, 139, 143
occipito-atlantal ligament, 278
talpaline canal, 143
fossa, 110, 133
nerve, 1049
parolfactory sulcus, 935
perforated space, 935
perforating arteries, 646
peroneal artery, 717
phreno-pericardiil ligament, 501
pillars of fornix, 950, 951
of soft palate, 1222
pubic ligament, 298
pulmonary nerves, 1072
plexus, 1069, 1072, 1091
radial carpal artery, 661
radio-ulnar ligament, 317
region, muscles of, 481
recurrent tibial artery, 713
region of skull, 139
root of spinal nerves, 982
sacral foramina, 62
sacro-coeckygeal ligament, 296
sacro-iliac ligament, 294
sacro-sciatic ligament, 295
scapular region, muscles of, 473
spinal artery, 640
sterno-clavicular ligament, 300
sterno-costal ligament, 290
subarachnoidal space, 978
superior dental nerve, 1048
ligament, 287
spinous process of ilium, 216
surface of liver, 1336
of stomach, 1277
temporal artery, 613, 642
diploic vein, 754
thoracic nerve, 1001
tibial artery, 710
gland, 794
nerve, 1023
veins, 758
tibio-fibular region, muscles of, 534
tibio-tarsal ligament, 349
triangle of neck, 618
tubercle of cervical vertebra, 50
tympano-malleolar ligament, 1106
ulnar recurrent artery, 664
vein, 745
Anterior vertebral region, muscles of, 408
vein, 733
wall of tympanum, 1163
Antero-lateral fontanelle, 103
ganglionic arteries, 629
Antero-median ganglionic arteries, 628
Antero-posterior diameter of pelvis, 210
Antheilia, 1154
fossa of, 1154
Antitrignacuse muscle, 1157
Antitragus, 1155
Antrum of Highmore, 108
mastoid, 87
opening of, 1103
of pylorus, 1279
tympanie, 87
Anus, 1323
arteries of, 1327
lymphatics of, 807, 1329
nerves of, 1320
veins of, 1328
Apex, 389
abdominal, 670
arch of, 503
branches of, 595
peculiarities of, 504, 505
relations of, 504
surgical anatomy of, 504
ascending, 500
descending, 676
sinus of, 501
thoracic, 667
transverse, 592
Aortic isthmus, 593
opening of diaphragm, 431
of heart, 568
of heart, 568
semilunar valves, 574
sinus of Valsalva, 575
spindle, 593
vestibule of Sibson, 574
Apertura scala vestibuli cochlæe, 1175
tympanie canaliculis chordie, 1163
Aperture of nose, cartilage of, 1107
Apical coil of cochlea, 1177
glands, 1101
Apopneosis of external oblique, 435, 1525
of internal oblique, 441
palatine, 406
pharyngeal, 404, 1233
Sibson's, 1393
of soft palate, 1222
supra-hyoid, 396
vertebral, 413, 418
Apophyse, 34
Appendages of eye, 1147
of skin, 1195
of uterus, 1509
Appendices epiploicae, 1270
Appendicular artery, 678
vein, 678
Appendiculo-ovarian ligament of Clado, 1312
Appendix, 102
auricle, left, 570
right, 507
ensiform, 159
vermiform, 1311
Appulis, 150
Aqueduct of mid-brain, 907
central gray, 907
Aquincuductus cochlæe, 89, 136
Fallops, 89
eminence of, 1162
vestibuli, 89, 153, 1175
INDEX

Aqueous chamber, 1138
humor, 1138
Arachnoid of brain, 976
structure of, 978
of cord, 858
structure of, 859
villi, 979
Arangi, body of, 573
Arbor vitae cerebelli, 895, 899
of pons, 1503
Arboriform cells, 821
Arch of aorta, 593
of atlas, 51
axillary, 415, 466, 648
carpal, anterior, 661
posterior, 661
crural, deep, 450, 1543
superficial, 438, 1541
palmar, deep, 660
superficial, 660
plantar, 719
pubic, 211
supraorbital, 80
tarsal, inferior, 625
superior, 625
of vertebræ, 48
zygomatic, 138
Arch commissure of Gudden, 941
Areate ligaments, 429, 451
internal, 429
middle, 429
Arcus semilunaris, 1120
Area cribrosa media, 89
superior, 89
of oblongata, 875
dorsal, 876
lateral, 876
vestibularis, inferior, 1186
superior, 1186
Areole of bone, primary, 44
secondary, 45
of mamma, 1516
Areolar coat of anal canal, 1325
of intestine, large, 1325
small, 1298
of liver, 1345
of òosphagus, 1239
dorsal, 1237
of rectum, 1325
of stomach, 1233
tissue, subcutaneous, 1190
subserous, 1256
Arm, arteries of, 630
bones of, 179
fascie of, 476
deep, 472
superficial, 472
lymphatics of, 787
muscles of, 472, 476
dissection of, 471, 476
surgical anatomy of, 480
nerves of, 994
veins of, 744
Arnold’s ganglion, 1053
branches of, 1053
nerves, 1070
canal for, 90
Arteria centralis retinae, 627
magna, 589
Arteria hallucis, 715
princeps cervicis, 611
receptaclei, 623
uterina ovaries, 689
Artery or arteries, 585
alveolar, 617
inferior, 616
superior, 617
anastomosis of, 585
anastomotica magna of brachial, 658
of femoral, 706
Artery or arteries, angular, 699
antero-lateral ganglionie, 629
antero-median ganglionie, 628
aoita, 589
abdominal, 670
arch of, 593
ascending, 590
descending, 667
thoracæ, 667
appendicular, 678
arteriae receptaclei, 623
articular, of knee, 710
auditory, 641, 1186
auricular, anterior, 613
posterior, 611
axillary, 649
azygos, of knee, 710
of vagina, 688
basilar, 641
brachial, 654
of brain, 630
brachial, 668
buccal, 616
of bulb, 602
bulbar, 641
calcanear, external, 718
internal, 718
carotid, common, 598
external, 602
internal, 620
carpal arch, anterior, 661
posterior, 661
radial, anterior, 661
posterior, 661
ulnar, anterior, 665
posterior, 665
central ganglionie system, 632
centralis retinae, 627
cerebellar, anterior inferior, 642
posterior inferior, 641
superior, 642
cerebral, anterior, 628
cerebral hemorrhage, 630
middle, 629
posterior, 642
cervical, ascending, 643
deep, 647
superficial, 644
transverse, 644
choroid, anterior, 630
posterior, 642
ciliary, 627
circle of Willis, 642
circumflex, of arm, 653
iliac, deep, 698
superficial, 704
of thigh, 705
coecyeal, 694
cochlear, 1186
colic, 673
colic, left, 680
middle, 678
right, 677
comes nervi ischiadici, 694
medius, 663
phrenie, 646
communicating, anterior cerebral, 628
to deep palmar arch, 666
posterior cerebral, 630
of omar, anterior, 664
coronary, 673
of heart, 592
of lip, inferior, 609
superior, 609
of corpus cavernosum, 692
cortical system of, 632
cræmsterie, 697
crico-thyroide, 605
eystic, 676
dental, anterior, 617
Artery or arteries, inferior, 616
posterior, 617
digital, plantar, 661
of omar, 664
dorsalis hallucis, 715
indicis, 601
lingue, 606
nasi, 626
pedis, 713
polieies, 661
scapula, 653
dural, 611, 612, 974
epigastie, deep, 697
internal, 697
superficial, 704
superior, 647
ethmoidal, 625
facial, 607
transverse, 613
femoral, 698
common, 700
deep, 704
fibular, superior, 712
of foot, 713
frontal, 613
from anterior cerebral, 628
from middle cerebral, 630
from ophthalme, 625
ganglionie, posterio-lateral, 642
ganglionie, median, 642
gastric, 673, 676
gastro-duodenalis, 675
gastro-epiploica dextra, 675
sinistra, 676
gluteal, 695
inferior, 694
duodenal, inferior, 691
middle, 688
superior, 650
of head, 598
of heart, 580
heaptic, 674
histology of, 586
hyoid branch of lingual, 606
of superior thyroid, 605
hypogastric, 686
in fétus, 685
ileo-colic, 677
iliac, circumflex, deep, 698
superficial, 704
common, 683
external, 695
internal, 685
ilio-humæus, 694
infra-hyoïde branch of superior thyroid, 605
infra-orbitæ, 617
innominate, 596
inoculation of, 585
intercostal, 609
anterior, 646
superior, 647
interior, 1432
interosseous, of foot, 715
of hand, 662
ulnar, 664
anterior, 664
posterior, 665
labial, inferior, 669
lachrymal, 624
laryngeal, inferior, 643
superior, 605
lateralis nasi, 609
lentuculo-striate, 630
lingual, 605
deep, 606
of lower extremity, 698
lumbar, 682
lymphatics of, 588
malar from lachrymal, 625
INDEX

Artery or arteries, malleolar, 713, 715
mammary, internal, 645
mandibular, 616
mandible, 592
masseteric, 616
maxillary, 611, 612
maxillary, external, 607
internal, 613
mediastinal, 646
posterior, 668
mediocrebellar, 642
medieerebral, 629
medialural, 615
meningeal, 616
of nasoral, 598
mylo-hyoid, 616
of metatarsal, 617
mesenteric, 617
metatarsal, 617
of muscle, 364
musculo-phenic, 646
mylo-hyoid, 616
nasal, from ophthalmic, 626
of septum, 699
naso-palatine, 617
of neck, 598
nerves of, 388
nutrient, of femur, 706
of fibula, 717
of humerus, 658
of tibia, 718
obturator, 689
ocelital, 610
occhophagal, 643, 668
ophthalinic, 624
orbital, 613
internal, 629
ovarian, 682
palatine, ascending, 603
descending, 617
inferior, 608
posterior, 617
palmar arch, deep, 660
superficial, 666
palpebral, 625
pancreatic, 676
pancreatico-duodenalis, inferor, 677
superior, 676
parietal, 613
ascending, 630
parieto-sphenoidal, 630
parieto-temoral, 630
parvidural, 616
den of penis, dorsal, 601, 1468
perforating, anterior, 646
of foot, 719
of hand, 662
of thigh, 706
pericardic, 643, 668
of pericardium, 563
perineal, superficial, 691
transverse, 692
peroneal, 717, 718
phyangyal, ascending, 612
phrenic, inferior, 682
superior, 646
of pia of brain, 982
plantar, 715, 719
popliteal, 707
postcerebellar, 641
postcerebral, 642
postchoroidal, 642
postcommunicant, 630
postdural, 612
Artery or arteries, postero-
lateral, 642
postero-median, 630
precerebellar, 642
precerebral, 628
prechordoid, 630
precommunicant, 628, 629
pulpal, 623
vertebral, 612
princeps haliencia, 715
pollicis, 660
profunda, of arm, inferior, 658
superior, 657
femoralis, 704
pterygo-palatine, 617
pterygoid, 616
pubic, accessory, 691
external, 704
internal, in female, 693
in male, 690
pulmonary, 580
pyloric, inferior, 675
superior, 675
radial, 659
radialis indicis, 662
ranine, 606
recurrent, palmar, 662
radial, 661
tibial, anterior, 713
posterior, 712
ulnar, anterior, 664
posterior, 664
renal, 680
inferior, 1432
of round ligament, 659
sacral, lateral, 604
middle, 683
scapular, posterior, 644
sciatric, 603
sigmoid, 680
spermatic, 681
spheno-palatine, 617
spinial, anterior, 640
dorsal, 641
lateral, 640
posterior, 641
rami, 640
saphenous, 640
spheicic, 670
sternal, 646
sterno-mastoid, 605, 611
stgio-mastoid, 611
subclavia, 633
subcostal, 669
sublingual, 606
submaxillary, 608
submental, 608
subscapular, 653
superficialis volae, 661
supra-acromial, 644
supra-hyoid, 606
supraorbital, 625
supraprenal, 680
suprascapular, 643
suprasternal, 644
sural, 700
tarsal, 714
temporal, 612, 613
anterior, 613, 642
depth, 616
middle, 613
posterior, 613, 642
terminal, 632
thoracic, acromial, 653
alar, 653
long, 653
superior, 651
thyroid axis, 642
inferior, 643
superior, 604
of thyroid gland, 605
Artery or arteries, thyroidia
inn, 596
ibial, anterior, 710
posterior, 715
recurrent, anterior, 713
posterior, 712
torsional, 608
tragical, 643
transversali collis, 644
humeri, 643
of trunk, 607
tympanic, from ascending
pharyngeal, 612
from internal carotid, 623
from internal maxillary, 615
ulnar, 602
recurrent, anterior, 664
posterior, 664
umbilical, in foetus, 583
of upper extremity, 633
uterine, 688
vaginal, 688
of vas deferens, 687
vasta brevis, 676
intestines tenues, 677
vessorium of, 588
vertebral, 639
vesical, inferior, 688
middle, 688
superior, 687
Vidian, 617
Arthrodia, 268
Arthrodology, 261
Articular arteries of knee, 710
inferior, 710
superior, 710
cartilage, 262
circumference of ulna, 191
corpuscles, 327
eminence of temporal bone, 84
lamella of bone, 261
processes of a vertebra, 49
synovial membrane, 284
Articulations, 281
acromio-clavicular, 301
of ankle-joint, 349
astragalo-scapoid, 356
asbatho-axial, 276
of axis with axis, 276
with occipital bone, 278
bimastial, 267
calcaneo-astragoid, 354
calcaneo-cuboid, 355
calcaneo-sacral, 355
carlo-meta-carpal, 323
d of carpus, 321
chondro-sternal, 290
coecyeal, 296
condyloid, 267
costo-central, 285
costo-chondral, 292
costo-sternal, 289
costo-transverse, 287
costo-vertebral, 285
crico-arytenoid, 1375
crico-thyroid, 1375
of cuboid with cuneiform, 358
with scaphoid, 357
of elbow-joint, 310
femoro-tibial, 337
of hip, 327
immovable, 266
interchondral, 291
interneural, 274
of knee, 356
of lower extremity, 327
jaw, 282
metacarpophalangeal, 326
metatarso-phalangeal, 301
mixed, 266
movable, 267
INDEX

Cells, glia, 832
of Golgi, 821, 902
gistatory, 1101
of Hensen, 1183
hepatic, 1338
horizontal, of Cajal, 1135
of Martinotti, 960
mastoid, 86
mitral, 960
molecular, 958
multipolar, 820
nerve, 820
axone of, 823
dendrites of, 822
olfactory, 1111
oxytotic, 1285
parietal, 1285
peptic, of glands, 1285
prickle, 1119
Purkinjean, 902
pyramidal, 958
of Sertoli, 1483
sphenoidal, 94
stellate, 821
unipolar, 820
Cementum of teeth, 1214
development of, 1216
Central canal of cord, 845
coil of cochlea, 1177
fissure, 926
ganglionic system of arteries, 632
lobe of cerebrum, 933
pathway, 964
sulcus of Roland, 926
tensor of diaphragm, 431
Centrifugal nerves, 827
Centripetal nerves, 827
fibre, 823
neurones, peripheral nerve beginnings of, 828
Centro-acinar cells of Langerhans, 1339
Centrum medianum, 914
vertebra, 48
Cephalic flexure of brain, 869
index of skull, 147
vein, 747
median, 746
Cephalo-auricular angle, 1154
Cerato-hyals
Cerebellar arteries, anterior, inferior, 642
posteroinferior, 641
superior, 642
cortex, microscopic appearance of, 902
peduncle, 900
pedunclulus, 888
tract of cord, direct, 852
veins, deep, 736
superficial, 736
Cerebellar-olivary fibres, 886
Cerebello-spinal tract of cord, 853
Cerebellum, 895
amygdala of, 871, 954
dentatum of, 900
hilum of, 890
embolus of, 900
falcata of, 895
fastigium of, 879, 900
fibres of, 902
association, 902
clinging, 903
commisural, 902
moss, 902
proper, 902
tendril, 903
fissures of, 896
folia of, 895
frenulum of, 895
Cerebellum, globulus of, 900
gray masses of, 890
hemispheres of, 896
internal structure of, 899
lobes of, 896
nuclei of, 890
peduncles of, 900
posternan of, 890
pedunclulus of, 909
preranum of, 899
vallecula of, 895
valvula of, 885
volum of, 893
vermis of, 895
weight of, 903
wurm of, 895
Cerebral artery, anterior, 628
branches of, 628
middle, 629
branches of, 629
posterior, 642
convolutions, 922.
See Gyre.
cortex, 939
nerve cells of, 938
fibres of, 959
structure of internal, 958
cranium, 71
fibre system, 961
fissures, 922, 923
gyrus, 922
hemispheres, 919
configuration of, 922
external morphology of, 919
gray masses of, 952
internal configuration of, 938
hemorrhage, arteries of, 630
lobes, 923
localization, 926
lymphatic vessels, 778
nerve, 1036
portion of internal carotid artery, 623
veins, 734
cortical, 735
depth, 735
inferior, 735
median, 735
superficial, 735
superior, 735
Cerebro-spinal axis, 833
fasciculus, lateral, 853
fluid, 855
Cerebrum. See Cerebral.
Ceruminos glands, 1159
Cervical artery, ascending, 643
depth, 647
superficial, 644
transverse, 644
canal, 1503
cardiac nerves, 1072
enlargement of spinal cord, 836
fasia, deep, 830
superficial, 838
surgical anatomy of, 391
flexure of brain, 869
ganglion, inferior, 1086
branches, central communica
ting, 1086
peripheral, 1086
middle, 1085
branches of, central communica
ting, 1086
peripheral, 1086
superior, 1081
branches of, 1083
central communicating, 1083
peripheral, 1083
surgical anatomy of, 1087
glands, deep, 785
Cervical glands, deep, accessory
chains to, 785
lower, 785
upper, 785
superficial, 783
anterior, 784
nerves, 986
divisions of, anterior, 988
dorsal, 986
from facial nerve, 1063
eighth, division of, dorsal, 987
ventral, 989
fifth, division of, dorsal, 987
ventral, 989
first, division of, dorsal, 986
ventral, 986
root of, dorsal, 986
fourth, division of, dorsal, 987
ventral, 988
posterior, 986
ventral, 988
roots of, 986
second, division of, dorsal, 986
ventral, 988
trunk of, 986
seventh, division of, dorsal, 987
ventral, 989
sixth, division of, dorsal, 987
ventral, 989
superficial, 990
third, division of, dorsal, 987
tendr, 988
pleura, 1393
plexus, 989
branches of, deep, 992
superficial, 987
posterior, 987
surgical anatomy of, 994
portion of internal carotid artery, 621
of oesophagus, 1236
region, superficial muscles of, 388
rib, 53, 167
veins, anterior deep, 733
posterior deep, 733
vertebra, 49
laminae of, 49
body of, 49
pelvis of, 49
processes of, 50
seventh, 53
Cervicalis ascendens muscle, 421
Cervico-facial nerve, 1063
Cervix of bladder, 1444
uteri, 1500
cavity of, 1503
Chassaignac's tubercle, 69
Cheek ligaments, 250
eye of, 1115
Cheeks, 1205
mucous membrane of, 1205
surgical anatomy of, 1234
Chemical composition of bone, 41
Chest, 156
articulations of, 161
attachment of muscles to, 161
boundaries of, 156
development of, 159
structure of, 159
surface form of, 166
surgical anatomy of, 167
Chiasm, 919, 1038
Chiasma or optic commissure, 1038
Chink of glottis, 1377
Choane, 146
INDEX

Crista vestibuli, 1174
Crucial ligaments of knee, 339
Cruiform ligament, 277
Crura, 869
crebri, 904, 905
pes of, 905, 910
diaphragm, 429
fornices, 951
of penis, 1454
Crural arch, deep, 450, 1543
superficial, 438, 1541
canal, 511, 1543
cisterna, 978
nerve. See Femoral nerve.
ing, 439, 511, 1544
septum, 1544
sheath, 511
Crureus muscle, 520
nerve to, 1022
Crus of helix, 1155
Crusta, 910
petrosa of, 1214
Crypts of, 364
Crural cisterna, 439, 910
Drusius, 1206
Decussato nervorum trochaen-
rion, 1041
Decussation of lemnisci, 882
of pyramids, 875, 881
Deep anterior thoracic nerve, 1001
branches of cervical plexus, 992, 993
Cardiac plexus, 1090
cerebral veins, 735
cervical artery, 647
fascia, 380
glands, 785
circumflex artery, 698
vein, 759
cural arch, 450, 1543
dorsal vein of penis, 762
epigastric artery, 607
vein, 759
external pudic artery, 704
fascia, 367
of arm, 472, 476
of back, 413
of femoral region, anterior, 515
of forearm, 480
of leg, 536
transverse, 540
of shoulder, 472
to thoracic region, anterior, 465
femoral artery, 704
lingual gums, 704
inguinal lymphatic glands, 704
lymphatic glands of upper ex-
tremity, 787
vessels of abdominal wall, 799
of lower extremity, 795
muscles of abdomen, 451
palmar arch, 660
fascia, 495
veins, 747
parotid lymphatic glands, 780
patellar bursa, 521
pectoral fascia, 466
perineal fascia, 1550
petrosal nerve, 1083
radial veins, 747
superficial external pudic ar-
tery, 704
temporal artery, 616
nerves, 1061
veins, 727
ulnar veins, 747
veins of foot, 758
785
of upper extremity, 758
Deiter, cells of, 1185
nucleus of, 853
process, 820
Deltoid eminence, 181
impression, 181
muscle, 472
tuber, 169
Deltoides of Heidenhain, 1228
Démons, membrane of, 1120
Dendraxesone, 823
Dendrites, 816, 820, 822
Dendrites, monopolar, 821
Dentary, inferior, 616
posterior, 617
band, 1215
canal, 1212
anterior, 107
inferior, 124
posterior, 106
fibres, 1212
follicle, 1216
lamina, 1215
nerves, anterior superior, 1048
inferior, 1053
middle superior, 1047
posterior superior, 1047
periestrum, 1214
plexus, superior, 1048
pulp, 1210
sac, 1216
Dentate gyre, 938
gray substance of, 960
ligament, 860
nucleus of cerebellum, 900
Dentato-fascicular groove, 937
Dentate line of cerebellum, 900
hilum of, 900
Dentinal sheath of Neumann, 1213
tubuli, 1212
Dentine, 1212
formation of, 1217
papilla, 1215
Depression, pterygoid, 125
trigeminal, 88
Depressions of bone, 34
Depressor alae nasi muscle, 378
anguli oris muscle, 350
labii inferioris muscle, 380
Dermince coat of hair-follicle, 1198
Dermis, 1190
Descentem, membrane of, 1220
Descending hypoglossal nerve, 988
Descending aorta, 667
branch of superior cervical
ganglion, 1084
colon, 1217
mesocolon, 1268
oblique muscle of abdomen, 435
palatine artery, 617
projection nerve fibres, 963
ramus of ischiium, 218
of pubis, 220
root of fifth nerve, 1042
Descent of ovary, 1538
of testicles, 1471
surgical anatomy of, 1472
Detrusor urinaris muscle, 1446
Development of alimentary can-
nal, 1247
of alveoli of teeth, 1217
of atlas, 59
of axis, 59
of brain, 863
of callosum, 941
of carpal bones, 207
of cementum, 1217
of clavicle, 172
do coccyx, 66
of cranium, 102
of dentine, 1217
of enamel, 1216
of ethmoid bone, 101
of femur, 231
of fibula, 241
of foot, 255
of frontal bone, 82
of humerus, 184
of hyoid bone, 156
of inferior turbinate bone, 120
Duct or ducts of kidney, 1429
lactiferous, 1518
of liver, 1348
lymphatic, right, 777
mammillary, 1518
nasal, 1152
pancreatic, 1359
parotid, 1225
of Rivinus, 1227
seminal, 1454
Stenson's, 1225
of submaxillary gland, 1226
thoracic, 775
thyroglossal, 1100, 1407
Wharton's, 1226
Ductless glands, 1407
Ductus arteriosus, 582
processes choledochus, 1331
delonymphaticus, 89, 1175
venous, fissure of, 1338
fossa of, 1339
Duodenal area of kidney, 1422
folds, 1270
fossa, 1270
glands, 1303
impression of liver, 1337
Duodenaljejunal fossa, 1271
Duodenomesocolic ligaments, 1271
Duodeno-jejunal ligament, 1264
Duodenum, 1290
arteries of, 1296
ascending portion of, 1294
descending portion of, 1293
first portion of, 1292
flexure of, superior, 1293
fourth portion of, 1294
horizontal portion of, 1293
interior of, 1296
lymphatics of, 1296
muscular coat of, 1296
nerves of, 1296
peritoneal coat of, 1296
pre-aortic portion of, 1283
second portion of, 1293
structure of, 1296
submucous coat of, 1296
superior portion of, 1292
surgical anatomy of, 1382
susory muscle of, 1294
third portion of, 1293
transverse portion of, 1293
veins of, 1296
Dura of brain, 972
arteries of, 974
lymphatics of, 974
nerves of, 974
processes of, 975
structure of, 972
veins of, 974
matter of brain, 972
of cord, 866
sinuses of, 736
spinal, 856
structure of, 858
Dural nerves, 611, 612
nerves, 1046
veins, 730, 734
Duverney, gland of, 1495

E
Ear, 1154
auditory meatus, external, 1158
auricle of, 1154
bones of, 1168
cartilages of, 1156
eochlea, 1173
external, 1154

Ear, external, auricle of, 1154
lobule of, 1155
internal, 1173
labyrinth, 1173
membranous, 1179
ossceous, 1174
middle, 1190
muscles of auricle, 1157
of tympanum, 1171
ossicula of, 1168
pinna of, 1154
semicircular canals of, 1175
surgical anatomy of, 1186
trumpet, 1163
tympanum, 1160
Eardrum membrane, secondary, 1162
Ectyle, von, glands of, 1101
Ectal areuate fibres of postoblongata, 886
polymorphous nerve cells, 958
efferent nerve, 827
root of spinal cord, 836
Egg tubes, 1515
Eighth nerve, 1064
surgical anatomy of, 1065
Ejacularis seminis muscle, 459
urine muscle, 459
Ejaculatory ducts, 1487
Elastic cartilage, 262
tissue, yellow, 264
Elbow, bend of, surgical anatomy of, 655
bone, 186
bursa of, 313
ligament of, anterior, 311
posterior, 311
Elbow-Joint, articulations of, 310
surface form of, 314
surgical anatomy of, 314
Eleventh nerve, 1073
surgical anatomy of, 1074
thoracic vertebra, 56
Ellipsoid of Krause, 1137
Elliptical recess, 1174
Embolic of cerebellum, 900
Eminence, articular, of temporal bone, 84
of bone, 34
canine, 106
deltoid, 181
frontal, 79
illeo-psoas, 217, 220
of Jacobson, 1110
nasal, 79
olivery, 93
parietal, 76
Eminetia abducensis, 880
articularies, 84, 135
couche, 1156
fossa triangularis, 1156
Emissary veins, 743
surgical anatomy of, 743
Emulgent vein, 766
Enamel cells, 1216
cuticle, 1214
fibres, 1215
jelly, 1216
prisms, 1213
development of, 1216
Enamel-organ of tooth, 1215
Enarthrosis, 268
Ephelochephalon, 800
Epibrachidal hernia, 1535
End-bulb of Krause, 826, 830
Endocardium, 576
Endo-exo-gnathion suture, 111
Endo-gnathion suture, 111
Endolymph, 1170
Endo-meso-gnathion suture, 111
Endomysium, 364
Endoneurium, 826
Endostemum, 36
Endothelium, corneal, 1121
Endothoracic fascia, 1303
End-plates, motor, 828
Endyma, 851
Endymal cells, 832
elinated, 818
Ensiform appendix, 159
surfaces of, 159
cartilage, 156
Enteral areuate fibres of postoblongata, 886
polymorphous nerve-cells, 959
Eosinophils, 36
Epactal bones, 103
Epibranchial branch of bronchus, 1385
Epencephalon, 860
Epieardium, 576
Epicondyly, 182
Epicephalic, 181
Epidermic coat of hair-follicle, 1198
Epilidymis, 1480
structure of, 1482
Epipidal space, 857, 973
Epipagastic artery, deep, 697
tissue peculiarity of, 977
surgical anatomy of, 698
internal, 697
superficial, 704
superior, 647
glands, superior, 800
plexus, 1091
vein, deep, 759
Epiglottis, 1373
cartilage of, 1373
cushion of, 1373
surfaces of, 1373
Epimsysium, 364
Epineurium, 826
Epiotic portion of temporal bone, 91
Epiphysial cartilage, 36, 867, 915
recess, 915
Epiphysis, 867, 915
abicanit of, 916
de bone, 34
postcommisurite of, 915
postperforation of, 916
structure of, 915
Episylyian ramus, 925
Epithalamus, 916
Epithelial corpses of Kohn, 1412
Epithelium. See Various organs.
germal, of Waldayer, 1513
lens, 1140
Transitional, 1437
Epitrochlea, 183
Epitympanic recess, 87, 1160
space, 87
Epipo-opharon, 1511
Erector tissue of penis, 1467
of vagina, 1497
Erector ditoriilis muscle, 463
penis muscle, 460
spine muscle, 419
Erythroblastos, 36
Etimho-frontal suture, 130
Etimho-sphenoidal suture, 130
Etimho bone, 98
articulations of, 102
cribiform plate of, 99
development of, 101
horizontal lamina of, 99
infundibulum of, 101
lateral mass of, 100
Fascia or fasciae, deep, 367
dentate, 683
depo-pelvic, 1556
dentorthaoric, 1393
of face, 367
of femoral region, anterior, deep, 515
superficial, 514
of foot, 544
of forearm, 180
of hand, 493
of hip, 495
iliac, 510
infraspinatus, 474
infundibuliform, 448, 1475
intercolunnlar, 438, 1474, 1526
intercostal, 429
ischio-retal, 456, 1558
lata, 515, 1539
falciform process of, 1540
iliac portion, 517, 1540
pubic portion, 517, 1540
of leg, 535
transverse, 540
of lower extremity, 509
masseteric, 383
of neck, 387
obturator, 1558
of orbit, 377
phalangeal, deep, 495
palpebral, 1149
parotid, 389, 1225
parotidoo-masseteric, 389
pectoral, deep, 496
pelvic, 1566
of perineum in male, deep, 460, 1550
superficial, 457
phenoico-pleural, 1395
plantar, 545
pre-tracheal, 391
prevertebral, 390
of quadratus lumborum, 451
recto-vesical, 1558
retro-renal, 1420
salpingopharyngea of Trötsch, 1165
of Scarpa, 435
semilunar, 478
of shoulder, deep, 472
superficial, 472
spemnale, 1471
external, 438, 1526
internal, 448
middle, 442
subseapular, 473
superficial, 306
supraspinatus, 474
temporal, 384
t of thigh, 514
of thoracic region, anterior, deep, 465
superficial, 465
of thorax, 426
transversalis, 447, 1529
triangular, 439
of trunk, 412
of upper extremity, 464
Faseial canal, 1548
Fasieuli, 264
propri, 849
Faseiculus albicaniothahalini, 914
archiormus pedis, 906
longitudinal, inferior, 962
superior, 962
marginalis, 849
pedunculomammillaris, 916
perpendicular, 962
rectus, 962
rectus, 962
flexor, 908
thalamomammillaris, 914, 916

| Fibres of auricles of heart, 577 |
| cardiac muscle, 563 |
| cerebelllo-olivary, 886 |
| of cerebellum, association, 902 |
| clinging, 903 |
| commissural, 902 |
| moss, 902 |
| proper, 907 |
| tendril, 903 |
| of cerebral cortex, 959 |
| of cord, longitudinal, 848 |
| cortico-thalamic, 914 |
| dental, 1212 |
| enamel, 1213 |
| intercolumnar, 438 |
| lens, 1140 |
| nerve, 563 |
| nerve, association, 961 |
| commissural, 963 |
| projection, 963 |
| thalamo-fenestral, 956 |
| thalamo-atriate, 956 |
| olivo-cerebellar, 886 |
| of pons, longitudinal, 887 |
| transverse, 887 |
| preanal, of levator ani, 455 |
| pré-rectales, 456 |
| of Purkinje, 577 |
| of Sharpey, 37 |
| sustentacular, 1131 |
| of tegument of mid-brain, 908 |
| thalamo-cortical, 914 |
| of ventricles of heart, 577 |
| Fibre-tracts in pre-oblongata, 888 |
| cerebellar prepeduncle, 888 |
| lateral lemniscus, 888 |
| medial lemniscus, 888 |
| longitudinal bundle, 888 |
| Fibris, side, 823 |
| Fibrique, terminal, 830 |
| Fibro-carilage, 262 |
| circumferential, 263 |
| connecting, 263 |
| interarticulare, 283, 300, 302 |
| triangular, 317 |
| intervertebral, 272 |
| semilunar, 339 |
| stratiform, 263 |
| Fibro-elastic coat of spleen, 1363 |
| Fibro-muscular coat of gall-bladder, 1351 |
| Fimbriae, side, 823 |
| articular, of 241 |
| attachment of muscles to, 241 |
| development of, 241 |
| lower extremity of, 241 |
| nutrient artery of, 717 |
| obtue line of, 240 |
| shaft of, 240 |
| stylod process of, 239 |
| surface form of, 241 |
| surface form of, 241 |
| surgical anatomy of, 244 |
| upper extremity of, 239 |
| Fibrous extension, 912 |
| region, muscles of, 542 |
| actions of, 543 |
| dissection of, 542 |
| surgical anatomy of, 544 |
| Fifth lumbar vertebra, 57 |
| nerve, 1041 |
INDEX

Ilium, venter of, 216
Impar ganglion, 1078
Impression, deltoid, 181
gastric, 1340
Incise fossa, 106, 123, 139
Incisor canal, 110
crest, 111
foramina, 110
nerve, 1033
tooth, 1206
Inscissa cardiae, 1401
inter-arytenoides, 1376
pancreatic, 1355
Incisures of Schmidt-Lauter-mann, 824
Incisural lines of dentine, 1213
Ineus, 1169
body of, 1169
ligaments of, 1171
processes of, 1169
Indices of skull, 147
Indusium, 938, 940
Infantile hernia, 1535
Infraclavicular-ligament, 301
alveolar artery, 616
branch of superior cervical ganglion, 1084
carotico-scapoid ligament, 356
cardiac nerve, 1086
carotid triangle, 618
cerebral veins, 735
cervical ganglion, 1086
constrictor muscle, 402
corony artery of lip, 609
dental artery, 616
canal, 124
foramen, 124
nerve, 1053
ethmoidal turbinate bone, 101
external frontal artery, 630
gemellus muscle, 530
gluteal artery, 694
line, 216
nerve, 1027
humero-humeral artery, 691
nerve, 1028
plexus, 1095
veins, 760
intimal frontal arteries, 628
labial artery, 609
lachrymal gland, 1151
laryngeal artery, 643
veins, 751
lateral angle, 63
lingualis muscle, 401
longitudinal fasciculus, 962
sinus, 738
maxilla bone, 122
horizontal portion of, 122
maxillary bone, articulations of, 123
attachment of muscles to, 125
development of, 125
horizontal portion of, borders of, 124
perpendicular portion of, 124
borders of, 124
processes of, 125
surfaces of, 124
nerve, 1050
meatus of nose, 145
medullary lumina, 901
mesenteric artery, 679
plexus, 1094
vein, 768
muscular line, 72
obliquus oculi muscle, 376

Inferior occipital fissure, 931
fossa, 133
olivary nucleus, 885
ophthalmic vein, 741
orbito-palpebral sulcus, 1147
palatine artery, 608
pancreatico-duodenal artery, 677
petrosal sinus, 742
phrenic arteries, 682
veins, 767
profunda artery, 658
pubic ligament, 298
pubdental nerve, 1028
pyloric artery, 675
radio-ulnar articulation, 317
ramus of ischioum, 218
of pubis, 220
rectus oculi muscle, 375
renal artery, 1432
sacro-sciatic foramen, 296
stepphanion, 76, 150
sterno-pericardiac ligament, 1028
superficial cerebellar veins, 736
tarsal arch, 625
thoracic artery, 643
veins, 751
turbinated ligament, 304
turbinate bone, 119
articulations of, 120
borders of, 120
development of, 120
processes of, 120
surfaces of, 120
crest, 107, 117
vena cava, 764
vestibular artery, 688
plexus, 762
vocal cords, 1378
Inflected fissure, 928
Infraventricular plexus, 790
Infracarotis of Gudde, 919
Infracostale muscle, 427
Infraglenoid margin of tibia, 237
tubercle, 176
Infrapharyngeal artery, 604
region, muscles of, 303
Infralacrimal glands, 785
Inframandibular artery, 1064
Inframarginal glands, 781
nerve, 1064
Infrarobital artery, 617
canal, 107, 140
foramen, 106, 140
groove, 107, 141
nerve, plexus of, 1063
Infrapatellar bursa, 342
Infrapiriform bursa, 307
muscle, 474
bursa of, 475
Infraspinous fossa, 174
Infrasternal depression, 166
Infratemporal crest, 95
fossa, 138
Infratrochlear nerve, 1045
Infundibula of kidney, 1424
Infundibular artery, 503
recess of third ventricle, 917
Infundibuliform sac, 448, 1475
Infundibulo-pelvic ligament, 1502
Infundibulum of brain, 917
of ethmoid, 101
of Fallopian tube, 1510
of heart, 571
Ingrasias, processes of, 96
Internal canal, 430, 1529
fossa, 1258
external, 1532
internal, 1532

inguinal fossa, middle, 1332
hernia, 1352
direct, 1535
incomplete, 1536
oblique, 1529, 1532
lymphatic gland, deep, 794
superficial, 791
surgical anatomy of, 794
region, 1243
Inion, 71, 150
Inlet of pelvis, 200
Inner condyle of femur, 228
Innominato artery, 596
branches of, 596
peculiarities of, 597
surgical anatomy of, 597
bone, 213
vein, 750
left, 750
right, 750
Insulation of arteries, 585
Insertion of muscles, 366
Inspiration, muscles of, 434
Insula, 903
apex of, 932
development of, 925
fissure of, 933
pole of, 933
Integument of serotum, 1473
Intervertebral cell islets, 1359
Intervertebral chondro-steral
ligament, 290
fibro-cartilage, 283, 300, 302
triangular, 317
ligament, 286, 331
sterno-costal ligament, 290
Interauralial furrow, 567
septum, 567
Intervenous muscle, 911
Intereventrealum, 907
Intercarotid body, 602
Intercavernous sinus, 742
Intercellular bilary passages, 1348
Intercerebral cleft, 921
fissure, 921
Intercrural articulations, 291
ligament, external, 292
Intercostal, 292
Intercavicular ligament, 300
Intercolumnar fascia, 438, 1474, 1526
fibres, 438
Intercostal muscle, 227
Intercostal arteries, 669
anterior, 646
collateral, 670
superior, 647
surgical anatomy of, 670
fascia, 426
glands, 807
muscles, 427
external, 427
internal, 427
nerves, 1011
abdominal, 1013
femoral, 1013
pectoral, 1011
surgical anatomy of, 1014
space, 156, 161
veins, 752
anterior, 752
posterior, 752
superior, left, 752
right, 752
Intercostal-lumbar nerve, 1013
Intercurral space, 904
Interglobular spaces of Czemak, 1212
INDEX

Jugular fossa, 91
ganglion, 1066
glands, internal, 785
lymphatic trunk, 785
nerve, 1083
process, 73
tuber cle, 74
vein, anterior, 728
external, 728
sinus of, 728
internal, 729
bulb of, 729
sinus of, 729
surgical anatomy of, 732
posterior external, 728
Juxta-aortic glands, left, 798
right, 797
Juxta-cervical lymphatic knot, 801
K
Keebring, valves of, 1209
Key and Retzius, foramen of, 859, 978
Kidneys, 1418
abnormalities of, 1433
areas of, 1422
arteries of, 1432
borders of, 1423
calices of, 1424
capsule of, fatty, 1419
type, true, 1423
connective tissue of, 1433
cortical substance of, 1424
ducts of, 1420
hilum of, 1423
horse-shoe, 1433
infundibula of, 1424
intermediate zone of, 1424
lymphatic vessels of, 802, 1433
Malpighian bodies of, 1426
capsule, 1426
tuft of, 1426
medullary substance of, 1425
minute anatomy of, 1426
nerves of, 1433
papillae of, 1425
pelvis of, 1424
Pyramids of Ferrein, 1425
of Malpighi, 1425
sinus of, 1423
structure of, 1423
surface form of, 1434
surfaces of, 1420
surgical anatomy of, 1434
tubuli uriniferi, 1429
variations of, 1433
veins of, 1433
Knee, bursae of, 342
ligaments of, 337
Knee-cap, 233
Knee-joint, surface form of, 345
surgical anatomy of, 345
Kohn, epithelial corpuscles of, 1412
Kollier, commissure of, 919
membrane of, 1185
Krause, ellipsoid of, 1137
end-bulbs of, 826, 830
Kühne, muscle-spindle of, 830
L
Labia pudenda majora, 1480
minora, 1490
Labial artery, inferior, 609
glands, 1204
nerve, 1048
Labium tympanicum, 1182
Labium vestibulare, 1182
Labyrinth, 1173
arteries of, 1186
membranous, 1179
nerves of, 1186
ossuses of, 1174
veins of, 1186
Lachrymal apparatus, 1151
artery, 624
peculiarities of, 625
bone, 112
articulations of, 113
attachment of muscles to, 113
borders of, 113
crests of, 141
development of, 113
lesser, 113
surfaces of, 113
canaliculari, 1152
canals, 1152
caruncle, 1152
crest, 113
dossa, 81
glands, 1151
structure of, 1151
surface form of, 1152
surgical anatomy of, 1153
sulcus, 113
tubercle, 109
Lactiferous duct, 1518
Lacuna magna, 1453
Lacunae, 1120
of bone, 38
Laws' is, 38
Laeus lacrimalis, 1148
Lagenae, 1182
Lalouette, pyramid of, 1409
Lambda, 129, 150
Lambdoid suture, 75, 78, 125
Lamina of bone, articular, 231
Lamellated corpuscles, 830
Lamina basalis, 1124
of brain, dorsal, 870
ventral, 870
of cornea, 1119
cristoba, 89
cristiform, 1118
of sclera, 1118
dental, 121
of ethmoid, horizontal, 99
perpendicular, 100
vertical, 100
fissa, 1118
periclastral, 954
reticularis, 1185
spiralis ossis of cochlea, 1177
suprachorioidea, 1122
vascular, 1122
of vertebræ, 34
Lancisi, nerve of, 940
Landzert, fossa of, 1271
Langer, foramen of, 466, 648, 790
lines of cleavage of, 1190
Langerhans, centro-acinar cells of, 1359
lands of, 1359
Large, deep petrosal nerve, 1049
Intestine, 1307
palatine nerve, 1049
superficial petrosal nerve, 1048
Laryngeal artery, inferior, 605
superior, 605
nerve, superior, 1071
external, 1071
internal, 1071
pouch, 1379
saccule, 1379
sinus, 1379
surface of epiglottis, 1373
veins, 751
Larynx, 1369
 aperture of, superior, 1376
arteries of, 1383
arterial branches of, 1380
cavity of, 1376
compartments of, 1376
lower, 1379
middle, 1377
glands of, 1382
joints of, 1374
ligaments of, 1374
lymphatics of, 782, 1383
membranes of, 1374
mucous membrane of, 1382
muscles of, 1379
nerves of, 1384
nerves of, 1377
rima glottidis, 1377
structure of, 1373
veins of, 1383
vulva of, 1379
vocal cords of, false, 1378
true, 1378
Lateral angle, inferior, 63
area of oblongata, 876
calcaneeal nerves, 1031
cell column, 840
cerebro-spinal fisscule, 853
column of spinal cord, 810
fissures of cord, 815
horn-cells of cord, 856
ligamentum, external, 282
internal, 282
of liver, 1431
of wrist, 320
masses of atlas, 51
of ethmoid, 100
occipital fissure, 931
odontoid ligaments, 280
patellar ligaments, 337
phaleno-pericardial ligaments, 561
planter nerve, 1032
region of skull, 136
scolic artery, 694
veins, 760
sacral ocygeal ligament, 297
sinus, 785
surgical anatomy of, 789
spinal arteries, 640
surface of liver, 1335
thoracic region, muscles of, 471
ventricle of brain, 941
body of, 941, 943
cells of, 941
choroid plexus of, 943
corpus of, 941
vertebral region, muscles of, 410
vestibulo-spinal tract of cord, 853
Lateralis nasi artery, 609
Latissimus dorsi muscle, 415
burst of, 476
Leaf, intercostodial glands of, 794
supraoccygeal glands of, 794
Left bronchus, 1386
cardinal vein, 771
colic artery, 490
plexus, 1095
INDEX

INDEX

Megacephalic skull, capacity of, 147
Melanobian glands, 1149
structure of, 1150
Meninges, 1181
Mentor, 122
Mesencephalon, 904
Mesenteric arteries, 798
artery, inferior, 679
superior, 677
Mesentery, 1206
development of, 1248
Mesenterico-somatic fold, 1271
Mesenterico-parietal fold, 1273
Mesial, 122
Mesial, 1195
Tympa, 1165
arteries of, 1167
lymphatics of, 1168
nerves of, 1168
secondary, 1177
structure of, 1167
Veins of, 1167
Membrane, basal, 1182
Bowman’s, 1119
of brain, arachnoid, 976
meningeal, 972
of Bruch, 1124
of choroid, 1122
of Corti, 1185
costo-coracoid, 459
erico-thyroid, 1375
of Incus, 1120
of Desse, 1120
fenestrated, of Henle, 587
hylaid, 1195
hypo-thyroid, 1374
of Jacobs, 1130
of Kolliker, 1185
Nasmyth’s, 1214
obturator, 528
occipito-atlantal, anterior, 278
posterior, 278
otolith, 1182
of Reichert, 1182
of Scarpas, 1162
of Shrapnell, 1136
of spinal cord, 856
arachnoid, 858
surgical anatomy of, 890
sartorius, 230
scapular, 234
thyro-hyoid, 1374
Membranous canal of cochlea, 1182
cranium, 102
labyrinth, 1179
portion of utricle, 1451
semicircular canals, 1180
Meningial artery, 611
artery, 623
Middle, 615
surgical anatomy of, 615
posterior, 640
small, 616
lymphatic vessels, 778
membranes of brain, 972
veins, 730, 734
Meninges of brain, 972
Meninx-achondrial veins, 754
Meninco-femoral joint, 344
Menisco-tibial joint, 344
Meniscus, 283
Mental foramen, 123, 140
nerve, 109
point of skull, 150
process, 122, 140
protrubance, 122
spines, 123
Mental tubercles, 122
Merkel, filtrum ventriculi of, 1376
Mesonephron, 904
Mesenteric arteries, glands along, 798
artery, inferior, 679
superior, 677
ganglion, 1094
plexus, inferior, 1094
superior, 1094
vein, inferior, 708
superior, 708
Mesenterico-mesocicoidal fold, 1271
Mesenterico-parietal fold, 1273
Mesentery, 1206
development of, 1248
Glands, 805
of vermiform appendix, 1269
Meso-exo-gonialith, 111
Meso-granual, 1181
INDEX

1589

Mid-brain, deep origin of ecranial nerves, 910
grey masses of, 910
intercalatum of, 907
pest of, 910
pyramidal tract of, 910
structure of, external, 905
internal, 906
substantia nigra of, 907
tegmentum of, 908
fibres tracts of, 908
Middle artery, 429
cardiac nerve, 1086
cerebral artery, 629
cervical ganglion, 1085
clino processes, 93, 132
colic artery, 678
constrictor muscle, 403
costa-transverse ligament, 288
cutaneous nerve, 1021
cases, 110
fossa of skull, 130
humborrhoidal artery, 688
gland, 796
veins, 760
inguinal fossa, 1382
internal frontal artery, 629
meatus of nose, 145
mediastinum, 1396
meningeal artery, 615
vesica, 754
odontoid ligament, 52, 281
palatine nerve, 147
sacral artery, 683
veins, 764
thoracic vein, 730
turbated bone, 101
vesical artery, 688
Mids-gut, 1246
Milk teeth, 1206
Minor cardiac nerve, 1086
Mitral nerve-cells, 900
orifice, 570
Molar tooth, 34
Mobile septum, 1107
Moderate baud, 572
Modiolus, 1177
Molar glands, 1203
tooth, 1208
Molecular nerve-cells, 958
Moll, glands of, 1148
Monakow’s tract of cord, 853
tractus rubrospinalis, 908, 909
Monaxonic neurones, 823
Monopolar dendrites, 821
Monro, foramen of, 866, 913
sulcus of, 916
Mons Veneris, 1490
Montgomery, glands of, 1516
Monticulus cerebelli, 896
Morgagni, columns of, 1326
crypts of, 1326
hydradys of, 1480
sinus of, 404
valves of, 1326
Motor end-plates, 828
neurones, 816
root of spinal cord, 836
Mouth, 1203
angle of, 1203
aperture of, 1203
cavity of, 145
proper, 1204
floor of, lymphatic vessels of, 782
mucous membranes of, 1204
INDEX

Muscle or muscles, corrugator cutis ani, 451
superficial, 373
cutis nasalis, 367
erector, 411, 1528
ercario-arytenoideus, posterior, 1380
ercario-thyroideus, 1380
erector, 520
deltoid, 1472
depressor alae nasi, 375
glabrous, 380
labio inferioris, 380
detrusor urinae, 1446
digastricum, 429
digastric, 396
dilator naris anterior, 378
posterior, 378
of dorsal region, 546
circularis, 459
urinae, 450
erector clitoridis, 463
depressor, 460
infraorbitalis, 410
of expiration, 434
of expression, 387
tenax brevis digitorum, 546
pollicis, 491
carpal radius brevis, 497
longior, 487
ulnaris, 489
coccygeus, 424
communis digitorum, 488
indicii, 492
longus digitorum, 536
pollicis, 491
mini digitalii, 493
osseus metacarpalis, 491
primi internodi pollicis, 491
proprius hallucis, 535
secundi internodi pollicis, 491
face, 367
of femoral region, anterior, 514
internal, 522
prior, 532
fibres, 363
structure of, 364
of flexor region, 542
flexor accessorius, 549
biceps digitorum, 577
collis, 549
mini digitalii, foot, 550
hand, 560
pollicis, 499
carpal radius, 481
ulnaris, 482
longus digitorum, 541
hallucis, 541
pollicis, 484
osseus metacarpalis, 500
pollicis, 498
profundus digitorum, 483
sublimis digitorum, 483
of foot, 544
of forearm, 480
fronsalis, 369
fusiform, 365
gastrocnemius, 537
genuflexor, inferior, 530
superior, 529
genio-glossus, 390
genio-hyohyoideus, 390
of gluteal region, 525
gluteus maximus, 525
medius, 526
minimus, 526
gracilis, 522
hamstring, 532
of hand, 493
of head, 367

Muscle or muscles, helicis major, 1157
minor, 1157
Hilton’s, 1351
hip, 525
Horner’s, 373
of humeral region, anterior, 476
posterior, 479
hyo-glossus, 590
of iliac region, 510
iliacus, 512
ilio-capsularis, 513
ilio-ischio-epigastricus, 456
ilio-costalis, 421
of infra-hyoid region, 393
infraoculares, 427
infraorbitalis, 474
insertion of, 506
of inspiration, 434
intercostalis, 427
external, 427
internal, 427
of intermaxillary region, 381
interossei of foot, 551
of hand, 501
interspinales, 423
intertransversales, 424
lateralis, 424
mediales, 424
involuntary, 363
of ischio-rectal region, 451
of larynx, 1381
latisseus dorsi, 415
of leg, 534
levator anguli oris, 380
septale, 416
ani, 453
glandula thyroidea, 1409
labii inferioris, 380
superioris, 379
alaeque naso, 375
mento, 387
palati, 405
palpebrarum, 373
superioris, 374
prostate, 456
urethra, 456
levator costarum, 428
ligamentous action of, 270
of lingual region, 395
lingualis, inferior, 401
superior, 401
transverse, 401
vertical, 401
longissimus dorsi, 421
longus capitis, 408
collis, 409
of lower extremity, 509
lumbricalis, foot, 549
hands, 499
of mandibular region, 380
masseter, 583
of maxillary region, 379
Müller’s, 376
multifidus spinae, 423
mylo-hyohyoideus, 397
naso-labialis, 399
of natal region, 378
of neck, 357
nerves of, 364
oblique, ascending, 439
descending, 435
external, 435
internal, 439, 1528
obliquus auriculae, 1157
capitis inferior, 424
superior, 424
oculi, inferior, 376
superior, 376
obturators externus, 531

Mouth, muscles of, 379
surface form of, 1229
surgical anatomy of, 1234
vestibule of, 1294
Movability of, 1365
Movements admitted in joints, 268
Mucilaginous glands, 265
Mucous membrane, 1228
pubis, 1228
of bladder, 1447
of gall-bladder, 1351
of oesophagus, 1239
of pharynx, 1293
of urethra, 1453, 1456
of tongue, 1228
Müller’s muscle, 376
“ring” muscle, 1126
Multifidus spinæ muscle, 423
Multinucleated cells, 820
Muscle or muscles, 363
of abdomen, 434
deep, 451
superficial, 434
aductor hallucis, 547
indicii, 501
mini digitalii, foot, 548
hand, 500
pollicis, 497
accelerator urinae, 459
accessorius ad ilio-costale, 421
of arm region, 472
adductor brevis, 523
longus, 522
magnum, 523
minimus, 523
obliquus hallucis, 549
pollicis, 499
transversus hallucis, 551
pollicis, 499
anconeus, 489
antragicus, 1157
of arm, 472, 476
artes of, 364
aryteno-epiglotitis, 1381
arytenoideus, 1389
arytenoideus, 1380
attollens auriculæ, 371
atraheus auriculæ, 371
of auricular region, 371
azygos uvulae, 407
of back, 412
biceps, arm, 477
flexor cubiti, 477
thigh, 532
bipenniform, 365
biventer cervicis, 422
Bowman’s, 1125
brachialis anticus, 478
buccinator, 382
bulbo-cavernous, 459
bundles, 363
cervicalis ascendenæ, 421
chondro-glossus, 399
ciliary of eye, 1125
circumflexus, 406
coccygeus, 457
complexus, 422
compressor nasii, 378
nasi, 375
saecculi laryngis, 1381
urethra in female, 464
in male, 462
constrictor, isthmus fauces, 400, 407
pharyngeus, inferior, 402
middle, 403
superior, 403
urethra, in female, 464
in male, 462
coraco-brachialis, 477
INDEX

Muscle or muscles, ocipitalis, 369
 occipito-frontalis, 369
 omo-hyoid, 395
 opponens, minimi digiti, 500
 pollicis, 488
 orbicular, 365
 orbicularis oris, 381
 palpebrarum, 372
 orbital, 374
 of palatine region, 405
 palato-glossus, 400, 407
 palato-pharyngeus, 407
 of palmar region, middle, 501
 palmaris brevis, 500
 longus, 482
 of palpebral region, 372
 pectineus, 522
 pectoralis major, 466
 minor, 470
 of pelvic outlet, 451
 pennisinus, 356
 of perineum in female, 462
 in male, 457
 peroneus brevis, 543
 longus, 542
 tertius, 537
 of pharyngeal region, 402
 pharyngoglossus, 400
 of plantar region, 547
 plantaris, 539
 platysma myoides, 388
 popliteus, 540
 pronator quadratus, 485
 radii teres, 481
 psoas magnus, 512
 parvis, 512
 of pterygo-mandibular region, 385
 pterygooid, external, 386
 internal, 386
 puboccocygeus, 454
 pyramidalis abdominis, 446
 nasi, 378
 pyriformis, 527
 quadratus femoris, 550
 lumbrorum, 451
 mento, 380
 quadriceps extensor, 518
 quadrilateral, 365
 of radial region, 486, 497
 of radio-ulnar region, posterior, 488
 recto-urethralis, 456
 recto-uterinus, 1503
 rectus abdominus, 444
 capitis anterior major, 408
 minor, 400
 lateralis, 408
 posticus major, 424
 minor, 424
 femoris, 518
 oscli, external, 375
 inferior, 375
 internal, 375
 superior, 375
 retraheus auriculium, 371
 rhomboideus, 365
 rhomboideus major, 416
 minor, 416
 "ring" of Müller, 1126
 risorius, 383
 rectores spinae, 423
 sacro-lumbalis, 421
 salpingo-pharyngeus, 407
 Santorini's, 383
 sartorius, 518
 scalenus anterior, 410
 mediob, 410

Muscle or muscles, sclenius posterior, 411
 of seapal region, anterior, 473
 posterior, 474
 semicircular, of rectum, 1325
 semitendinosus, 533
 serratus magnus, 471
 posticus inferior, 417
 superior, 417
 of shoulder, 472
 skeletal, 363
 of sole of foot, 547
 soleus, 538
 sphenicter, 365
 ani, external, 452
 internal, 453
 vagina, 463
 spinals colli, 422
 dorsi, 421
 spinae of Kühne, 830
 splenius, 418
 capit, 418
 colli, 418
 sterno-clido-mastoid, 391
 sterno-hyoid, 394
 sterno-mastoid, 391
 sterno-thyroid, 394
 striated, 363
 striped, 363
 stylo-glossus, 399
 stylo-hyoid, 397
 stylo-pharyngeus, 405
 subanconeus, 450
 subclavius, 470
 subcutaneus, 521
 subscapularis, 473
 of superficial cervical region, 388
 splenii longus, 486
 radii brevis, 489
 of supra-hyoid region, 396
 supraspinales, 423
 supraspinatus, 474
 suspensory, of duodenum, 1294
 temporal, 354
 of temporomandibular region, 383
 tensor fascia femoris, 517
 palati, 406
 tarsi, 373
 tympani, 1171
 teres major, 475
 minor, 475
 of thigh, 514
 of thoracic region, anterior, 465
 lateral, 471
 of thorax, 426
 thyro-arytenoid, 1381
 thyro-epiglottides, 1381
 thyro-hyoid, 395
 tibialis anterior, 535
 posticus, 541
 of tibio-fibular region, 534
 of tongue, 400
 extrinsic, 400
 intrinsice, 400
 trachelo-mastoid, 421
 trapezius, 1157
 transversalis abdominis, 444
 cervicis, 421
 colli, 421
 transversus auriculue, 1157
 menti, 390
 of perinei superficialis, in female, 462

Muscle or muscles, transversus perinei superficialis, in male, 459
 trapezius, 413
 triangular, 365
 triangularis menti, 380
 sterni, 427
 triceps, 479
 extensor cubiti, 479
 of trunk, 412
 of ulnar region, 500
 unstriated, 363
 unstriped, 463
 of upper extremity, 464
 of ureters, 1446
 vasti of femoris, 520
 internus, 520
 vegetative, 363
 of vertebral region, anterior, 408
 lateral, 410
 voluntary, 363
 zygomaticus major, 379
 minor, 379

Muscular coat of anal canal, 1324
 of bladder, 1446
 of duodenum, 1296
 of intestine, large, 1324
 small, 1298
 of cesophageus, 1238
 of rectum, 1324
 of stomach, 1282
 of vermiform appendix, 1312
 fibres, cardiac, 363
 portion of urethra, 1451
 structure of heart, 577
 substance of tongue, 400

Muscle papillares of ventricle, left, 575
 right, 572
 pectinati of auricle, left, 570
 right, 568
 pubo-vesicalis, 444
 Musculo-cutaneous nerve, 1002, 1003
 Musculo-phrenic artery, 464
 Musculo-spiral groove, 181
 nerve, 1007
 branches of, 1007
 Myelencephalon, 577
 Myelolines, 824
 Myelolines of axones of cord, 855
 Myeloccelle, 845
 Myelon, 834
 Myelo-hyoid artery, 416
 muscle, 397
 ridge, 123
 Myelo-hyoidean groove, 124
 Myocardium, 576
 Myrtiform fossa, 106

N
Naboth, ovules of, 1505
Nails, 1195
 body of, 1195
 edge of, 1195
 lunula of, 1195
 matrix of, 1195
 ridges of, 1195
 ungual fold of, 1195
 wall of, 1195
 Nares, anterior, 142, 1108
 posterior, 142, 1108
 septum of, 142
 Nasal angle, 105
INDEX

Nasal artery from internal maxillary, 617
from ophthalmic, 626
of septum, 699
transverse, 626
bones, 104
articulations of, 105
attachment of muscles to, 105
borders of, 105
development of, 105
surfaces of, 105
cartilages, 1106
cavity, 142
crest, 111, 116
duct, 1152
fossa, 142, 1108
arteries of, 1111
atrium of, 1110
inner wall of, 1110
lymphatics of, 1112
mucous membrane of, 1110
nerves of, 1112
outer wall of, 1109
surgical anatomy of, 1112
veins of, 1111
groove, 105
nerve, 1044
branches of, 1045
notch, 80
portion of pharynx, 1231
process, 80
of superior maxillary, 109
region, muscles of, 378
slit, 143
spine, 80
anterior, 111, 139, 143
posterior, 116, 135, 143
venous arch, 729
Nasion, 80, 139, 150
Nasmyth's membrane, 1214
Naso-frontal vein, 740
Naso-labial ridge, 380
Naso-labialis muscle, 381
Naso-maxillary suture, 139
Naso-palatine artery, 617
canal, 121
groove, 121
nerve, 1050
Naso-pharynx, 1231
Nates of quadrigemina, 905
Naviculare bone, 249
articulations of, 249
attachment of muscles to,
249
surfaces of, 249
tuberosity of, 249
Neck, arteries of, 395
fascic of, 387
lymphatic glands of, 778, 783
vessels of, 786
muscles of, 387
triangles of, posterior, 620
surgical anatomy of, 618
veins of, 724, 728
Nelaton's line, 232
Nerve or nerves, 825
abducens, 1057
accessory, 1073
acoustic, 1064
afferent, 827
ansa hypoglossi, 1077
of arm, 994
Arnold's, 1070
of arteries, 588
articular, of anterior tibial, 1033
of articular-temporal, 1052
of great sciatric, 1030
of internal plantar, 1032
popliteal, 1031
Nerve or nerves, articular, of
peroneal, 1033
of posttibial, 1031
of ulnar, 1006, 1186
auditory, 1044
auricular, anterior, 1052
posterior, 1062
of vagus, 1070
auriculo-temporal, 1052
beginnings, peripheral, 828
of centripetal neurones, 828
blood-vessels of, 826
of bones, 41
buccal, 1051
from facial, 1063
buccinator, 1051
calcaneal, lateral, 1031
medial, 1031
calcaneco-planatar, 1031
cardine, cervical, 1072
great, 1086
inferior, 1086
middle, 1086
minor, 1086
superior, 1085
trigeminal, 1072
cardio-motor, 1081
carotico-typanic, 1083
cartilages, 1067
cavernous, large, 1095
small, 1095
centrifugal, 827
centripetal, 827
cephalic, 1036
cervical, 986
superficial, 990
cervico-facial, 1063
chorda tympani, 1052, 1061
clivary, long, 1045
short, 1045
circumflex, 1002
coccygeal, 1023
cochlear, 1064, 1186
communicantes hypoglossi, 988
communicating, fibular, 1031
tibial, 1031
of Cuminum, 1050
cranial, 1036
cural, anterior, 1021
accessory of Winslow, 1020
cutaneous, of abdomen, 1018
external, 1002, 1018
intermediate dorsal, 1034
internal, 1003, 1021
plantar, 1032
lateral, 1018
medial dorsal, 1034
middle, 1021
of museulo-cutaneous, 1034
museulo-spinale, 1008
of obturator, 1020
palmar, 1004
of perineal, 1028
of peroneal, 1033
of small sciatric, femoral, 1028
gluteal, 1028
perineal, 1028
of supra-orbital, 1044
of thorax, 1012
of ulnar, 1006
dorsal, 1006
palmar, 1006
dental, anterior superior, 1048
inferior, 1033
midle superior, 1047
posterior superior, 1047
descendens hypoglossi, 988
noni, 1076
Nerve or nerves, digastic, from
facial, 1062
digital, foot, 1032
hand, 1055
dorsal, 1010
of clitoris, 1030
of penis, 1030
dorsal-lumbar, 1016
dura of brain, 974
dural, 1046
from hypoglossal, 1076
of inferior maxillary, 1051
of vagus, 1070
efferent, 827
eighth, 1064
eleventh, 1073
of eyeball, 1038
facial, 1059
femoral, 1021
fifth, 1041
first, 1037
ventral cutaneous, 1011
of foot, 1032
fourth, 1041
frontal, 1043
ganglia of, 827
spinal, 853
ganglion of ciliary, 1040
lenticular, 1040
of Scarpa, 1065
vestibular, 1065
gastrie, 1072
genito-urinal, 1018
femoral, 1016
glosso-pharyngeal, 1066
gluteal, inferior, 1027
superior, 1027
gustatory, 1052
hernorrhoidal, inferior, 1028
of heart, 886
hypogastric, 1018
hypoglossal, 1074
ilie, 1017
ilio-hypogastric, 1017
ilio-inguinal, 1018
incisor, 1053
inframandibular, 1064
infraxillary, 1064
infraorbital, 1002
infraorbicular, 1045
intercostal, 1011
intercosto-humeral, 1013
interosseus, anterior, 1004
dorsal, 1008
posterior, 1008
of tibial, 1034
volar, 1004
Jacobson's, 1067
jugular, 1083
labial, 1048
of labyrinth, 1186
lacrimal, 1043
of Lanei, 940
laryngeal, of vagus, inferior, 1071
superior, 1071
external, 1071
internal, 1071
lingual of fifth, 1052
of glosso-pharyngeal, 1067
lumbar, 1015
lumbo-inguinal, 1018
malar, 1062
of superior maxillary, 1046
mandibular, 1050
masseteric, 1051
mastoid, 990
maxillary, inferior, 1050
superior, 1046
median, 1004
mental, 1053
INDEX

Nerve or nerves, muscular, of external plantar, 1053 of great sciatric, 1050 of hypoglossal, 1077 of internal plantar, 1032 of pectoral, 1031 of musculo-cutaneous, 1034 of musculo-spiral, 1007 of perineal, 1030 of post-tribial, 1031 of sciatic plexus, 1027 of tibial, 1033 of unlar, 1006 musculo-cutaneous, 1002, 1034 musculo-spiral, 1007 mylo-hyoid, 1033 nasal, 1044 from Meckel's ganglion, 1048 ganglion branch of, 1045 naso-palantine, 1050 ninth, 1066 obturator, 1020 accessory, 1020 ocelomotor, from facial, 1062 great, 986 small, 989 oculomotor, 1039 nucleus of, 911 osphageal, 1072 olfactory, 1037 ophthalmic, 1043 optic, 1038 orbital, of superior maxillary, 1046 origin of, 827, 828 palatine, anterior, 1049 external, 1050 large, 1049 middle, 1050 posterior, 1050 small, 1050 palmar, of unlar, 1006 palpebral, 1048 parotid, 1052 perforating, of Casseous, 1002 of pericardium, 563 pericranial, 1041 perineal, 1028 peroneal, 1030 common, 1033 deep, 1033 petrosal, deep, 1083 great deep, 1049 superficial, 1048 large deep, 1049, 1083 superficial, 1048 pharyngeal, 1050, 1067, 1070 phrenic, 992 of pia of brain, 982 plantar, lateral, 1032 medial, 1031 plexus of, 826 abdominal aortic, 1094 adrenal, 1092 annular, 1121 brachial, 994 cardiae, 1090 carotid, internal, 1083 caverneous, 1083 cervical, 989 dorsal, 984 coccygeal, 1034 cervical, 1072, 1094 colic, left, 1005 coronary, 1090, 1094 cystic, 1094 of dental, superior, 1048 epigastric, 1091 fundamental, 1121 gastrie, 1094 gastro-duodenal, 1094 Nerve or nerves, plexus of, gastro-epiploic, 1094 left, 1094 hemorrhoidal, inferior, 1095 superior, 1095 hepatic, 1094 hypogastric, 1095 infraorbital, 1062 intra-epithelial, 1121 lumbar, 1016 mesenteric, inferior, 1094 superior, 1094 osophageal, 1069, 1072, 1091 ovariun, 1094 pancreatic, 1095 patellar, 1021 pelvic, 1095 pharyngeal, 1067 phrenic, 1092 prostatic, 1095 pudendal, 1026 pudic, 1026 pulmonary, 1091 dorsal, 1069, 1072 ventral, 1069, 1072 pyloric, 1094 renal, 1072, 1093 sacral, 1020, 1093 dorsal, 984 seatie, 1026 sigmoid, 1095 solar, 1081 spermatic, 1094 splenic, 1072, 1094 subclavian, 1086 subepithelial, 1121 supracranial, 1092 thoracic aortie, 1087 tympanic, 1067 uterine, 1095 utero-vaginal, 1095 vaginal, 1095 vertebral, 1086 vesical, 1095 peneugastic, 1068 popliteal, external, 1033 internal, 1030 portio dura, 1059 malleol, 1060 postribial, 1031 ptetragoidal, external, 1051 internal, 1051 ptetrago-palantine, 1050 pudendal, inferior, 1028 pudic, 1028 pulmonary, dorsal, 1072 ventral, 1072 radial, 1088 recurrent, of internal maxillary, 1051 larvingale, of vagus, 1071 respiratory, of Bell, external, 1000 internal, 992 saeral, 1023 sphenous, 1222 external, 1031 internal, 1022 long, 1024 short, 1031 seapalar, posterior, 999 of Scars, 1050 seatie, great, 1030 small, 1027 seoret, long, 1028 second, 1038 seventh, 1059 sixth, 1057 spermatic, external, 1018 sphenio-palatine, 1047 Nerve or nerves, sphenoidal, 1054 spinal, 822 accessory, 1073 splanchnie, 1057 renal, 1088 stylo-hyoide, 1062 subarachnoidal, 1047 suboccipital, 986 subepaular, 1001 superficialis colli, 990 supra-auricular, 902 supraclavaeicular, 991 supramammillary, 1063 supraretinal, 1014 suprascapular, 1000 suprasternal, 901 supratrochlear, 1044 sural, 1033 sympathetic, 827 system, 815 cell-element of, 816 development of, 816 structure of, 810 supporting tissue elements of, 832 temporal, of auriculo-temporal, 1052 deep, 1051 from facial, 1002 of superior maxillary, 1046 temporomalar, 1046 tenth, 1068 termination of, 828 third, 1039 thoracic, 1010 anterior, 1001 long, 1009 posterior, 1001 thoracico-lumbar, 1014 thyro-hyoid, 1077 thyroid, 1086 fibial, 1090 tissue, chemical composition of, 833 development of, 818 tonsillar, 1067 trifacial, 1041 trigeminal, 1041 trochalear, 1041 nucleus of, 910 twelfth, 1074 tympanic, 1067 from facial, 1061 unlar, 1005 vagus, 1088 vasomotor, 1081 vestibular, 1065 Vidian, 1048 Nerve-cell, 820 axone of, 823 body external morphology of, 820 internal morphology of, 822 of cerebral cortex, 958 dendrites of, 822 of Martinotti, 960 mitral, 960 Nerve-endings in muscle, 364 Nerve-fibre, axis-cylinder of, 823 Nerve-fibres, 825 centripetal, 827 centripetal, 823 cerebral, 901 cortex, 959 commissural, 963 projection, 963 thalamo-frental, 956 thalamo-sтратie, 956 vasomotor, 826
INDEX

Nerve-path, 825
Nervi nervorum, 826
Nervous papilla, 1191
Nervus cutaneus patellae, 1022
intermedius, 894
superficialis cordis, 1085
Neumann, dental sheath of, 1213
Nervi arch, 34
tube, 817
Neuraxone, 820
Neuromeningeal canal, 1252
Neurilemma of cord, 824
amyelonic axones with, 825
without, 825
nucleus of, 825
Nurite, 820
Neuroblasts, 818
Neuro-central suture, 59
Neuro-muscular spindles, 830
Neuro-tendinous spindles, 830
Neuroglia of cord, 815, 832
Neuroes, 816, 820
afferent, peripheral axone of, 819
centripetal, peripheral nerve, beginnings of, 828
diagonal, 823
excito-glandular, 816
excito-motor, 816
forms of, 820
monaxon, 823
doxon, 823
motor, 816
polyaxon, 823
sensor, 816
peripheral axone of, 819
theory of, 831
Neuropore, 863
Nexal root of eighth nerve, 1065
Nidus avis of cerebellum, 898
laryngei, 890
pharyngeo, 890, 892
Ninth nerve, 1066
surgical anatomy of, 1067
Nipple, 1516
structure of, 1518
Nissel's bodies, 822
Nodal point, 1116
Nodes, hemolymph, 774
Nodular lobe of cerebellum, 898.
Nose, 1105
aperture of cartilage of, 1107
arteries of, 1108
cartilage of, 1106
dorsum of, 1106
fosse of, 142, 1108
integument of, 1107
interior of, sympathetic vessels of, 782
lymphatics of, 1108
meatus of, inferior, 145
middle, 145
superior, 101, 144
mucous membrane of, 1108
muscles of, 1107
nerves of, 1108
outer, 1106
septum of, 142
cartilage of, triangular, 1107
structure of, 1106
veins of, 1108
Notch, cotylloid, 220
ecliptal, 82
ilio-sciatic, 217
intercylindrely, 227
intervertebral, 49
lachrymal, 107
nasal, 80
popliteal, 236
pre-occipital, 922
pre-ternal, 157
Notch, pterygoid, 96
of Riviinus, 1161
sacro-sciatic, 211
great, 217
lesser, 218
scapular, great, 175
sigmoid, 125
sphenio-palatine, 118
supraorbital, 80, 140
supra-occipital, 175
supraternal, 411
trochlear, 1370
Nucleal line, inferior, 72
superior, 72
plane, 72
Nuek, canal of, 1472, 1513
Nuclei of abducent nerve, 804
of accessory nerve, 800
of acoustic nerve, 892
of cerebellum, 890
of cochlear nerve, 892
of facial nerve, 803
of gloso-pharyngeal nerve, 890
of hypoglossal nerve, 889
of origin, 889
penis, 887
of termination, 889
of trigeminal nerve, 804
of vagus nerve, 890
Nucleus, accessory cuneate, 884
ala cinereus, 891
ambiguus, 890, 892
arcuate, 886
dentate of cerebellum, 900
emboliformis, 900
fastigi, 900
funiculi cuneati, 876
teres, 886
globosus, 890
incertus, 888
intercalatus, 886
lateralis, 886
lentis, 1142
of oculomotor nerve, 911
of olive, 895
superior, 827
posterior, 886
rubor, 906
simitarianis, 914
of Stilling, 847
tegmenti, 908
trigeminal nerve, 910
Nuel, space of, 1185
Nuhn and Blandin, glands of, 1101
Nutrient artery of femur, 706
of fibula, 717
of humerus, 658
of tibia, 718
Nymphæ, 1490
O

Oblique, 129, 150
Obex, 881
Oblique diameter of pelvis, 210
inguinal hernia, 1529, 1532
complete, 1533
incomplete, 1533
ligament, 316
line of clavicle, 169
of fibula, 210
of radius, 192
of tibia, 237
muscles, ascending, 439
aponeurosis of, 441
descending, 435
e external, 435
aponeurosis of, 435
Oblique muscles, internal, 439
aponeurosis of, 441
dissection of, 443
ridges of scapula, 172
of trapezium, 200
of ulna, 190
sacro-iliac ligament, 294
sinus of pericardium, 562
vein of Marshall, 771
Obliques auricular muscle, 1157
capsis, inferior muscle, 424
superior muscle, 424
oculii muscle, inferior, 376
superior, 376
Oblongata, 874
areas of, 875
fissures of, 874
funiculus cuneatus of, 876
gracilis, 876
lateralis of, 876
olive of, 876
pyramids of, 875
restis of, 876
tuberculum cinereum of, 876
vessels of, 736
Obstetric perineum, 1490
Obturator artery, 689
peculiarities of, 690
buies, 333
canal, 528
crest, 220
eexternus muscle, 531
fasela, 538
foramen, 220
groove, 217, 220
internus muscle, 528
bursa of, 528
ligament, 528
membrane, 528
nerve, 1020
accessory, 1020
vein, 761
Occipital artery, 610, 642
branches of, 611
bone, 71
angles of, 75
articulations of, 76
attachment of muscles to, 76
borders of, 75
development of, 75
structure of, 75
surfaces of, 71
bulb, 946
crest, external, 72, 136
internal, 74, 133
diploic vein, 734
fissures, 926, 931
inferior, 931
lateral, 931
fossa, inferior, 133
groove, 86
lobe, 931
fissures of, 931
gray substance of, 959
lymphatic glands, 779
nerve of facial, 1062
great, 986
small, 989
point of skull, 150
protuberance, external, 71, 136
internal, 73
sinus, 739
triangle, 620
vein, 277
Occipitalis muscle, 309
Occipito-atlantal ligament, anterior, 278
posterior, 278
Occipito-axial ligament, posterior, 280
INDEX

Ovary, supports of, 1513
surgical anatomy of, 1515
veins of, 1515
Ovicapsule of Graafian follicles, 1514
Oules of Naboth, 1505
Ovum, discharge of, 1515
Oxytic cells, 1285

P

Pacchionian bodies, 979
depressions, 78
glands, 737
Pacian corpuscles, 830
Pads of adipose tissue, 255
Palatal index of skull, 147
region, muscles of, 405
dissection of, 405
surgical anatomy of, 408

Palate, 1220
bone, 115
articulations of, 119
attachment of muscles to, 119
development of, 119
horizontal plate of, 116
perpendicular plate of, 117
processes of, 118
tuberosity of, 117, 135
vertical plate of, 117
hard, 1220
muscles of, 405
soft, 1221
surgical anatomy of, 1234
vail of, 1221

Palatine aponeurosis, 406
artery, ascending, 608
descending, 617
inferior, 608
posterior, 617
surgical anatomy of, 617
canal, anterior, 143
posterior, 107, 116
accessory, 116, 135
foramen, great, 116
posterior, 117
fossa, anterior, 110, 133
glands, 1221
nerve, anterior, 1049
external, 1050
large, 1049
middle, 1050
posterior, 1050
small, 1050
process of superior maxillary bone, 110
spine, 116
veins, 727

Palato-glossus muscle, 400, 407
Palato-mandibular canal, 107
Palato-pharyngeus muscle, 407

Palmar arch, deep, 660
superficial, 666
surface marking of, 667
surgical anatomy of, 667
cutaneous nerve, 1004
fascia, deep, 495
surgical anatomy of, 496
interosseous arteries, 662
plexus of nerves, 745
recurrent arteries, 662
region, middle, muscles of, 501

Palmaris brevis muscle, 500
longus muscle, 482

Palpebral arteries, external, 625
internal, 625
fascia, 1149

Palpebral ligaments, 1149
nerves, 1048
portion of conjunctiva, 1150
region, muscles of, 372
dissection of, 372

Pampiniform plexus of veins, 765

Pancreas, 1355
arteries of, 1360
body of, 1357
borders of, 1357
development of, 1254
dissection of, 1355
head of, 1357
lymphatic vessels of, 804
lymphatics of, 1360
neck of, 1357
nerves of, 1360
peritoneal relations of, 1358
structure of, 1359
surface form of, 1360
surfaces of, 1357
surgical anatomy of, 1360
tail of, 1358
veins of, 1360

Pancreatic area of kidney, 1414
artery, 676
duct, 1359
juice, 1360
plexus of nerves, 1094
Pancreatica magna artery, 676
Pancreatic-duodenal artery, inferior, 677
superior, 676
plexus of nerves, 1094
vein, 768

Papilla, bile, 1296
dentine, 1215
lachrymal, 1152
spirals, 1183

Papilke circumvallate, 1099
corneal, 1100
filiform, 1100
fungiform, 1100
maxima, 1099
medial, 1100
minimae, 1100
simple, 1100
structure of, 1100
of tongue, 1099

Papillary layer of skin, 1191
Paracentral fissure, 928
gyre, 900
Paraduodenal fossa, 1371
Paramammaery gland, 811
Paramastoid process, 73
Paranasal fissure, 927
Parametrium, 1501
Paramyotomes, 1359
Paraplexus, 943, 945, 946
Parasympathetic bodies, 1417
Parathyroid glands, 1412
embryology of, 1413
structure of, 1413
surgical anatomy of, 1413

Paroxones, 823
Parenychyma of lungs, 1403
tissue of testicle, 1482
Paries caroticus, 1163
jugularis, 1161
labyrinthina, 1162
mastoid, 1162
tegmentalis, 1161
Parietal artery, 613
arteries, ascending, 630
bone, 76
articular muscles of, 79
attachment of muscles to, 79
development of, 78
surfaces of, 76
borders of, 78

Parietal cells of gastric glands, 1285
diploe vein, external, 734
eminence, 76
fissure, 930
foramen, 76
gyre, 931
layer of pleura, 1303
lobe, 930
fissures of, 930
gyre of, 931
lymphatics, 507
pericorneum, 1257
surface of liver, 1387
of stomach, 1278

Parieto-colic fold, external, 1273
internal, 1273
Parieto-sphenoidal artery, 630
Parieto-temporal artery, 630
Paro-ophoron, 1512
Parocciplidal fissure, 930
gyre, 931

Parotid capsule, 1226
duct, 1225
structure of, 1226
surface form of, 1225
crass, 380, 1225
gland, 1224
accessory, 1225
ducts of, 1226
duct of, 1225
lymph, 1225
lymphatics of, 1226
nerves of, 1226
veins of, 1226

lymphatic glands, 779
deep, 780
superficial, 779
nerves, 1002
recess, 1225

Parotidico-masseterica fascia, 389
Parovarium, 1511
Pars liniaris retinae, 1125, 1130
intermedia of Whisberg, 1059
iridica retinae, 1130

Parvicular artery, 616
Patella, 223
apex of, 234
articular muscles of, 234
attachment of muscles to, 234
borders of, 234
development of, 234
ligaments of, 337
structure of, 234
surface form of, 234
surfaces of, 233
surgical anatomy of, 234

Patellar bursa, deep, 521
plexus, 1021
Path of light stimuli, 1137
Path, gustatory, 1067
optic, 1038
Pecquet, reservoir of, 775
Pecten osis pubis, 219
Pecten muscul, 522
nerve to, 1022
Pectoral fascia, deep, 466
gland, 788
intercostal nerve, 1011
region, dissection of, 465
ridge, 181

Pectoralis muscle, major, 466
minor, 470

Pechuainedes of ealium, 936
cerebellar, 900
medipedeuncle, 901
postpedunene, 900
prepedunce, 901
Pelvic colon, 1317
INDEX

Pelvic fascia, 1556
ligament, transverse, 461
plexus, 1095
peritoneum of gangliated cord, 1089
Pelvis, 209
axes of, 211
brim of, 209
eavity of, 210, 1440
boundaries of, 1440
contents of, 1440
diameters of, 210
diaphragm of, 1241
differences between male and female, 212
false, 209
of kidney, 1424
lower circumference of, 211
lymphatic vessels of, 799
lymphatics of, 795
muses of, 451
outlet of, 211
position of, 211
surface form of, 222
surgical anatomy of, 222
ture, 209
inlet of, 209
superior circumference of, 209
veins of, 755
Pendulous portion of urethra, 1452
Penile portion of urethra, 1452
Penis, 1463
arteries of, 1469
dorsal, 608
body of, 1465
corpora cavernosa of, 1465
corpus spongiosum, 1468
crura of, 1469
dosum of, 1165
freumen of, 1465
ligaments of, 1469
lymphatic vessels of, 799
lymphatics of, 1409
nerves of, 1030, 1470
dorsal, 1030
prepuce of, 1465
root of, 1464
septum of, 1467
structure of, 1465
surgical anatomy of, 1470
veins of, 1469
dorsal, 608
pubis of, 762
Pennaform muscles, 365
Pepic cells of glands, 1285
glands, 1285
Perforated space, anterior, 935
Perforating arteries, anterior, 935
of hand, 662
of thigh, 706
eutaneous nerve, 1028
of Cavernous, 1002
Pericardial folds, 1271
fossa, 1271
Pericardial arteries, 464, 668
Pericardial pleura, 1394
sac, 1246
Pericardiotheoracic cavity, 1246
Pericardium, 559
arteries of, 563
fibrous layer of, 560
nerves of, 563
serous, 562
sinus of, oblique, 562
superficial, reverse, 560
structure of, 560
surgical anatomy of, 563
vestigial fold of, 563
Pericerebrum, 1206
Perichondrium, 261, 262
Perichondroal space, 1118
Periultral lamina, 934
Periurethral nerves, 1044
Perilymph space, 1174
Perinervium, 304
Perineal artery, superficial, 691
transverse, 692
body, 1222, 1496, 1555
eutaneous nerve, 1028
fascia, deep, 1550
ligament, transverse, 461
nerve, 1028
Perineum, 1322, 1496
dissection of, 1547
in female, 1554
muscles of, 462
lymphatic vessels of, 799
in male, 1549
central tendinous point of, 1549
fasciae of, 457
muscles of, 457
obstetrie, 1490
surgical anatomy of, 1547
Perineum, 826
Perigastrium, 37
dental, 1214
Perineal axone of afferent neurone, 819
branches of lumbar portion of a gangliated cord, 1089
of middle cervical ganglion, 1086
of pelvic portion of gangliated cord, 1089
of sacral portion of gangliated cord, 1089
of superior cervical ganglion, 1083
of thoracic portion of gangliated cord, 1087
nerve beginnings, 828
centripetal neurones, 828
pathway, 964
veil of His, 818
Peritoneal coat of duodenum, 1286
of stomach, 1281
relations of pancreas, 1358
Perisecletomy lymph-space, 1113
Peritoneum, 1255
development of, 1245, 1252
ligaments of, 1264
lymphatic vessels of, 800
surgical anatomy of, 800
mesenteries of, 1266
omenta of, 1264
parietal, 1257
structure of, 1256
surgical anatomy of, 1274
visceral, 1257
Peritracheo-bronchial glands, 809
Perivascular lymph-spaces, 772
Permanent teeth, 1206
development of, 1218
ereption of, 1210
superadded, 1218
Peroneal artery, 717
anterior, 717
branches of, 717
peculiarities of, 717
posterior, 718
groove, 248
nerve, 1033
common, 1033
deep, 1033
spine, 246
tubercle, 246
Peroneus brevis muscle, 543
longus muscle, 542
tertius muscle, 537
Perpendicular furcularis, 962
line of ulna, 190
plate of ethmoid bone, 100
of palate bone, 117
Pes anserinus, 1060
of extura cerebi, 1065, 910
hippocampus, 947
leonis, 947
Petit, canal of, 1140
triangle of, 487
Petro-mastoid portion of temporal bone, 91
Petro-occipital fissure, 128
suture, 75, 133
Petro-sphenoidal fissure, 128
suture, 136
Petro-squamous sinus, 739
suture, 88
Petro-tympanic fissure, 84, 1162
Petrosal nerve, deep, 1083
great deep, 1049
superficial, 1048
large deep, 1049, 1083
superficial, 1048
process, 93
sinus, inferior, 742
superior, 742
Petrosus ganglion, 1066
bursa of, 1467
portion of internal carotid artery, 622
of temporal bone, 136
Peyer's glands, 1304
patches, 1304
Phalanges of foot, 255
articulations of, 255, 361
attachment of muscles of, 255
development of, 255
of hand, 206
articulations of, 206, 327
attachment of muscles, 206
development of, 208
ligaments of, 327
Pharyngeal aponoeurosis, 404, 1235
artery, ascending, 612
branches of, 612
surgical anatomy of, 612
branch of vagus nerve, 1070
bursa, 1234
glands, 1233
nerve, 1060, 1067
plexus of, 1067
portion of tongue, 1097
region, muscles of, 402
dissection of, 402
ring, lymphatic, 1234
spine, 73, 135
tonsil, 1231, 1234
tubercle, 73, 135
veins, 730
phlebus of, 730
Pharyngo-epiglottic fold, 1232
Pharyngo-glossus muscle, 400
Pharynx, 1230
aponeurosis of, 1233
arteries of, 612
fibrous coat of, 1233
thymus of, 1231
laryngeal part of, 1232
lymphatic vessels of, 782
mucous coat of, 1233
muscles of, 402
nasal part of, 1231
oral part of, 1231
structure of, 1232
surgical anatomy of, 1234
INDEX

Popliteus muscle, 540
Pore, gustatory, 1100
Porta, 806, 913
Potal sinus, 729
vein, 769
system of, 768
Portio dura of seventh nerve, 1053
ganglia of, 1059
mollis of auditory nerve, 1059
Post-anal gut, 1252
Post-central fissural complex, 930
fissure, 930
gyre, 931
Post-glennoid process, 84
Post-pharyngeal gland, 784
Postbrachium, 905
Postcranial fissure, 925
Posteva, 764
peculiarities of, 764
relations of, 764
surgical anatomy of, 766
Postcerebellar artery, 641
Postcerebral artery, 642
branches of, 642
Postchoroid artery, 642
Postcostal region, 978
Postcommissure of epiphysis, 915
Postcommunicant artery, 630
Postcoron, 945
Postdural artery, 612
Posterior aural artery, 611
nerve, 1062
vein, 727
bicipital ridge, 181
calcaro-astroglial ligament, 354,
399
arpal arch, 661
artery of ulnar, 665
cerebral artery, 642
cerebral plexus, 887
chondro-epithelial ligament, 290
chondro-xiphoidal ligament, 290
choroid artery, 642
cnoid process, 93, 132
common ligament, 272
cordial foramen, 73, 133, 136
fossa, 136
costo-transverse ligament, 288
costochondral ligament, 290
crucial ligament, 339
deeep cervical vein, 733
dental canals, 1066
divisions of cervical nerves, 986
ehmoideal canal, 82, 100
cells, 101, 145
foramen, 83, 130, 141
siinuses, 101
external jugular vein, 728
extremity of ribs, 161
head of, 161
neck of, 161
uterine ligament, 162
femoral region, muscles of, 532
frenestrated space, 589
fontanelle, 73, 103
fossa of skull, 132
gluteal line, 216
humeral region, muscles of, 470
inferior cerebellar artery, 641
spinous process of ilium, 130
intercostal veins, 752
intenal frontal artery, 629
interosseous artery of ulna, 665
nerve, 1068
interosseous ligament, 292
interosseous ligament, 225
ligament of incus, 1171
of Winslow, 337
Posterior ligament of wrist, 320
longitudinal ligament, 272
spinal vein, 752
median gannglionc arteries, 642
vein, 736
medistal veins, 668
glands, 808
medistinum, 1397
medullary vein, 901
mending artery, 640
mases, 1108
nasal spine, 116, 135, 143
occpito-atlantoidal ligament, 278
occpito-axial ligament, 250
palatine artery, 617
canal, 107, 116
canals, accessory, 116, 135
foramen, 135
nerve, 1049
parafocalsy sulus, 935
peroneal artery, 718
pillar of soft palate, 1222
pillars of fornnix, 950, 951
public ligament, 298
radial carpal artery, 601
radio-ulnar ligament, 317
regional division, 498
recurrant tibial artery, 712
root of spinal nerves, 983
sacral foramina, 63
sacral-occygeal ligament, 296
sacro-ilaeal ligament, 294
sacro-sciatic ligament, 294
scapular artery, 644
nerve, 999
region, muscles of, 474
semicircular canal, 1167
spinal artery, 641
sterne-clavicular ligament, 300
sterne-costo-ligament, 290
surface of liver, 1337
of stomach, 1278
superior dental nerves, 1047
spinos process of ilium, 216
temporal artery, 613, 642
diploic vein, 734
thoracic nerve, 1000
tibial artery, 715
veins, 758
thio-fibular region, muscles of, 537
thio-tarsal artery, 349
triangle of neck, 620
tubercle of cervical vertebra,
tympano-malleolar ligament, 1166
ulnar recurrent artery, 664
vein, 745
vertebral vein, 733
wall of tympanum, 1162
Postero-lateral fontanelles, 103
ganglionic arteries, 642
Postero-median ganglionic artes,
630, 642
Postero-medial ganglionic artes,
630, 642
Postforses, 940
Postgemina, 905
Postgeneculum, 905
Posthypophysis, 867, 917
Postinsula, 933
Postoblongata, areuate fibre
system of, 886
descamation of lemniscus, 882
gray masses of, 886
internal structure of, 881
pyramidal decussation of, 881
raphe of, 885
rests of, 885
of Wilder, 874
Postoperculum, 925
Postorbital limbus, 930
Postparietal gyre, 931
Postpenduncle of cerebellum, 900
Postforamnum, 908, 916
Postpontile recess, 874
Postramus of cerebellum, 899
Postrhinal fissure, 953
Posttibial nerve, 1031
Postvermis, 896
Pouch, Douglas's, 1502
of Prussak, 1172
recto-vaginal, 1502
uterus-vagina, 1490, 1502
Poupart's ligament, 438, 1527
Pre-anal fibres of levator ani, 455
Pre-aortic glands, 798
Pre-anure urinary glands, 779
Pre-oblongata, 878
fibre-tracks in, 888
gray masses in, 888
internal structure of, 887
nucleus incertus, 888
superior olivary nucleus, 887
Pre-opercular notch, 922
Pre-operculum, 925
Pre-sternal notch, 157
Pre-ternal, 157
Prebrachium, 905
Precava, 752
relations of, 752
surgical anatomy of, 753
Precentral fissure, 927
superior, 927
gyre, 929
Precerebellar artery, 642
Precerebellum, 628
branches of, 628
Prechordal artery, 630
Precommisure, 932
Precommunicant artery, 628, 629
Precoron, 943
Precuneal fissure, 931
Prefacial, 625
Prefores, 940
Pregemina, 905
Pregeniculum, 913, 914
Prehypophysis, 917
Preinsula, 933
gyres, 933
Presacral glands, 785
Prenaxillary bones, 110
Prepatalar bursa, 342, 521
Prepedunecida, 879
Precentral, 888, 901, 909
Preperforation, 867, 935
Prepuce of clitoris, 1494
of penis, 1465
Prepyramidal tract of cord, 853
Prenatus of cerebellum, 899
Pressure curves of humerus, 183
Presylvian ramus, 924
Pretreacheal fascia, 391
glans, 786
Prevermis, 896
Prevertebral fascia, 390
Prickle cells, 1119
Primordial ova, 1514
Prinsep's bladder artery, 715
pollicis flexor, 462
Pro-gnathous skull, index of, 148
Pro-otic portion of temporal bone, 91
Processus processes, acromion, 175
alveolar, 140
angular, 80
external, 140
internal, 140
of atlas, 55
auditory, 88
basilar, 73
INDEX

101

Quadratus lumborum, fascia of, 451
muscle, 451
menti musc. 380

Quadriceps extensor muscle, 518
Quadrigemina, 809, 905, 907
branchia, of, 905
nates of, 905
postgemina, of, 905, 907
pregeminu, of, 905, 907
structure of, 905
testes of, 905
Quadrilateral muscles, 365

R
Radial artery, 659
branches of, 601
peculiarities of, 600
relations of, 659
surface marking of, 660
surgical anatomy of, 660
fossa, 183
head of humerus, 183
nerve, 190
recurring artery, 661
region, muscles of, 486, 497
dissection of, 486
vein, 745
Radial indices artery, 662
Radiate fissure, 928
Radio-carpal articulations, 319
surface form of, 320
Radio-ulnar articulation, 315
inferior, 317
surface form of, 319
middle, 316
superior, 318
surface form of, 316
surgical anatomy of, 316
ligaments, anular, 316
anterior, 317
oblique, 316
principal, 316
posterior, 317
round, 316
region, anterior, muscles of, 481
surgical anatomy of, 486
posterior muscles of, 488
surgical anatomy of, 493

Radius, 192
articulations of, 194
attachment of muscles to, 194
development of, 194
lower extremity of, 193
shaft of, 192
borders of, 192, 193
surfaces of, 193
squirrel cavity of, 193
structure of, 194
surface form of, 194
surgical anatomy of, 194
upper extremity of, 192
Rami of lower jaw, 124
Ramus epiophyseal, 925
hypophyseal, 925
of ischium, ascending, 218
descending, 218
prespylavian, 924
of pubis, ascending, 219
descending, 220
inferior, 220
superior, 219
subpylavian, 924
Ramus arytenoideus, 606
vein, 729
Raphé of perineum, 1549
of postoblongata, 885
of serotum, 1473

Raphé of tongue, 1997
Receptaculum chyli, 775
Reynolds, epiphyseal, 87
infundibular of third ventricle, 917
postpylary, 874
Recesseus coeoilares of Réiehert, 174
recti, 902
Reciprocal reception, articulation by, 267
Rei glandular, 1326
glands, 806
valves, 1326
Repte-urethralis muscle, 456
Repto-uterinus muscle, 1503
Repto-vaginal fold, 1502
pouch, 1322, 1502
Repto-vesical fascia, 1558
pouch, 1322
Rectum, 1320
acicular coat of, 1325
terries of, 1327
curves of, 1321
lymphatics of, 807, 1329
mucous membrane of, 1326
mucous coat of, 1324
nerves of, 1320
prostatic portion of, 1321
sacroccycygeal portion of, 1320
serous coat of, 1324
structure of, 1324
submucous coat of, 1325
supports of, 1322
surface form of, 1331
surgical anatomy of, 1331
veins of, 1328
Rectus abdominis muscle, 444
capitis anteius major muscle, 408
minor muscle, 409
lateralis muscle, 409
posterior major muscle, 424
minor muscle, 424
femoris muscle, 518
oculi muscle, external, 375
inferior, 375
internal, 375
superior, 375
Recurrence artery, palmar, 662
radial, 661
tibial, anterior, 713
posterior, 712
ulnar, anterior, 664
posterior, 664
laryngeal nerve, 1071
Reflections of pleura, 1392
Refraacting media of eye, 1138
Riehert, recessus coeoilares of, 1174
Reit, island of, 933
Réiehst, membrana, 1182
Renal artery, 680
inferior, 1432
bloodvessels, 1432
impression of liver, 1337
pexus, 1072, 1063
surface of spleen, 1361
veins, 767
zone of Hyrtl, exsanguinated, 1432
Reservoir of Pericuet, 775
Respiration, muscles of, 433
organs of, 1369
Respiratory nerve of Bell, external, 1000
internal, 902
Restis of oblongata, 876
of postoblongata, 885
Rete testis of Haller, 1482
Reticular formation of eord, 845
Retina, 1130
nerve-fibres of, 1132
physiological, 1130
pigmentary layer of, 1137
rods of, 1135
structure of, 1131
supporting framework of, 1137
retinacula of capsular ligament of, 329
patellar, 520
Refractions auriculari muscle, 371
Retro-aortic glands, 797
Retro-esoeal fossa, 1272
Retro-colic fossa, 1272
Retro-cruetal glands, 795
Retro-duodenal fossa, 1271
Retro-peritoneal fossa, 1270
space, 1257
Retro-pharyngeal glands, 784
space, 301, 1230
Retro-rectal space, 312
Retro-renal fascia, 1320
Retro-sternal glands, 807
Reitzus, brown stric of, 1214
fundiform ligament of, 544
gyrsus fascicolaris of, 958
intrathymic of, 937
space of, 1442
Rhinecephalon, 920, 934
central part of, 936
cerebral part of, 936
Rhodopsin, or visual purple, 1130
Rhombencephalon, 574
Rhomboid impression, 170
Rhomboid ligament, 200
Rhomboidal muscles, 365
Rhomboides major muscle, 416
minor muscle, 416
Rib, 163
ganglion of, 1077
Ribs, 163
anterior extremity of, 162
articulations of, 255
attachment of muscles to, 165
cervical, 53, 167
common characters of, 161
development of, 165
false, 161
floating, 161
peculiar, 163
posterior extremity of, 161
shaft of, 162
structure of, 165
tail, 161
Ridges, bicapital, 181
epicondyle, 181
glutea, 226
mylo-hyoid, 123
gastro-abdominal, 380
oblique, of trapeziun, 200
of ulna, 190
pectoral, 181
pronator, 190
pterygoid, 95, 137
superciliary, 80
supracondyilar, external, 181
internal, 181
supraorbital, 140
temporal, 75, 80
trapezoid, 160
Riedel’s lobe of liver, 1343
Right ascending lumbar vein, 732
azygos vein, 752
bronchus, 1384
cardiac vein, 771
collic artery, 977
coronary artery, 952
plexus, 1000
forechamber of heart, 567
innominate vein, 750
INDEX

Sacral nerve, division of, dorsal, 1023
ventral, 1025
roots of, 1023
portion of ganglionic cord, 1089
veins lateral, 760
dorsal, 764
muscle of Müller, 1126
Ripa, 912
Risorius muscle, 383
Rivinus, muscles of, 1227
notch of, 1161
Rod-bipolars, 1135
Rod-cells, 1136
Rod-fibre, 1136
Rod-granules, 1135
Rods of Corti, 1184
of retina, 1135
Rolandi, 926
Rolando, fissure of, 926
Roots of cervical nerves, 986
of fifth nerve, ascending, 1042
descending, 1042
of lumbar nerve, 1015
of lung, 1402
of penis, 1464
of sacral nerves, 1023
of spinal nerves, 983
dorsal, 983
ventral, 983
of thoracic nerves, 1010
of tongue, 1097
of vagus nerve, ganglion of, 1060
Rosenmüller, fossa of, 1231
gland of, 794
accessory, 1151
optic of, 1511
Rostral fissure, 928
Rostrum, 920
of sphenoid bone, 94, 135
Rotary joint, 257
Rotatores spine muscle, 423
Round ligament, artery of, 689
of liver, 1342
of uterus, 1503
Roux's amputation of foot, 229
Rubo-spinal tract of cord, 533
Rudimentary organ of Jacobson, 1110
Rudinger, dilator tube muscle of, 1165
Ruge of scrotum, 1473
of stomach, 1283
of vagina, 1496
Ruytsch, tunie of, 1123

S
SACS, abdominal, 1246
dental, 1216
lachrymal, 1152
pericardial, 1246
pleural, 1246
Saccule of vestibule, 1180
Sacculi alveolare, 1386
Saccus-larynx, 1379
Sacral artery, lateral, 694
middle, 683
canal, 64
cornea, 62
foramin. anterior, 62
posterior, 63
groove, 63
lymphatic glands, 797
nerve, 1025
Sartorius muscle, nerve to, 1022
Scalea media, 1182
tympani of cochlea, 1178
vestibuli of cochlea, 1178
Sclerena muscles, anticus, 410
medius, 410
posticus, 411
Scalp, skin of, 368
 Scalpa, fossa of, 1155
Scaphoid bone of foot, 240
articulations of, 240
attachment of muscles to, 240
surfaces of, 240
tuberosity of, 240
of hand, 197
articulations of, 198
attachment of muscles to, 198
surfaces of, 198
fossa, 97, 135, 1154
skull, 146
Scapula, 172
angles of, 175
articulations of, 178
attachment of muscles to, 178
base of, 176
borders of, 175, 176
development of, 177
dorsum of, 173
head of, 176
ligaments of, 303
spine of, 175
structure of, 177
surface form of, 178
surgical anatomy of, 178
wrist of, 172
Scapular arteries, posterior, 644
glands, 778
nerve, posterior, 999
notch, great, 175
region, anterior, muscles of, 473
dissection of, 473
posterior, muscles of, 474
dissection of, 474
Scapulo-clavicular articulation, 301
Scarf skin, 1191
Scars, fascic of, 435
foramina of, 110, 135, 1050
ganglion of, 1065
membrane of, 1102
nerve of, 1066
triangle of, 518, 698
Schachows, spiral tube of, 1427
Schindleyosis, 266
Schlemm, canal of, 1118, 1121
ligament, 307
Schmidt-Lautermann, incisions of, 824
Schneiderian membrane, 1110
Schorig, concentric lines of, 1213
Schultz, commissa tract of, 551
Schwann, medullary sheath of, 824
Seiatic artery, 603
nerve, great, 1030
branches of, 1030
small, 1027
branches of, 1028
notch, great, 217
plexus, 1026
veins, 761
Sclera, 1117
structure of, 1118
Sclereral cilius, 1115
Sclerotic coat, 1117
Scleral hernia, 1533
nerve, long, 1028
Scrotum, 1472
INDEX

Supracondylar ridge, internal, 181
Supracondyloid glands of Leaf, 794
Supraepitrochlear glands, 787
Supraglenoid tubercle, 176
Suprathyroid aponeurosis, 396
artery, 606
glands, lateral, 784
median, 784
region, muscles of, 396
Supramandibular nerves, 1063
Supramarginal gyre, 931
Supramastoid crest, 84, 137
Supramaxillary lymphatic glands, 781
nerves, 1063
Supracapital spine, 88
triangle, 88
Supraorbital arch, 80
artery, 625
foramen, 80, 140.
nerve, 684
notch, 80, 140
ridge, 140
vein, 726
Suprapatellar bursa, 342, 521
Supraenial artery, 680
capsule, 1437
arteries of, 1440
left, 1438
lymphatic vessels of, 502
lymphatic of, 1440
nerves of, 1440
relations of, 1437
right, 1437
structure of, 1438
veins of, 1440
glands, 1437
accessory, 1438
impression of, 1337
plexus of nerves, 1092
veins, 767
Suprascapular artery, 643
ligament, 304
nerve, 1000
notch, 175
Suprascleral lymph-space, 1113
Supraspinales muscle, 423
Supraspinatus fascia, 474
muscle, 474
Supraspinous fossa, 174
ligament, 275
Suprasternal artery, 644
nerves, 989
notch, 411
space, 389
Supratentorial fossa, 1223
Supratrochlear foramen, 183
glands, 787
nerve, 1044
Supravaginal portion of uterus, 1500
Surface form of abdominal aorta, 672
of acromio-clavicular articulation, 303
of ankle-joint, 353
of axillary artery, 651
of bladder, 1449
of bones, 34
of brachial artery, 650
of carotid arteries, common, 601
external, 603
of carpus, 206
of clavicle, 172
of common iliac arteries, 685
of dorsalis pedis artery, 714
of dboat-joint, 314
Surface form of external auditory meatus, 1160
of eyelids, 1152
of femoral artery, 702
of femur, 231
of fibula, 241
of fifth nerve, 1055
of foot, 257, 302
of heart, 680
of hip, 335
of lumen, 185
of hyoid bone, 156
of inferior radio-ulnar articulation, 319
of internal iliac artery, 695
of intestines, 1331
of kidney, 1434
of knee-joint, 345
of lachrymal gland, 1153
sac, 1153
of liver, 1333
of lungs, 1405
of metacarpo-phalangeal articulation, 327
of mouth, 1229
of muscles of abdomen, 450
of back, 426
of face, 387
of head, 387
of lower extremity, 552
of upper extremity, 302
of vertebral region, 411
of pancreas, 1360
of parotid duct, 1225
of patella, 254
of pelvis, 222
of plantar arteries, 719
of popliteal artery, 709
of radial artery, 660
of radio-carpal articulation, 230
of radius, 194
of rectum, 1331
of scapula, 178
of shoulder-joint, 309
of skull, 148
of spleen, 1366
of sterno-clavicular articulation, 301
of sternomastoid muscle, 303
of sternum, 166
of stomach, 1288
of subclavian artery, 637
of superior radio-ulnar articulation, 316
of temporomandibular articulation, 284
of tibial artery, anterior, 711
posterior, 716
of trachea, 1389
of tricuspid valve, 1055
of trigeminal nerve, 1055
of ulnar artery, 663
of venniform appendix, 1331
of vertebral column, 69
Surgical anatomy of abdominal aorta, 672
of abdunent nerve, 1058
accessory nerve, 1074
of acromio-clavicular articulation, 303
of ankle-joint, 353
of arch of aorta, 594
of artery of bulb, 692
of ascending pharyngeal artery, 612
of auditory nerve, 1062
of axilla, 647
of axillary artery, 651
Surgical anatomy of axillary vein, 748
of axygos veins, 753
of bend of elbow, 655
of bile duct, 1354
of bladder, 1449
of brachial artery, 656
plexus, 1099
of carotid arteries, common, 601
external, 603
internal, 623
gland, 1064
of ear, 207
of cavernous sinus, 740
of cervical fascia, 391
ganglion, 1087
plexus, 994
of cheeks, 1234
of clavicle, 172
of colon, 1334
of common iliac arteries, 685
of conjunctiva, 1154
of deep epigastric artery, 698
of descent of testicles, 1472
of dorsalis pedis artery, 714
of duodenum, 1332
of ear, 1156
of eighth nerve, 1065
of elbow-joint, 314
of eleventh nerve, 1074
of emissary veins, 743
of external iliac artery, 696
of eye, 1144
of eyelashes, 1153
of eyelids, 1153
of facial artery, 610
nerve, 1064
veins, 726
of fossa of femoral region, 517
of femoral artery, 702
of femur, 232
of fibula, 244
of foot, 258, 362
of gall-bladder, 1354
of glosso-pharyngeal nerve, 1067
of gums, 1234
of hemorrhoidal veins, 761
of heart, 580
of hernia, 1523
of hip, 335
of humerus, 185
of hyoid bone, 156
of hypoglossal nerve, 1077
of inferior calceneo-scaphoid ligament, 356
thyroid artery, 643
of innominat artery, 597
of intercostal artery, 670
nerve, 1014
of iliac artery, 687, 695
jugal vein, 732
mammary artery, 647
pubic artery, 1161
of intestines, 1331
of ischiop-rectal region, 1547
of kidney, 1434
of knee-joint, 345
of lachrymal gland, 1154
sac, 1154
of lateral sinus, 739
of ligaments of vertebra, 281
of lingual artery, 606
of limbs, 1234
of liver, 1354
of lumbar plexus, 1034
INDEX

Temporal nerves from auriculo-temporal, 1052
depth, 1051
depth, 1051
depth, 1051
from facial, 1046, 1062
ridges, 76, 80
veins, 727
Temporary teeth, 1206
eruption of, 1219
Temporo-facial nerve, 1062
Temporo-malar filaments, 115
foramen, 115
temperature, 1046
Temporo-mandibular articulations, 282
surface form of, 284
surgical anatomy of, 284
region, muscles of, 383
Temporo-maxillary articulation, 138
vein, 727
Temporo-pontile tract, 910, 957
Tendo Achillis, 538
bursa of, 538
oscul, 372
Tempus, 366
of diaphragm, central, 431
cordiform, 431
flexor, fibrous sheaths of, 548
Tenon, capsule of, 113
Temporal fascia of tensor, 517
palati muscle, 406
tarsi muscle, 373
tympanic muscle, 1171
canal for, 1163
Tenth nerve, 1068
surgical anatomy of, 1072
thoracic vertebra, 56
Tentorial sinus, 738
Terminology, 875
Teres major muscle, 475
minor muscle, 475
Terma, 867, 917
Terminal arteries, 632
Tibias triangular, 1471
mublrebs of Galen, 1511
of quadrigemina, 705
Testicles, 1471
coverings of, 1472
descent of, 1471
gubernaculum testis, 1471
lobes of, 1482
lymphatic vessels of, 802
mediastinum testis, 1481
prenchyma of, 1482
rete testis, 1482
sheaths of proper, 1481
size of, 1481
structure of, 1482
surgical anatomy of, 1484
trabecula of, 1482
tabuuli seminiferi of, 1482
tuina albuginea, 1482
vaginalis, 1481
vasculosa, 1482
tunics of, 1481
weight of, 1481
Testicular bag, 1472
Thalamencephalon, 911
Thalami, 867, 912
Thalamo-cortical fibres, 914
Thalamo-frontal fibres, 956
Thalamo-olivary tract, 886
Thalamo- striate fibres, 956
Thalamus, 912
connections of, 914
fibres of, 914
structure of, 914
Thalamic radiation, 914
Thebesian valve, 569, 771
Thecal synovial bursa, 205
Thigh, bones of, 225

Thigh, fascia of, 514
muscles of, 514
Third nerve, 1039
ventricle of brain, 869, 916
Thoracic aorta, 667
branches of, 668
surgical anatomy of, 668
aortic plexus, 1087
artery, acromial, 653
alar, 653
long, 653
superior, 652
axis, 653
cardiac nerves, 1072
duct, 775
structure of, 777
ganglion, 1087
nerves, 1010
branches of, 1010
divisions of, 1010
roots of, 1010
portion of gangliated cord, 1087
of cæsophagus, 1236
region, anterior, fascia of, deep, 465
superficial, 465
muscles of, 465
lateral, muscles of, 471
surgical anatomy of, 471
surface of lungs, 1400
trachea, lymphatic vessels of, 813
vein, long, 748
vertebral, 53
bodies of, 53
eleventh, 56
first, 55
lamine of, 54
ninth, 55
peculiar, 55
pedicles of, 54
processes of, 54
tenth, 56
twelfth, 56
wall, lymphatic glands of, 807
vessels of, 810
Thoracico-epigastric vein, 748
Thoracico-lumbar nerve, 1014
Thorax, 156
boundaries of, 156
cavity of, 238
fascia of, 426
lymphatics of, 807
muscles of, 426
nerves of, cutaneous, 1012
openings of, lower, 558
upper, 558
veins of, 744
Thumb, ligaments of, 323
metacarpal bone of, 203
muscles of, 466
Thymic artery, 596
lymphatic vessels, 813
Thymus gland, 1414
arteries of, 1415
lobes of, 1414
lymphatics of, 1415
nerves of, 1415
structure of, 1414
veins of, 1415
Thyro-arytenoid ligament, inferior, 1378
superior, 1378
muscle, 1351
Thyro-epiglottic ligament, 1375
Thyro-epiglotticus muscle, 1381
Thyro-glossal duct, 1100, 1407
Thyro-hyals of hyoid bone, 155
Thyro-hyoid ligaments, 1374
membrane, 1374
Transverse sinus, 743
of pericardium, 562
suture, 128
Transversus articulur muscle, 1157
menti muscle, 380
perineal superficialis muscle, 459, 462
Trapezius, 857
bone, 200
articulations of, 200
attachment of muscles to, 200
surfaces of, 200
Trapezius muscles, 413
Trapezoid bone, 200
articulations of, 201
surfaces of, 200
ligament, 302
ridge, 169
Treitz, fossa of, 1270
suspensory ligament of, 1294
Triangle, carotid, inferior, 618
superior, 396, 619
of elbow, 655
of election, 619
Hesselbach's, 1532
of necessity, 618
of neck, anterior, 618
posterior, 620
surgical anatomy of, 618
occipital, 620
Petit's, 437
Scarpa's, 518, 698
subclinial, 620
submaxillary, 386, 619
suboccipital, 425
suprarneral, 85
Triangular cartilage of septum of nose, 1107
fascia of abdomen, 439, 1527
of urethra, 460
interarticual fibro-cartilage, 317
ligament of urethra, 460
muscles, 365
Triangularis menti muscle, 380
sterni muscle, 427
Triceps extensor cubiti muscle, 479
Triceps brachii, 569
valve, 572
Trifacial nerve, 1041
surface marking of, 1055
surgical anatomy of, 1055
Trigeminal depression, 88
nerve, 1041
distribution and connections of, 1055
nuclei of, 894
afferent, 894
efferent, 894
surface marking of, 1055
surgical anatomy of, 1055
Trigone of bladder, 1447
Trigonum habene, 912, 915
hypoglossi, 880
lennii, 905
olfactoriurn, 935
vagi, 880
ventriculi, 944
vesica, 1447
Trigoid bodies, 822
Trochanter, great, 225
bursa of, 333
lesser, 225
rudimental, third, 226
Trochanteric fossa, 225
Trocheles of femur, 227
of humerus, 183
Trochlear fossa, 82
Trocchlear nerve, 1041
nucleus, 910
surgical anatomy of, 1041
surface of astragalus, 246
Trochoid, 267
Tubal, anastomotic vein of, 735
Toldt, rectus, 1172
True vocal cords, 1378
Trunk, arteries of, 667
articulations of, 271
fascia of, 412
muscles of, 412
of vagus nerve, ganglion of, 1069
Tube or tubes, bronchial, 1384
egg, 1515
Eustachian, 1163
Fallonian, 1510
lymphatic vessels of, 801
neural, 817
spiral, of Schachowa, 1427
tonsil, 1165
Tuber, 867, 917
cinerum, 917
Tubercle of cerebellum, 898
Tuberculum, adductors, 227
amygdaloid, 945
cord, 51
cervical vertebra, anterior, 50
posterior, 50
Tussachian's, 69
conid, 169
conical, of Santorini, 1376
cuneate, 876
cuneiform, of Wrisberg, 1376
of Darwin, 1155
deltoid, 169
epiglottis, 1373
of femur, 225
genial, 123
of hyoid bone, 155
infraglenoid, 176
jugular, 109
laebral, 109
mental, 122
of navicular bone, 249
olfactory, 935
peroneal, 246
pharyngeal, 73
pleyroid, 97
of quadratus, 226
of ribs, 162
of scapohoid, 198
supraglenoid, 176
of tuba, 236
of ulna, 188
of zygoma, 84
Tuberculum acusticum, 880
anterius, 913
caudatum, 1340
cinerum, 876, 884
impar, 1253
vestibularis, 880
Tuberosity, bicipital, 192
of calcaneus, 246
eobull, 248
of femur, inner, 228
outer, 228
of humerus, 179
of ischium, 218
maxillary, 196
of navicular bone, 249
of patale bone, 117, 135
of radius, 192
of ribs, 162
of scapohoid, 198
of tibia, external, 236
interna, 236
Tubuli, lactiferi, 1519
Tubuli seminiferi, 1482
uriniferi, 1427
Tunica of Ruysehe, 1123
Tunica adventitia, 1288
albugineas, 376, 1467, 1482
interna, 1130
propria, 1114
vaginalis, 1472, 1475, 1481
cavity of, 1481
parietal portion of, 1481
visceral portion of, 1481
vessels of testes, 1482
Tunics of eye, 1117
testicle, 1481
Turbinate bone, inferior, 119
articulations of, 120
development of, 120
surfaces of, 120
middle, 101
sphenoidal, 143
superior, 100
crest, 116, 117
Turek, bundle of, 910. Note. fasciculus of, 854
Turner, intraparietal sulcus of, 639
Twelfth nerve, 1074
surgical anatomy of, 1077
thoracic vertebra, 56
Tympanic antrum, 87
aperture, 1161
artery from ascending pharyngeal, 612
from internal carotid, 623
maxillary, 615
attic, 87
cavity, 1160
nerve, 1067
from facial, 1061
plexus of, 1067
sulcus, 1159
Tympanohyal process, 92
Tympanomalleolar ligaments, 1166
Tympanum, 1160
arteries of, 1172
cavity of, 1160
floor of, 1161
fundus of, 1161
mucous membrane of, 1172
muscles of, 1171
nerves of, 1173
ossicles of, 1168
pyramids of, 1163
roof of, 1161
veins of, 1173
walls of, 1163
U

ULNA, 186
articulations of, 191
attachment of muscles to, 191
development of, 191
lower extremity of, 191
shaft of, 190
structure of, 191
surface form of, 191
surgical anatomy of, 194
tubercle of, 188
upper extremity of, 186
coronoid process of, 186
olecranon process of, 186
sigmoid cavities of, 188
Ul nar artery, 662
peculiarities of, 663
surface marking of, 663
surgical anatomy of, 663
groove, 183
nerve, 1005
Veins, cystic, 769
- of diploe, 733
- of penis, 702
- dorso-spinal, 753
- dorso-median, 736
- of dura of brain, 974
- dural, 730, 778
- emissary, 748
- emulent, 766
- epigastric, deep, 750
- superficial, 756
- of face, exterior of, 725
- facial, 720
- femoral, 758
- of fingers, superficial, 745
- of foot, 725
- frontal, 725
- of Galen, 735
- gastrice, 768
- gluteal, 761
- hemorrhoidal, external, 760
- inferior, 760
- middle, 760
- superior, 768
- of hand, superficial, 745
- of head, 724
- of heart, 580
- hepatic, 767
- histology of, 722
- hypogastric, 768
- iliae, circumflex, deep, 750
- common, 764
- external, 759
- internal, 760
- ilio-lumbar, 764
- innominate, 750
- intercostal, 752
- intersosseus, of forearm, 747
- intervertebral, 765
- intralobular, 767
- jugular, 728
- laryngeal, inferior, 751
- lingual, 729
- longitudinal, inferior, 738
- of lower extremity, 753
- lumbar, 765
- ascending, 753, 765
- right, 765
- mammary, internal, 750
- masseteric, 727
- maxillary, internal, 727
- median, 745
- anterior, 736
- posterior, 736
- medicebral, 735
- medidural, 734
- medulli-spinai, 755
- meningal, 750, 754
- meningo-rachidian, 754
- mesenteric, 768
- of muscle, 764
- nasso-frontal, 740
- of neck, 724
- of oblongata, 736
- obturator, 761
- occipital, 727
- oesophageal, 751
- ophthalnic, 740
- orbital, 727
- ovarian, 766
- palatine, 727
- palmar, deep, 747
- pancreatic, 768
- of pelvis, 755
- pharyngeal, 730
- phrenic, 767
- of pin of brain, 982
- plantar, 758
- plexus of, palmar, 745
- paraspiniform, 755
Veins, plexus of, pharyngeal, 730
- phrenic-venial, 761
- pharyngoidal, 727
- spermatic, 765
- spinal, 753
- thyroid body, 751
- uterine, 765
- vaginal, 765
- vesical, inferior, 763
- superior, 761
- popliteal, 758
- portal, 760
- system of, 768
- postcava, 764
- precava, 752
- profunda femoris, 759
- vertebral, 767
- pudic, 760
- pulmonary, 723
- pyloric, 768
- radial, 745
- deep, 747
- ranine, 729
- renal, 767
- sacral, lateral, 760
- middle, 764
- saphenous, 756
- sciatric, 761
- spermatic, 765
- spinal, 753
- splenic, 768
- subclavicular, 736
- subcostal, 733
- subcutaneous, 740
- subclavicular, 767
- submaxillary, 727
- subcostal, 736
- subauricular, 726
- supracranial, 767
- sylvian, superficial, 735
- systemic, 724
- temporal, 727
- temporomaxillary, 727
- thoracic, long, 748
- thoracico-epigastric, 748
- of thorax, 744
- thyroid, accessoriy, 731
- gland, 731
- inferior, 751
- middle, 730
- superior, 730
- thyroid, ima, 751
- tibial, 758
- tracheal, 751
- ulnar, 745
- of upper extremity, 744
- uterine, 780
- vaginal, 763
- velar, 735
- vertebral, 735
- ventro-medial, 736
- vasmian, 735
- of vertebral bodies of, 755
- vertebral, 782, 751
- vaginal, 730
- Vela, medullary, 901
- Volar veins, 735
Velem, 881, 895, 902, 946, 981
- interposum, 912, 946
- medullary, 901
- anterior, 901
- inferior, 901
- posterior, 901
- superior, 901
- penduncula, palati, 1221
- Vena axygos major, 752
- minor, 753
- basis vertebrarum, 49, 755
- cava, ascending, 764
Vena cava, inferior, 764. See Postcava.
- superior, 752. See Precava.
Vena magna Galeni, 735
Vena basis vertebrarum, 755
- comites, 725, 747
- corporis striati, 735
- interlobulares of kidney, 1432
- Thesies, 771
- vertebrarum, 1123
Venesction, 746
Venasan arch, nasal, 725
- plexus, intraspinal, 732
- on thyroid body, 751
Venter ili, 216
- of seapula, 172
Ventral cerebellar-spinal tract of cord, 854
- column of spinal cord, 840
- crista, 905
- fissure of oblongata, 874
- horn-cells of cord, 866
- of cornus, 844
- lamina of brain, 870
- root of spinal cord, 836
- nerve, 882
- spinal artery, 640
- spino-cerebellar tract, 901
- vestibulo-spinal tract of cord, 854
- white commissure of cord, 854
Ventricle of brain, fifth, 920, 921, 941
- fourth, 878
- lateral, 941
- third, 859, 916
- infundibular recess of, 917
- Verga's 951
- of heart, fibres of, 577
- left, chordae tendineae of, 575
- columnae carneae of, 575
- right, 571
- chordae tendineae of, 572
- columnae carneae of, 572
- of larynx, 1379
Ventricular portion of heart, 570
- veins, 735
- Ventro-lateral fissure, 857
- Ventro-medial fissure, 874
- Ventro-paramedian fissure of spinal cord, 839
- vein, 736
- Verga's ventricle, 951
- Vermian vein, 735
- Vermiform appendix, 1311
- arteries of, 1313
- canal of, 1312
- lymphatics of, 1314
- mesentery of, 1299
- mucous membrane of, 1313
- muscular coat of, 1312
- serous coat of, 1312
- structure of, 1312
- submucous coat of, 1313
- surface form of, 1331
- surgical anatomy of, 1332
- veins of, 1313
- Vermis, 856
- Verenae gyro hippocampi, 933
- Vertebrarum, 48
- bodies of, veins of, 755
- centrum of, 48
- cortical, 49
- seventh, 53
- coccgeal, 61
- development of, 58
- dorsal, 53
- false, 61
- general characters of, 48
- immovable, 61
- ligaments of, 272
INDEX

Vertebrae, lumbar, 56
fifth, 57
process of, articular, 49
spinous, 49
transverse, 49
prominens, 53
sacral, 61
structure of, 58
thoracic, 53
peculiar, 55

Vertebral apanurosis, 413, 418
artery, 639
surgical anatomy of, 641
border of seapula, 176
canal 49
column, 48
articulations of, 271
surface form of, 69
surgical anatomy of, 69
foramen, 49
groove, 156
ligaments, 272
plexus of nerves, 1086
region, muscles of, anterior, 408, 411
lateral, 410
ribs, 161
vein, 732, 751
Vertebral arterial foramen, 50
Vertebro-echondral ribs, 161
Vertebro-pericardial ligaments, 590
Vertebr-pleural ligament, 1309
Vertebral-ternal ribs, 161
Vertex of skull, 129, 150
Vertical linguial muscle, 401
plate of palate bone, 117
Verumontanum, 1451
Vesical arteries, 657, 688
plexus of nerves, 1095
of veins, inferior, 762
superior, 761
trigone, 1447
Vesicle, prostatic, 1451
Vesicles of brain, 864
optic, 865
Gratiolet, 1514
seminal, 1486
Vesico-uterine ligament, 1502
Vesicula prostatica, 1450
Vestibular artery, 1186
ganglion, 1065
terminus, 1065
branches of, 1065
nuclei of, 893
window, 1182
Vestibule, aortic, of Sibson, 574
of ear, 1174
of mouth, 1204
of nose, 1100

Vestibule of vagina, 1491
Vestibulo-spinal tract, of cord, lateral, 853
ventral, 854
Vestigial fold of pericardium, 563
Vibrisso, 1106
Vieq d'Azayr, band of, 989
bundle of, 914, 916
Vidian artery, 617
canal, 96, 135
terminus, 1049
veins, 750
Vieusens, ansa of, 1086
Villi of small intestine, 1300
sinoval, 264
Viscera, development of, 1245
Visceral cranium, 71
layer of pleura, 1391
lymphatics, 808
peritoneum, 1257
portion of tunica vaginalis, 1481
surface of liver, 1336
of stomach, 1278
Visual axis, 1116
purple, 1130
Vitreous body, 1130
humor of eye, 1139
table of skull, 34
Vocal cords, false, 1378
terminus, 1378
process, 1373
Voice, organs of, 1389
Volar intersosseous nerve, 1004
Volkmann's canals, 38
Voluntary muscles, 363
Vomer, 120
alse of, 121, 143
articulations of, 122
development of, 122
surfaces of, 121
Vomerine cartilage, 1107
Vortex of heart, 578
Vulvo-vaginal gland, 1495

W

Waldeyer, germinal epithelium of, 1513
odontoblasts of, 1211
Wedge bodies, 249
Wharton's duct, 1226
White commissure of cord, 584
fibrous tissue, 263
line of Hilton, 1327
substance of cord, 545, 556
Wilder, post-oblongata of, 874
Willis, circle of, 631, 642
Winslow, necessary anterior cranial nerve of, 1020

Winslow, ligament of, posterior, 337
uncinate process of, 1357
Wirsung, canal of, 1359
Womb, 1498
Worm of cerebellum, 895
Wormian bones, 108
development of, 104
Wrisberg, cardiac ganglion of, 1000
cartilages of, 1373
cuneiform tubercle of, 1376
ligament of, 341
nerve of, 1003
pars intermedia of, 1059
Wrist, articulations of, 319
bursa of, 494
Wrist-joint, 319
ligament of, 320
surface form of, 320
surgical anatomy of, 320

X

Xipho-pericardial ligament, 561
Xiphoipoid appendix, 159
surfaces of, 159
cartilage, 157

Y

Y-ligament, 330
Yellow elastic tissue, 264
spot of Sommering, 1131

Z

Zinn, ligament of, 375
zonule of, 1139
Zona arcuata, 1183
fasciulata, 1439
glomerulosa, 1439
orbicularis, 329
peptinata, 1183
reticularis, 1439
tecta, 1183
Zones of brain, longitudinal, 870
Zonula ciliaris, 1139
Zonule of Zinn, 1139
Zygoma, 84
Zygomatic arch, 138
fossa, 138
lymphatic glands, 781
process of malar, 115
of temporal bone, 84
Zygomaticus major muscle, 379
minor muscle, 379
Zymogen granules, 1352