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NORMAL HISTOLOGY

The Medical Epitome Series

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The Medical Epitome Series.

NORMAL HISTOLOGY.

A MANUAL FOR STUDENTS AND PRACTITIONERS.

BY

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AUTHOR'S PREFACE.

THE author of this epitome has endeavored to supply the student, and the practitioner also, who wishes to review or prepare for an examination, with a condensed treatise containing the essential facts in histology.

The subject is becoming so extensive that many have not the time to study carefully the larger books, except as works of reference; simplicity has, therefore, been the chief guide in the preparation of this work, and it is in no way intended to replace the more complete or larger volumes.

It has been the intention of the writer to tabulate clearly and concisely the most important points for the student, and such embryology has been included as will aid in a correct understanding of histology and a better appreciation of pathology. A special chapter has been added on the technique of preparing and staining tissues.

In conclusion the author wishes to acknowledge his indebtedness to Dr. Arthur Kipp, who rendered much aid in the preparation of the work, to the Editor of this Series, and to the publishers, who have extended him many courtesies.

J. R. W.

LOUISVILLE, KY., 1903.

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EDITOR'S PREFACE.

In arranging for the editorship of *The Medical Epitome Series* the publishers established a few simple conditions, namely, that the Series as a whole should embrace the entire realm of medicine; that the individual volumes should authoritatively cover their respective subjects in all essentials; and that the maximum amount of information, in letter-press and engravings, should be given for a minimum price. It was the belief of publishers and editor alike that brief works of high character would render valuable service not only to students, but also to practitioners who might wish to refresh or supplement their knowledge to date.

To the authors the editor extends his heartiest thanks for their excellent work. They have fully justified his choice in inviting them to undertake a kind of literary task which is always difficult—namely, the combination of brevity, clearness, and comprehensiveness. The authors have shown a consistent interest in the work and an earnest endeavor to coöperate with the editor throughout the undertaking. Co-operation of this kind ought to result in useful books, in brief manuals as contradistinguished from mere compends. The editor desires at this opportunity to express his appreciation of their helpfulness in the matter of producing the proper character of work.

In order to render the volumes suitable for quizzing, and yet preserve the continuity of the text unbroken by the interpolation of questions throughout the subject-matter, which has heretofore been the design in books of this type, all questions have been placed at the end of each chapter. This new arrangement, it is hoped, will be convenient alike to students and practitioners.

V. C. P.

NEW YORK, 1903.

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NORMAL HISTOLOGY.

CHAPTER I.

THE CELLS.

HISTOLOGY is that medical science which treats of the microscopic normal anatomy of tissues of the human body.

The various tissues of the body are **constructed**, primarily, of *cells* and *intercellular substance.*

Histology first treats of the cell as a tissue-element and later discusses the relation of the various tissues to each other as found in the different organs of the human body.

The Typical Cell.—The *cell* is typically a minute mass of protoplasm, irregular in shape, and having embedded in its substance a spherical body, the *nucleus.* Each cell has a structure and individuality peculiar to itself, and is divided into cell-wall, cell-body, nucleus, nucleolus, and centrosome.

The *cell-body*, or *cytoplasm*, constitutes the larger portion of the cell and is divided into the *spongioplasm*, a reticulum of delicate fibres; the *hyaloplasm*, which is a clear semifluid substance filling the spaces between the fibres; and lastly the *metaplasm*, which consists of the small granules often found in the cell-protoplasm.

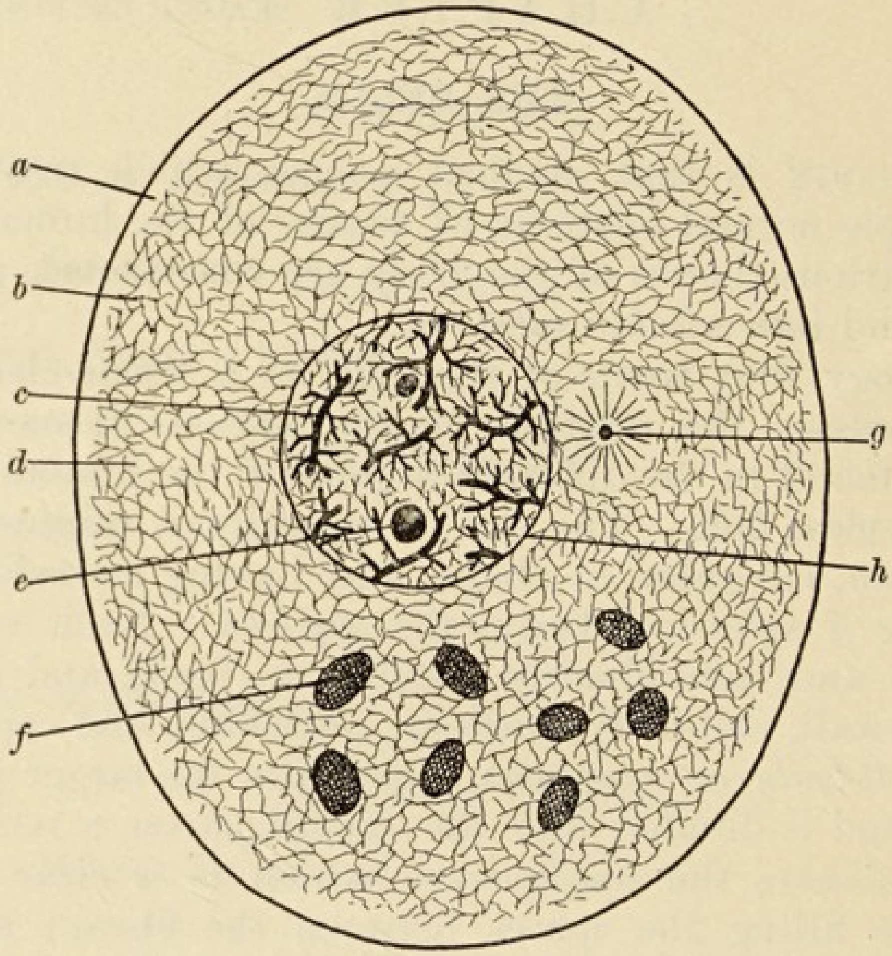
The *nucleus* is a round body within the cell and composed of the nuclear membrane or wall, and the nuclear matrix, a semifluid fibrillated or reticulated substance. The nuclear fibrils are of two varieties, the *chromatin* and the *achromatin* fibrils, respectively, according to whether they stain readily or not.

A small highly refractive body is often found within the meshwork of the nucleus, called the *nucleolus.* There may be one or several nuclei present in a nucleus.

The *centrosome* is a small refractive body within the nucleus, concerned in the multiplication of the cell. During this process it leaves the nucleus and appears in the cytoplasm or cell-body. It is surrounded by a clear area with delicate radiating filaments.

Specialized Cells.—Certain cells have peculiar characteris-

FIG. 1.



Schematic diagram of a cell: *a*, ectoplasm, composed of hyaloplasm; *b*, spongioplasm; *c*, chromosome, composed of "chromatin," and forming a part of the intranuclear reticulum: between these chromatic fibres is the achromatin; *d*, hyaloplasm in the meshes of the spongioplasm; *e*, one of the two nucleoli represented in the diagram; *f*, one of eight bodies constituting the metaplasm represented; *g*, centrosome, with radiate arrangement of the surrounding spongioplasm; *h*, nuclear membrane. (Dunham.)

tics, as those with *cilia*, or hair-like processes, and those with long protoplasmic arms, as in nerve-cell fibres.

Cells are classified also according to form, function, motion, irritability, and methods of reproduction.

Reproduction of Cells.—Cells multiply by *direct division* or

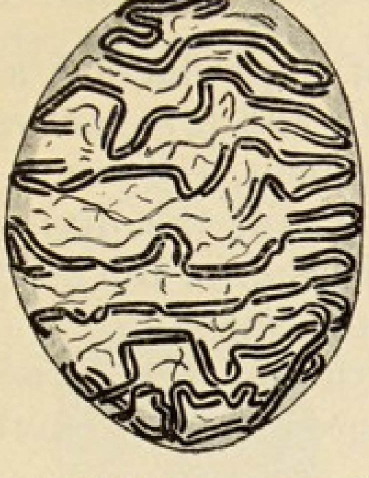


FIG. 2.—Continuous convolution.

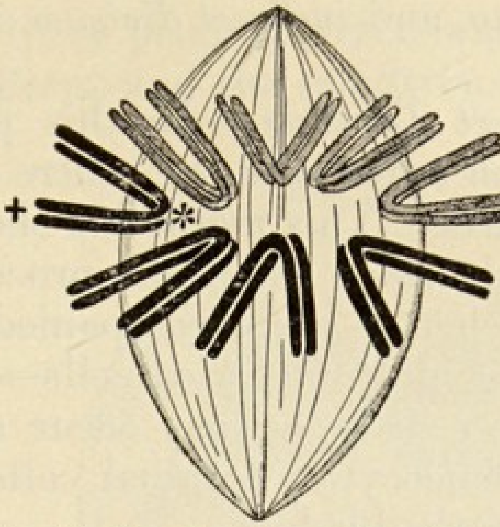


FIG. 3.—Equatorial or aster stage.

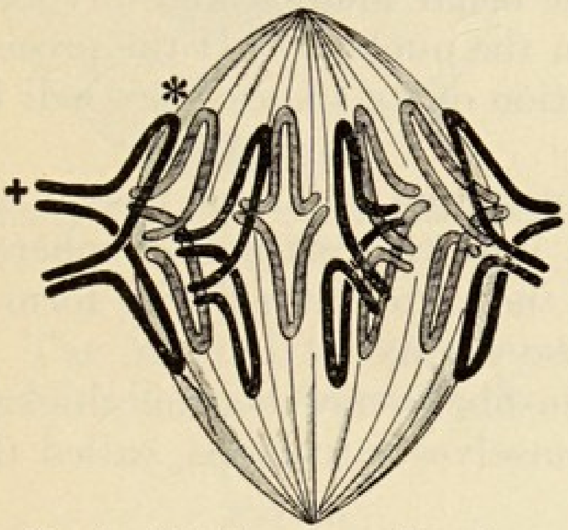


FIG. 4.—Metakinesis, earlier stage.

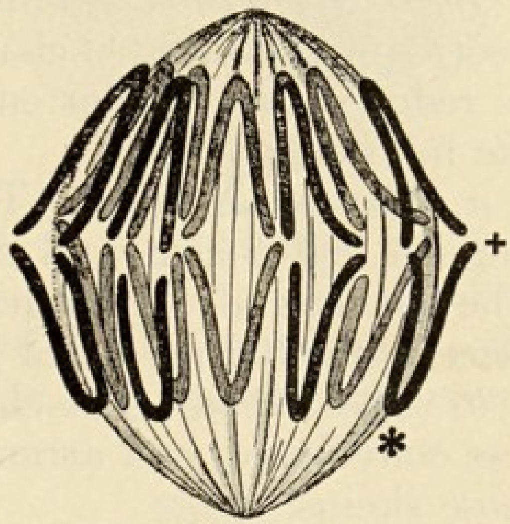


FIG. 5.—Metakinesis, later stage.

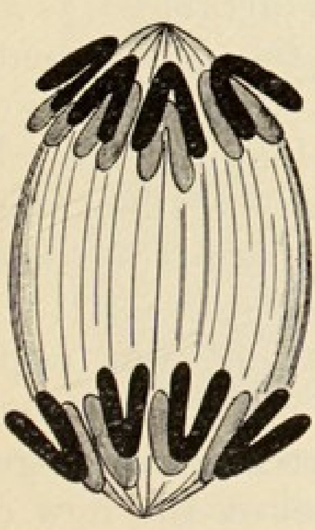


FIG. 6.—Diaster stage.

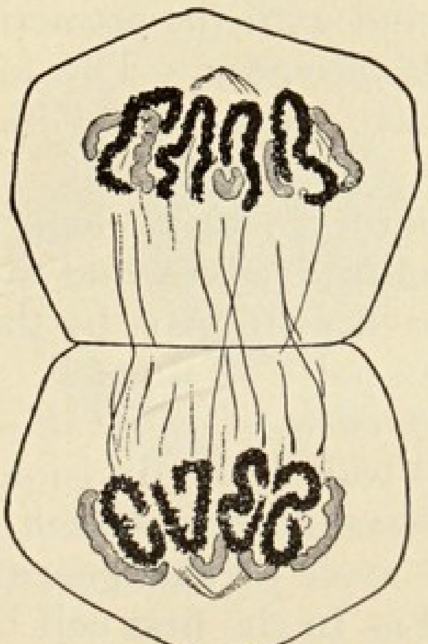


FIG. 7.—Double segmented convolution.

Diagrammatic representation of stages of karyokinesis. (Flemming.)

budding, and *indirect division* or *karyokinesis*, *mitosis* or *karyomitosis*.

Direct Division.—In this process of reproduction a constriction appears in the centre of the cell and it separates into two parts. This method is the less frequent, and seems often to result from abnormal processes, in which the division of the nucleus is not accompanied by a division of the cell, thus forming multinucleated cells—*e. g.*, giant cells.

Direct division may occur along with indirect division in many leucocytes, decidual cells, cartilage-cells, and epithelial cells of the bladder.

Indirect Division.—This is the usual method and involves a series of complicated changes in the nucleus. If the process be reduced to a tabular enumeration of its stages, they will be the following:

a. Resting Nucleus.—The centrosome enlarges, passes out into the cytoplasm, and divides into two attraction-spheres. The nucleus also enlarges and the chromatin-fibrils form a dense convolution, called the close skein.

b. Close Skein.—The chromatin-fibrils now become thicker, less convoluted, and arrange themselves into loops, called the loose skeins.

c. Loose Skein.—The fibrils now form in loops or chromosomes and with the attraction-spheres make the spindle.

d. Mother-Star.—The loops are now arranged as a wreath with each apex toward the centre of the cell, resembling a star.

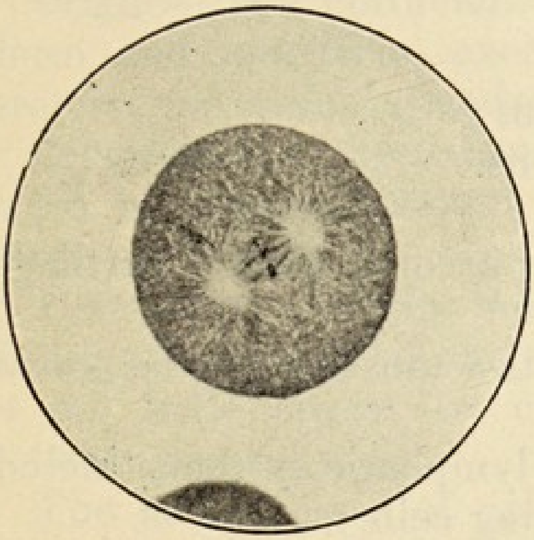
e. Diaster.—Each loop undergoes longitudinal cleavage, splitting into halves, and the two separate wreaths or daughter-stars are drawn apart by the attraction-spheres to the extreme opposite poles of the cell.

f. Division of the Cell.—A constriction now appears in the cell-wall and a division into halves occurs completely.

g. New Nuclei.—Each daughter-wreath undergoes the reverse cycle of changes, and the nuclei of the new cells are formed as in the first cell before division.

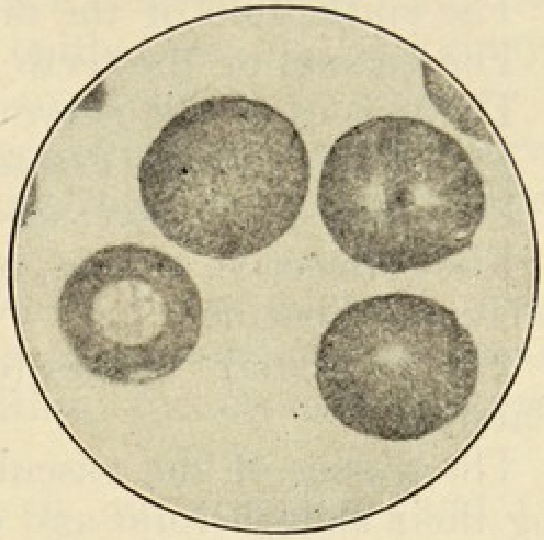
The Ovum.—The first cell from which all cells or tissues are formed is the ovum, and by multiplication of this cell and of the resulting daughter-cells three primary layers originate, namely, the *ectoderm*, the *mesoderm*, and the *entoderm*.

FIG. 8.



Spindle, showing chromosomes, asters, and centrosomes.

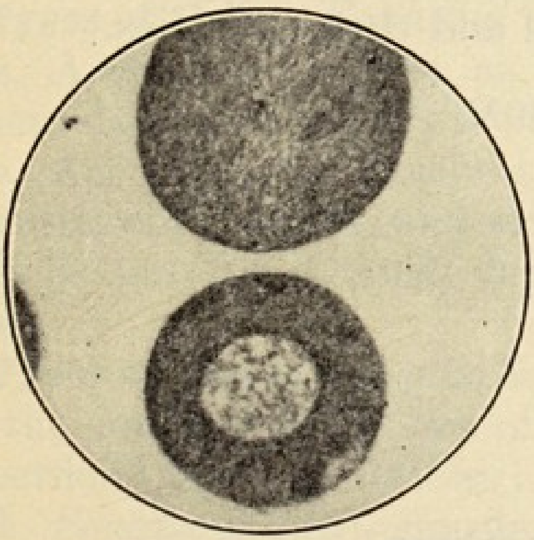
FIG. 9.



Showing four stages of nucleus.

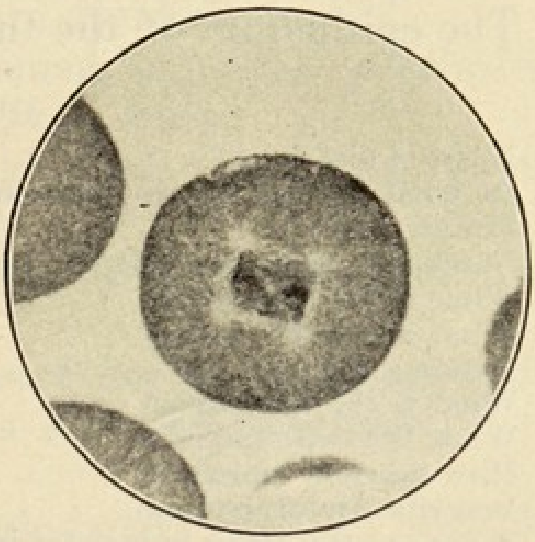
The normal tissues are classified into four groups—the *epithelial*, the *connective*, the *muscular*, and the *nervous* tissue.

FIG. 10.



Resting nucleus and loose skein.

FIG. 11.



Cell, showing four asters.

Karyokinesis—indirect division of the cell.

All the tissues of the body are derived from these three *blastodermic* layers, as follow:

I. From the *ectoderm*—

The epithelium of the outer surface of the body, hair, nails, etc.;

The epithelium of the nasal tract;

The epithelium of the mouth;

The enamel of the teeth;

The tissues of the nervous system;

The retina and the crystalline lens.

II. From the *mesoderm*—

The connective tissues, including areolar, tendon, cartilage, bone, and dentine;

The muscular tissues (except the muscles of the sweat-glands);

The tissues of the vascular and lymphatic systems, including their endothelium and circulating cells;

The sexual glands and passages (except the vagina);

The kidneys and ureters (except the bladder and urethra).

III. From the *entoderm*—

The epithelium of the digestive tract (except the mouth and anus);

The epithelium of the respiratory tract;

The epithelium of the urinary bladder and urethra;

The epithelium of the thyroid and thymus bodies.

QUESTIONS.

What is histology?
Of what are the tissues constructed?
Define a cell.
Name the parts of a cell.
What is the cell-wall?
What is the cell-body?
Define a nucleus.
What is the nucleolus?
What is a centrosome?
How do cells reproduce?
Describe direct division.
What are the other names for indirect division?
What part of the cell is principally concerned in indirect cell-division?
Name the stages of indirect cell-division.
From what do all cells originate?
Name the three primary layers.
How do we divide tissues?
What tissues are derived from the ectoderm? What from the mesoderm? What from the entoderm?

CHAPTER II.

THE EPITHELIAL TISSUES.

Origin.—The epithelial tissues are derived from the ectoderm and entoderm, except the epithelium of the kidneys, ureters, and sexual glands, which are from the mesoderm.

Composition.—*Epithelium* is composed largely of cells separated by a small amount of intercellular substance holding them together.

Epithelium contains no *bloodvessels*, but obtains its nutrition by absorption of the nutritive juices conveyed by means of the little spaces or clefts within the cement-substance between the cells.

The *nerve-supply* of epithelium is not abundant, and the existence of nerve-fibrils within the epithelium in many places has not been established, but in other localities of extreme sensibility, as the tactile surfaces, nerve-fibrils terminating among the epithelial cells have been demonstrated.

Occurrence.—The epithelial cells cover the skin, the mucous and serous cavities, and enter into the formation of the glands.

Types of Cell.—*Epithelial cells* are divided :

a. According to *form*, as columnar, cuboidal, polyhedral, spheroidal, tessellated (pavement), and scaly ;

b. According to *function*, as glandular (mucous, peptic, oxyntic, etc.), serous, and sensory.

Cells may be ciliated, flagellated, or have amœboid processes.

Types of Tissue.—*Epithelial tissues* are classified according to the number of layers of cells and the character of the superficial layer, as follows :

I. *Squamous*—(*a*) simple (single-layer) and (*b*) stratified (several layers).

II. *Columnar*—(*a*) simple (single-layer) and (*b*) stratified (several layers).

III. *Modified*—(*a*) ciliated, (*b*) goblet, (*c*) pigmented.

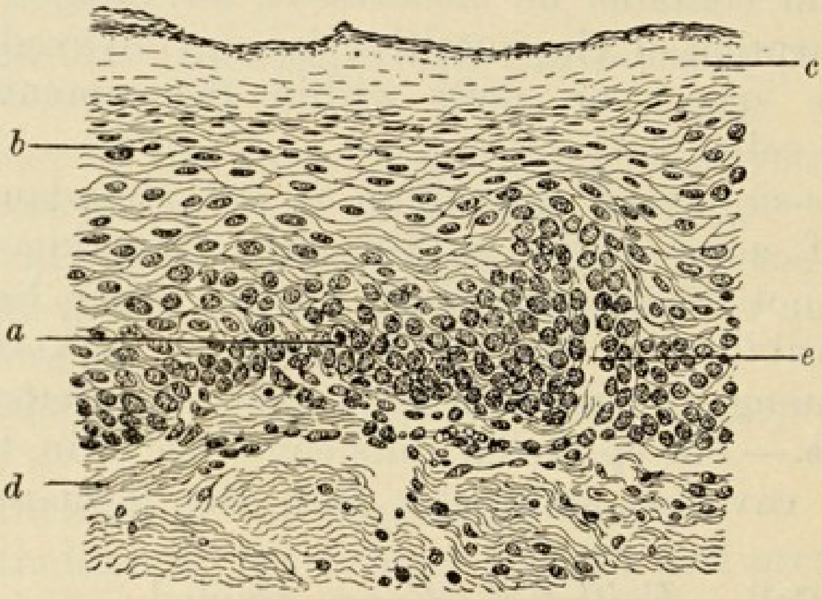
IV. *Specialized*—(*a*) glandular, (*b*) neuro-epithelium.

I. **Squamous Epithelium:**

a. Simple (single-layer).—This type consists of a single layer of thin, flattened cells with a large nucleus, and is found lining the air-sacs of the lung and in a few other places.

b. Stratified (many-layer).—This is more common and is arranged in several layers. The shape and size of the cells vary in the different layers; those in the deeper layers are cuboidal or spheroidal, while those on the surface are flattened like scales. This variety is widely distributed, and found in

FIG. 12.



Stratified squamous epithelium, œsophagus of rabbit: *a*, deeper layers of rounded germinal cells; *b*, more superficial layers of flattened cells; *c*, surface layer of horny cells; *d*, underlying fibrous tissue; *e*, papillary projection from the fibrous layer. (Dunham.)

the epidermis of the skin, the mouth, etc. That lining the bladder and ureter is sometimes called *transitional* epithelium.

II. **Columnar Epithelium:**

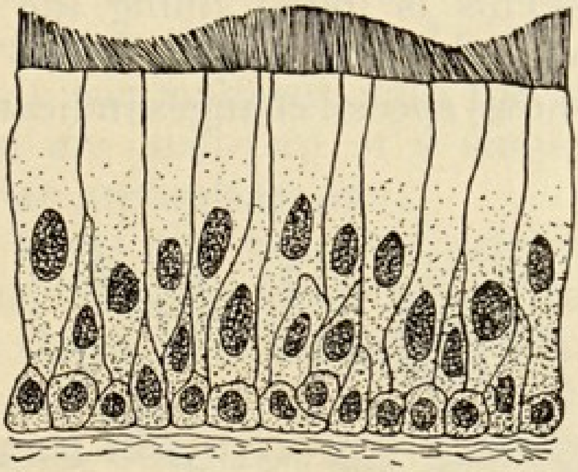
a. Simple (single-layer).—This is of a single layer of elongated, more or less cylindrical or hexahedral cells, perpendicular to a basement-membrane, and found in the intestines, in certain portions of the kidney, etc.

b. Stratified (many-layer).—In this type, occasionally the outer—*i. e.*, most superficial—cells are distinctly columnar, while in the deeper layers they are irregular. It occurs in the trachea, olfactory mucous membrane, larger gland-ducts, etc.

III. **Modified Epithelium:**

a. Ciliated.—This variety is limited to the most superficial layer of columnar cells, if stratified, and consists of delicate, hair-like processes on the outer end or free surface of the cell. These cilia are modifications of the cell-protoplasm, and when carefully studied by special methods of staining are found to be made up of an outer layer of hair-like processes, next a cuticular layer, with a row of *basal granules* immediately below this, and lastly a series of fine threads converging toward the nucleus of the cell. These last make up the fibrillar structure of the protoplasm. It occurs principally in the respiratory tract, where the cilia are supposed to

FIG. 13.



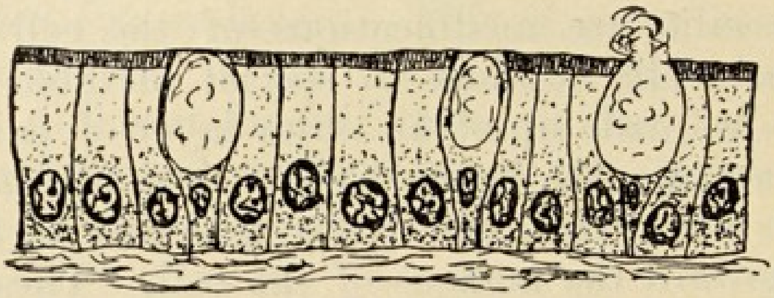
Ciliated columnar epithelium (stratified) from trachea, showing ciliary wave. (Nichols and Vale.)

remove small particles of dust by keeping up a vibration or sweep centrifugally toward the nose.

b. Goblet.—Between the columnar cells of the most superficial layer of columnar epithelium, if stratified, lining mucous surfaces, are found elliptical cells resembling goblets, and containing mucus, which is discharged upon the outer surface of the epithelium. These cells are sometimes called *unicellular glands*, or *gland-cells*. They are distinguished from the other cells by their larger size and clear protoplasm. This type occurs in all mucous membranes, especially in the intestinal tract.

c. Pigmented.—When epithelial cells contain a coloring-matter, as in the deeper layers of the epidermis of certain races and the outer layer of the retina, this variety is present.

Fig. 14.

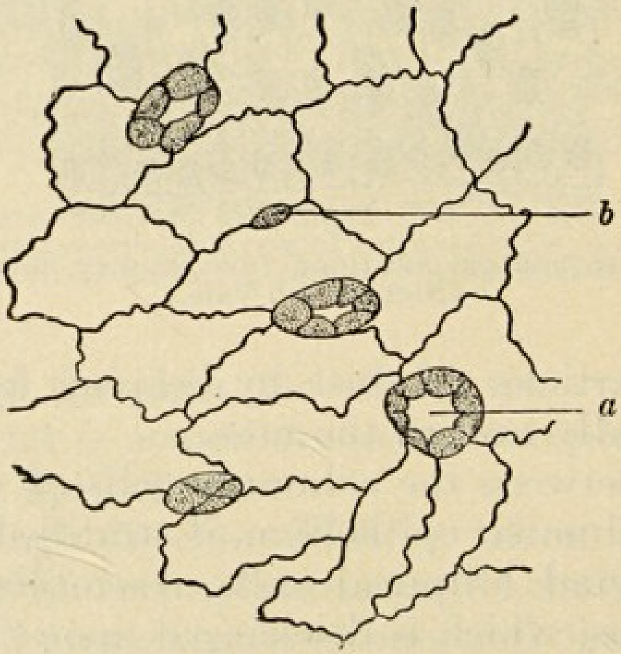


Simple columnar epithelium and goblet-cells, from the intestine. Shows the striated free cuticular margin of the cells in this situation. (Nichols and Vale.)

IV. **Specialized Epithelium:**

a. Glandular.—This is found lining the glands, and the cells are columnar, spherical, or polyhedral in shape. The protoplasm often shows special changes indicating the character of the secretion.

Fig. 15.



Endothelium on a serous surface of the frog: *a*, stoma bounded by endothelial cells with granular cytoplasm; *b*, pseudostoma. The nuclei of the cells are not represented. (Klein.)

b. Neuro-Epithelium.—This is a type of cells modified so as to aid the nerves, which terminate in or near them, to appreciate the special senses, and are found in the retina, nose, etc.

THE ENDOTHELIAL TISSUES.

Origin.—Endothelial tissues are developed from the mesoderm.

Classification.—This variety of tissue is usually classified with the epithelial tissues on account of its resemblance especially to the squamous, but more properly belongs to the connective tissues, as it owes its origin to the same layer of the blastoderm.

Composition.—It consists of a single layer of very thin polygonal flat cells having faintly granular protoplasm and a flattened oval nucleus. The small amount of intercellular cement-substance, and the slightly wavy borders of the cells cause their boundaries to appear indistinct unless special methods of staining are resorted to. Small openings, called *stomata,* occur between the cells and allow the cavities lined with these cells, to communicate with the lymph-vessels.

These stomata are made up of a single layer of cubical cells with granular protoplasm.

Endothelium forms the lining of serous cavities, lymph- and blood-vessels. In the latter places the cells are of an irregular oblong shape, with serrated borders.

THE CONNECTIVE TISSUES.

Origin.—These tissues are all developed from the mesoblastic layer of the blastoderm, and by specialization and differentiation of the intercellular substance are formed the various types of this group.

Composition.—Connective tissues are composed of cells separated by much intercellular substance or fibres, and may be solid, gelatinous, or fluid. As the name implies, these tissues hold together the other tissues and thus supply the framework of the body.

Classification.—They are divided into three main groups—

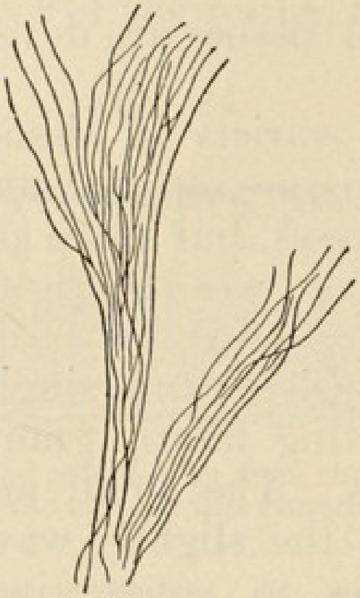
I. *Fibrous connective tissues.*

II. *Cartilage.*

III. *Bone.*

Fibrous connective tissues are subdivided into—(A) the *chief*

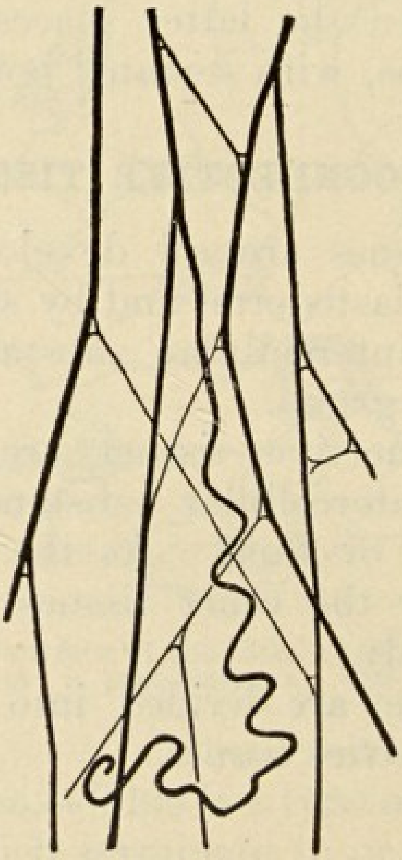
FIG. 16.



Fibres of white fibrous tissue teased apart to show the individual fibrils. (Dunham.)

varieties: (*a*) white fibrous, (*b*) yellow elastic, and (*c*) areolar; into—(B) the *special varieties:* (*a*) gelatinous, (*b*) adenoid, and (*c*) adipose.

FIG. 17.

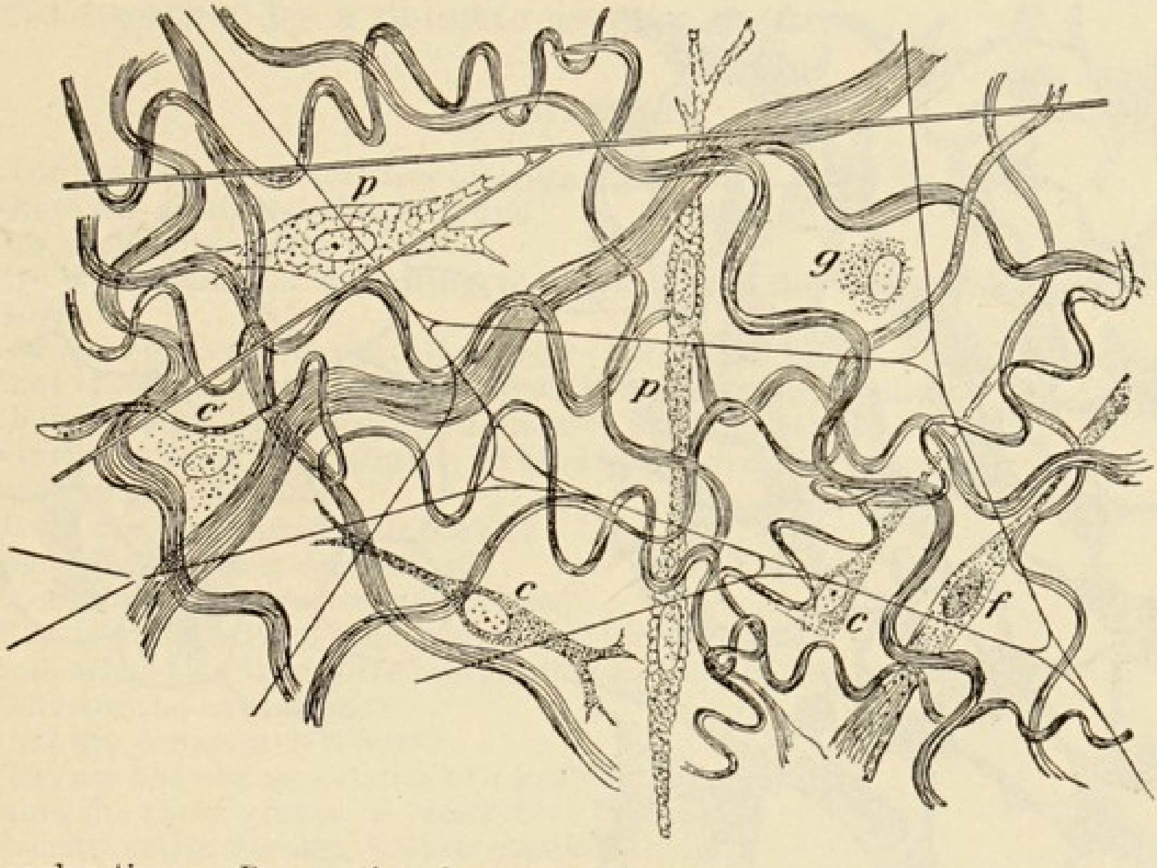


Elastic fibres. From subcutaneous areolar tissue. (Schäfer.)

a. White fibrous is composed of layers or bundles of fine silky fibrils, parallel or interlacing. This tissue is found most typical in tendons, and the cells are arranged in long chains between the fibres. Two kinds of cells are noted in this tissue, the fixed or stellate and the wandering, which resemble the leucocytes.

b. Yellow elastic occurs as a network of branching yellow

FIG. 18.



Areolar tissue. Preparation from the subcutaneous tissue of a young rabbit: *c'*, endothelioid cell; *p*, *p*, cells with granular cytoplasm; *c*, *c*, *f*, cells of the fusiform or stellate variety not yet fully developed; the white fibres are in bundles pursuing a wavy course; the elastic fibres are delicate and form a very open network; *g*, leucocyte of a coarsely granular variety. (Schäfer.)

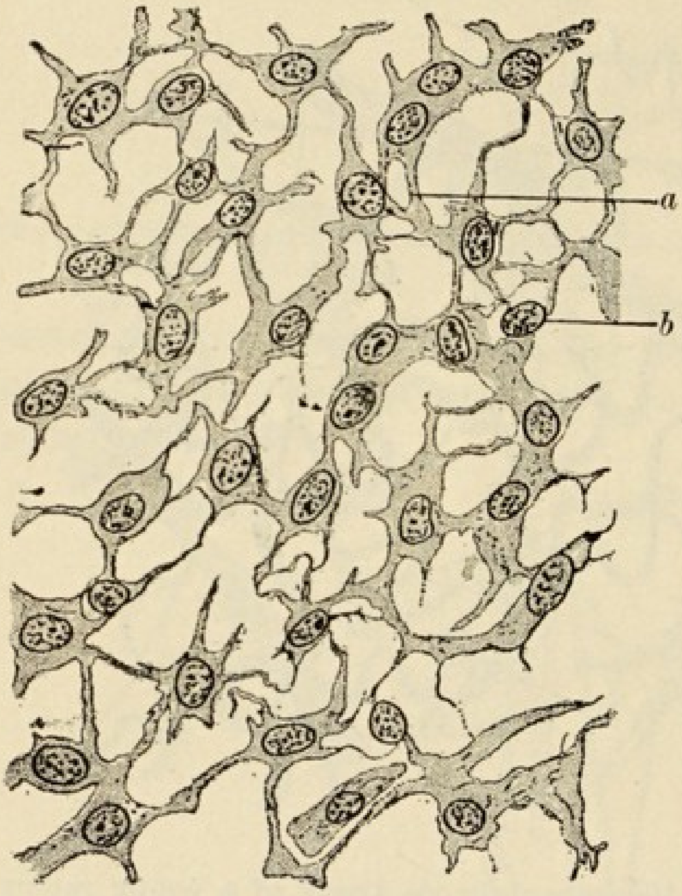
fibres, nearly the same width throughout their length, and when broken curled at the ends. This tissue occurs in the ligamentum nuchæ and helps to make up areolar tissue.

c. Areolar is widely distributed and occurs in the subcutaneous, subserous, and submucous tissues. It is composed of both white fibrous and yellow elastic, which interlace to form a network in which are embedded connective-tissue corpuscles or cells.

The density of areolar tissue depends upon whether the bundles of fibres are numerous, making a very compact interlacement, or whether they form a loose, open network. Between the meshes of fibres is a semifluid clear substance known as the *matrix*, or *ground-substance.*

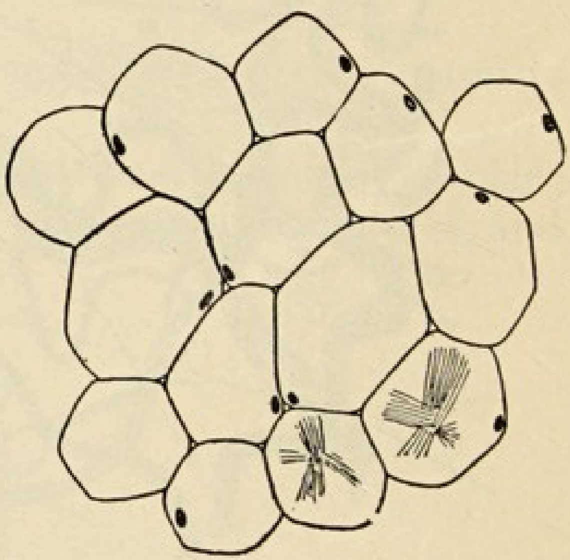
Gelatinous or *mucous* tissue is found in the jelly of Wharton of the umbilical cord and the vitreous humor of the eye.

FIG. 19.



Embryonic connective tissue (mesenchymatous tissue): *a*, nucleus of stellate cell; *b*, cytoplasmic process. The intercellular substance is of gelatinous consistency and optically homogeneous. (Böhm and Davidoff.)

FIG. 20.



Adipose tissue. Crystals of fatty acids are represented in two of the cells. (Nichols and Vale.)

It consists of large stellate cells embedded in a soft substance through which are scattered a few fibres and wandering cells.

This tissue is really not a separate variety, but should be considered only as an early stage of developing fibrillar connective tissue.

In the mucous tissue of the vitreous humor of the eye are less cells and the semifluid ground-substance is very abundant

Adenoid or *lymphatic* tissue makes up the stroma of the lymphatic glands, and sometimes called retiform.

This tissue is a delicate network of minute fibrils and contains lymphoid cells within its meshes.

Adipose or *fatty tissue* is widely distributed and consists of spherical connective-tissue cells, distended with oil derived from its protoplasm. The nucleus and remaining cell-body have been pushed to one side and appear crescent-shaped, while the oil is surrounded by the thin cell-wall. This tissue is held together by a delicate areolar tissue.

QUESTIONS.

What are the characteristics of epithelium?
Where are epithelial tissues found?
How do we divide the cells?
Give a classification according to the shape of the cell; according to the function.
How are epithelial tissues classified? Name the four principal varieties.
What is simple squamous epithelium? Stratified epithelium?
What is simple columnar epithelium? Stratified epithelium?
Describe ciliated epithelium. Where is it found?
Describe goblet-cells.
Where are pigmented cells found?
Describe glandular epithelium.
Where do we find neuro-epithelium?
What is endothelium, and where is it found?
From what two layers are most epithelial tissues derived?
What are the exceptions?
What are connective tissues?
What are the characteristics of connective tissues?
Name the three groups of connective tissues.
Describe white fibrous; yellow elastic; areolar.
Where do we find gelatinous tissue? Where adenoid tissue?
Describe adipose tissue?

CHAPTER III.

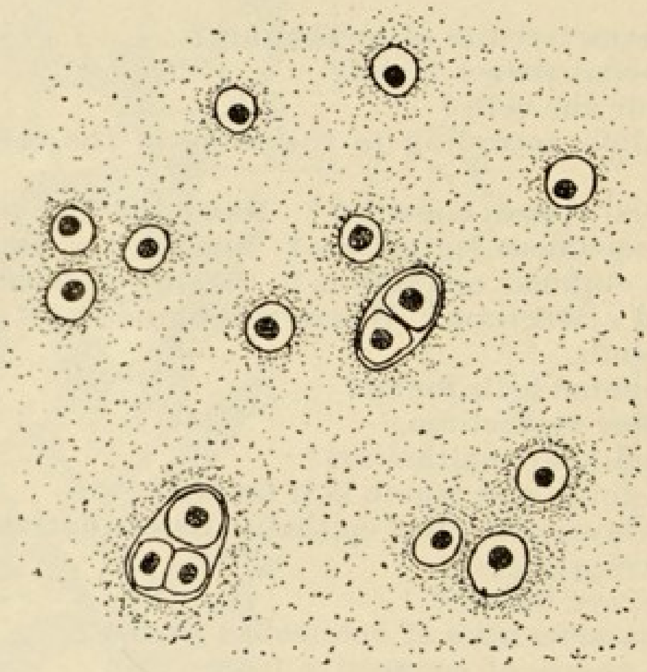
CARTILAGE.

CARTILAGE is a variety of connective tissue consisting of cells or corpuscles embedded in a condensed intercellular substance or matrix, the character of which gives rise to three types: the *hyaline*, the *fibrous*, and the *elastic*.

This tissue represents a transition between the connective tissues and bone, and is distinguished from the fibrous connective tissues by the hard and dense consistency of its matrix and the shape of its cells.

Hyaline Cartilage.—This consists of a clear, nearly homogeneous *matrix*, with very delicate fibres holding together its glassy substance. The *cells* are large, irregular, and oval in shape, have large nuclei, and are grouped in patches. They lie in small spaces called *lacunæ*, and the matrix around the cells appears condensed, making a capsule.

Fig. 21.



Hyaline cartilage. (Nichols and Vale.)

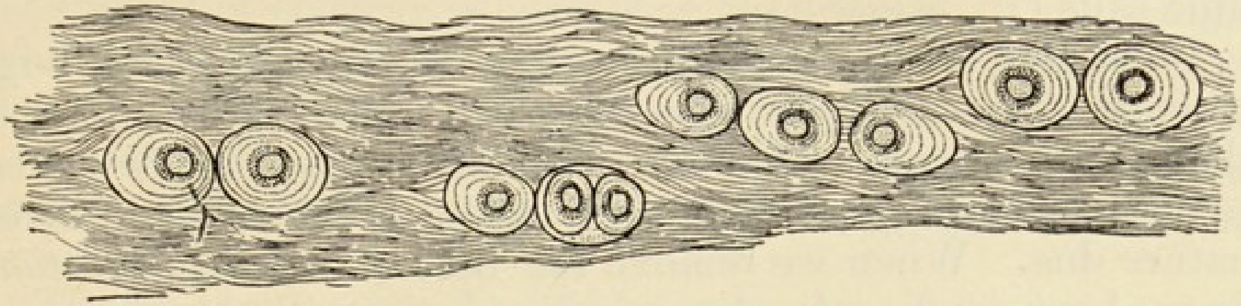
The cells in the superficial layers are more flattened, smaller, and spindle-shaped than those in the deeper layers, and on the outer surface the cells are arranged in parallel rows.

The outer covering of the cartilage is called the *perichondrium*, and consists of dense fibrous tissue.

Hyaline cartilage is found in the articular ends of bones, ribs, trachea, etc.

Fibrous cartilage is hyaline cartilage to which have been added bundles of white fibrous connective tissue throughout its matrix to give increased strength and flexibility. The cells of this variety are less numerous, and are generally arranged in small groups. It is not so widely distributed, and is found in the intervertebral disks.

FIG. 22.

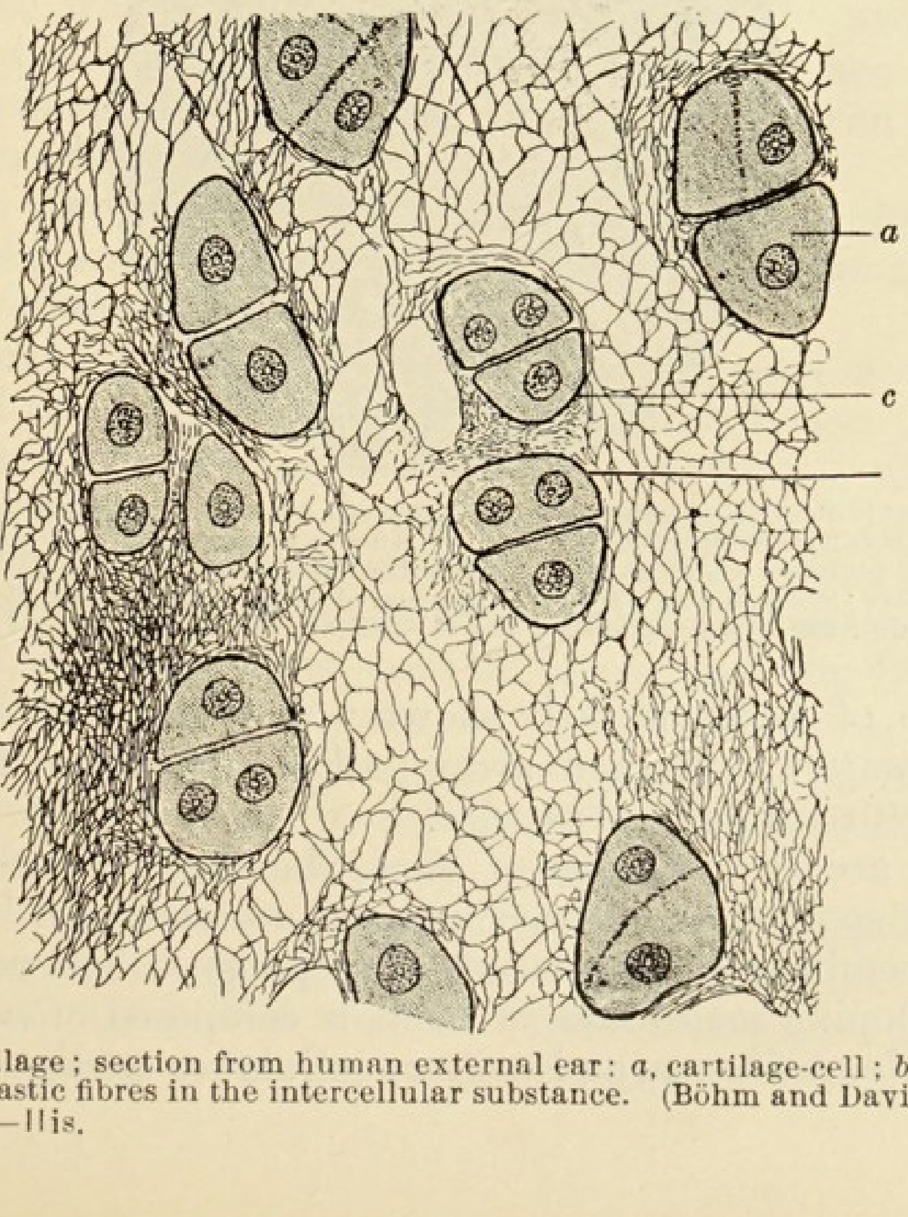


Fibrocartilage. Section from human intervertebral disk. The cell to the left presents a branching process extending into the intercellular substance. (Schäfer.)

Elastic cartilage differs from the preceding varieties in that it contains yellow elastic fibres in the matrix to give it great elasticity.

This type is found in the ears, epiglottis, etc.

FIG. 23.



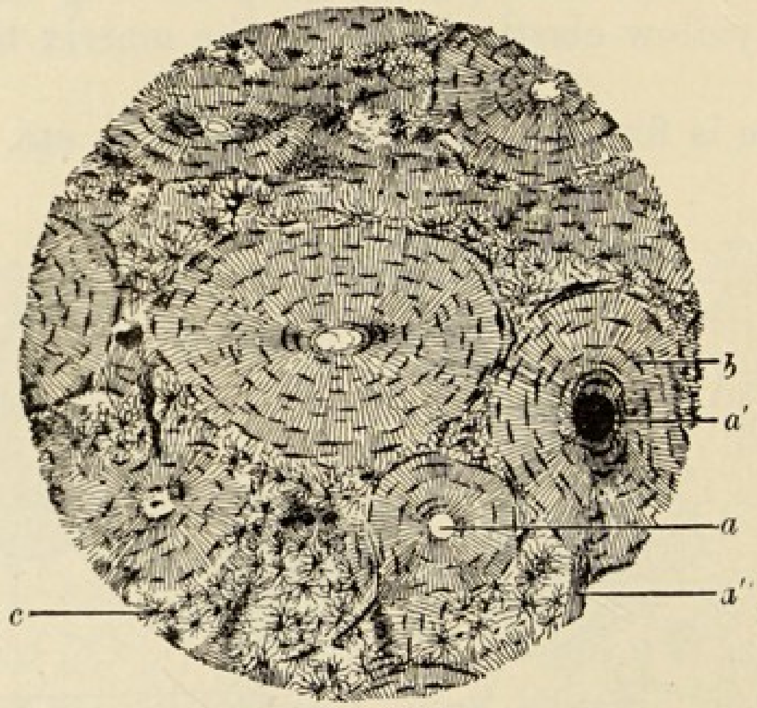
Elastic cartilage; section from human external ear: *a*, cartilage-cell; *b*, *c*, network of elastic fibres in the intercellular substance. (Böhm and Davidoff.)

BONE.

Bone is a type of connective tissue, dense in structure, **composed of** cells or corpuscles and a matrix impregnated with lime salts.

Bone, like all the other connective tissues, possesses a large amount of intercellular substance, but differs from these in that it has a deposit of lime salts within the interfascicular cement-substance, and to this deposition is its hard and dense nature due. When we remove the lime salts (*decalcification*) from bone and only the organic framework remains, the

FIG. 24.



Ground section of dried bone; human femur: *a*, Haversian canal in cross-section; *a'*, Haversian canal occupied by débris; *a''*, anastomosing branch from *a'*, in nearly longitudinal section; *b*, lacuna belonging to the Haversian system, of which *a'* occupies the centre; *c*, lacuna in excentric laminæ of bone between the Haversian systems. The delicate lines connecting the lacunæ are the canaliculi. (Dunham.)

structure of bone is well shown; and likewise when the organic matter is burned away (*calcination*) there is left an exact picture of bone structure.

There are two **varieties** of bone, the *compact* and the *cancellous* or spongy, the former being dense and hard, while the latter resembles the framework of a sponge. The **periosteum**, the enveloping membrane of bone, is composed of two layers, an outer dense fibrous, and an inner cellular or *osteogenetic* layer.

Compact bone forms the shafts of the long bones and the outer part of the flat and irregular bones. It is composed of a system of tubes, called the *Haversian canals*, surrounded by a series of concentric *lamellæ* or *bone-plates*. These canals, which connect with the central marrow-cavity, supply nutrition to the bone and contain blood, lymph, and marrow.

Between the various lamellæ are small spaces called *lacunæ*, or little lakes, and connected with these are small canals, the *canaliculi*.

The lacunæ contain the *bone-cells* or corpuscles, and their branches extend into the canaliculi, thus receiving their nutrition. The lacunæ are arranged in rows more or less parallel with the Haversian canals.

The lamellæ are arranged, in the shaft of long bones, into three sets: (1) The *general* or *fundamental*, those beneath the periosteum and surrounding the medullary canal. (2) The *Haversian*, which are arranged concentrically around the Haversian canals. (3) The *interstitial*, which are between the Haversian systems, filling the spaces between adjacent Haversian systems.

Certain fibres pierce the lamellæ vertically to the surface of the bone and hold the plates together. These are called the *perforating fibres* of *Sharpey*.

Cancellous or spongy bone occurs in the ends of the long bones and the centres of the flat or irregular bones. It is of a less dense structure, and the large cavities are filled with marrow from which it derives its nourishment, not having such a complete system of vessels as in the compact variety.

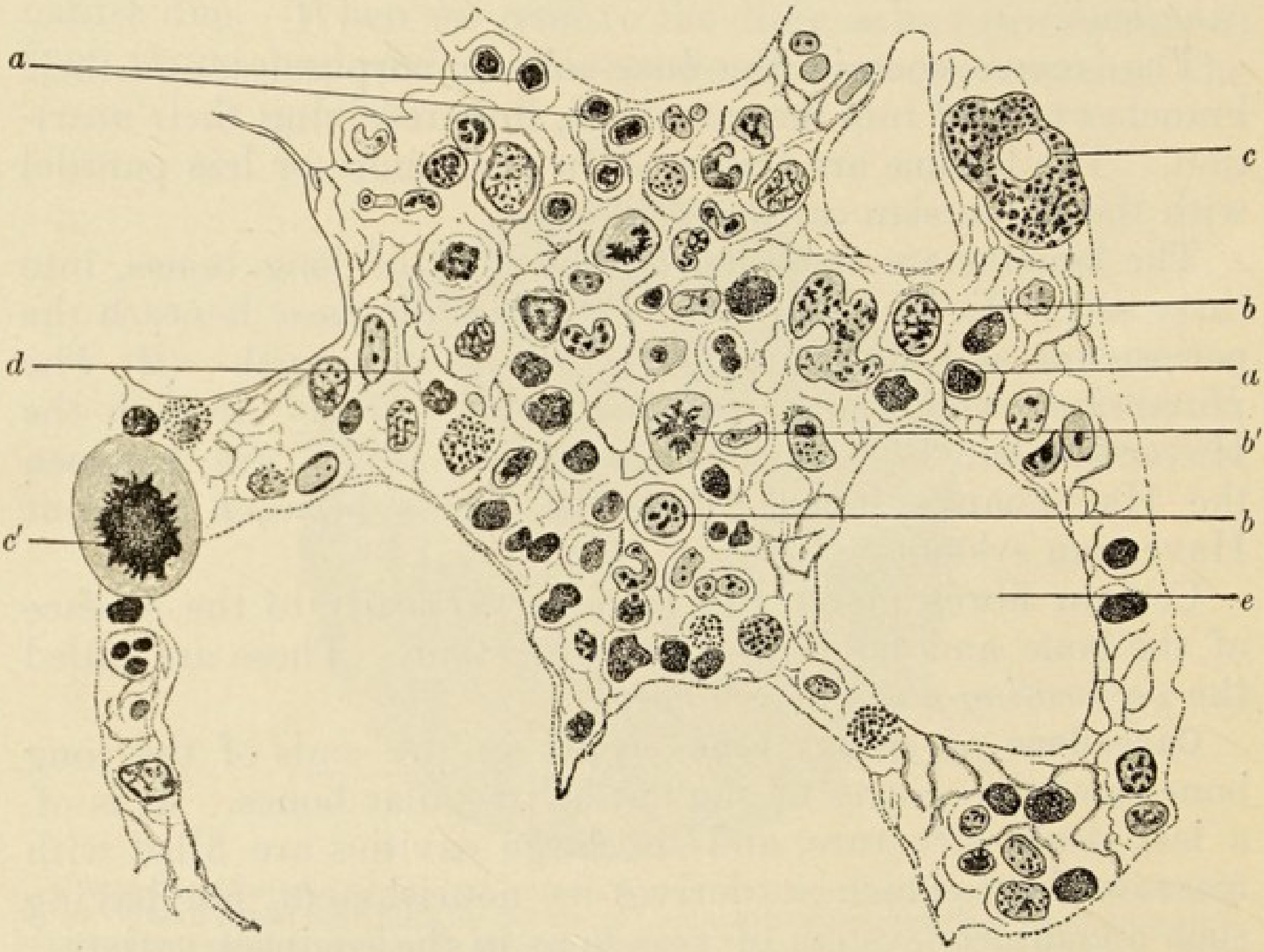
Bone-marrow is a soft vascular tissue found in the medullary canal, the cancellous ends of bones, and the Haversian canals. It is divided into the *red* and the *yellow marrow*.

Red marrow occurs in the ends of long bones, in the bodies of the vertebræ, and in the cavities of the flat bones in adults and throughout the bones in the young.

The red marrow is a lymphoid organ, and is probably the main source of the formation of the red blood-cells.

It is composed of a delicate connective-tissue reticulum with a capillary network, in the meshes of which are the marrow-cells, resembling leucocytes, and divided into eosinophiles, myelocytes, erythroblasts, and basophiles. Many of these marrow-cells contain pigment-granules, which are the remains of disintegrated red blood-cells. The red marow contains few fat-cells, and bloodvessels and nerves are found only in small numbers.

Fig. 25.



Section of red marrow; human: *a*, *a*, erythroblasts; *b*, *b*, myelocytes; *b′*, myelocyte undergoing division; *c*, giant cell with a single nucleus; *c′*, giant cell with dividing nucleus; *d*, reticulum; *e*, space occupied by a fat-cell (not represented); *f*, granules in a portion of an acidophilic cell. (Böhm and Davidoff.)

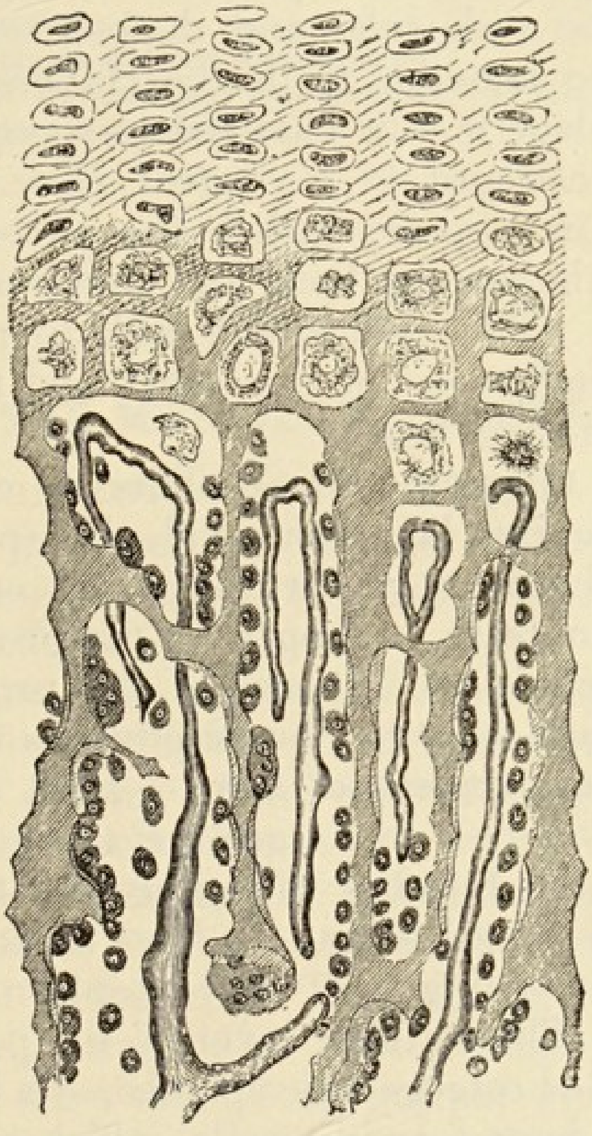
Yellow marrow differs from the red only in that it contains large quantities of fat-cells, to which it owes its color. It arises from the red marrow by a diminution of the marrow-elements and by an increase in fat.

Dentine resembles bone except that it is devoid of Haversian canals and lacunæ, and has long, parallel *tubules* in place of canaliculi.

Bone Development.—This occurs by two methods, the *cartilaginous* and the *membranous.*

Cartilaginous Development of Bone.—Most of the bones of the body, except those of the head, are first modelled in hyaline cartilage and covered with the perichondrium or early

Fig. 26.



Development of bone, cartilaginous method. (Klein.)

periosteum. The process is best divided into the following stages:

Proliferation and Calcification.—The cartilage-cells at certain places in the bones begin to arrange themselves in rows, enlarge, and a deposition of lime salts occurs known as *centres of ossification.* The hyaline matrix is transformed into a number of calcified trabeculæ inclosing spaces called the *primary areolæ,* in which are the cartilage-cells. These soon gradually disintegrate and disappear.

Vascularization of Cartilage.—The cellular layer of the periosteum, containing the osteoblasts, now sends processes into the substance of the cartilage, and bloodvessels are formed which penetrate the calcified trabeculæ and enlarge the areolæ.

Cartilage changed to Embryonic Bone.—The osteoblasts now surround the trabeculæ and deposit several layers of bone in concentric lamellæ as in the Haversian system, and the calcified cartilage is now changed to spongy bone.

Spongy Bone changed to Periosteal Bone.—Larger bone-forming cells now appear, called the *osteoclasts,* and these destroy some of the spongy bone and construct the central or medullary canal. The periosteum also deposits layers of bone on the circumference of the shaft and the spongy bone is changed to periosteal bone.

Formation of Compact Bone.—This is effected by the osteoblasts developing layers around the spongy bone, and dense bone gradually replaces the early embryonic bone. The long bones increase in length by the growth at the ends of the shaft, which is an advance of the process of ossification of the cartilage between the diaphysis and epiphysis.

Membranous Development of Bone.—Most of the bones of the skull are developed in connective tissue by a deposition of lime salts in the bundles of connective tissue along the surface. In these bundles the cells have arranged themselves in a layer, and becoming rich in protoplasm are converted into osteoblasts. The cellular layer of the periosteum sends out processes, called osteogenetic spiculæ, of a bony nature and surrounded with bone-forming cells, which secrete layers of bone as in the formation of the lamellæ of the Haversian system. The tissue becomes more vascular and the osteoclasts absorb the spongy bone to make marrow-cavities, while the dense bone is deposited from the periosteum.

QUESTIONS.

What is cartilage? Name the three varieties.
Describe hyaline cartilage.
What is fibrocartilage?

What is elastic cartilage?
What is bone?
Describe the periosteum.
Name the two varieties of bone.
Where is compact bone found?
Name the parts of an Haversian system.
What are the lamellæ? The lacunæ? The canaliculi?
Where do you find spongy bone?
Name the kinds of bone-marrow.
Describe red marrow.
Describe yellow marrow.
Name the two methods of bone development.
Name the stages of the cartilaginous method. Describe each stage.
Describe the membranous method.

CHAPTER IV.

THE MUSCULAR TISSUES.

THESE tissues are **divided into** three **kinds**—the *non-striated*, the *striated*, and the *cardiac*. All are **derived from** the mesoderm except those fibres found in the sweat-glands, which are from the ectoderm.

The cells of muscular tissue are characterized by possessing the power of contractility; and according as the contraction is under the control of the will or not, they are divided into *voluntary* and *involuntary*.

The **non-striated muscle,** also called **involuntary,** is a type found in the walls of arteries, intestinal tract, etc., and is not under the control of the will. The cells or fibres are fusiform or spindle-shaped, surrounded by a delicate sheath, have an oblong nucleus, very fine longitudinal striations, and are cemented closely together, They usually lie in groups, and these may be combined to form layers, as seen in the muscular coats of the intestine. When we cross-section a group of these cells, they appear as polygonal or round areas of unequal size, because the section passes through the cells at different parts of the spindles, and the smaller areas do not contain a section of the nucleus as do the larger ones.

The **striated or voluntary muscle** forms the skeletal muscles, the outer muscles of the eye, muscles of the ear, pharynx,

Fig. 27.

larynx, tongue, œsophagus, and those around the anus and sexual organs, and is controlled by the will. The exceptions are the muscles of the upper part of the œsophagus and the cremaster externus, which are not under the control of the will. The fibres are cylindrical in shape, parallel, and covered with a distinct elastic membrane called the *sarcolemma*, under which are large oval nuclei. Striations, made up of alternate dark and light parallel transverse lines, give this variety of muscle its name. When highly magnified, there may be distinguished a dark line (*Krause's membrane*) in the centre of

Fig. 28.

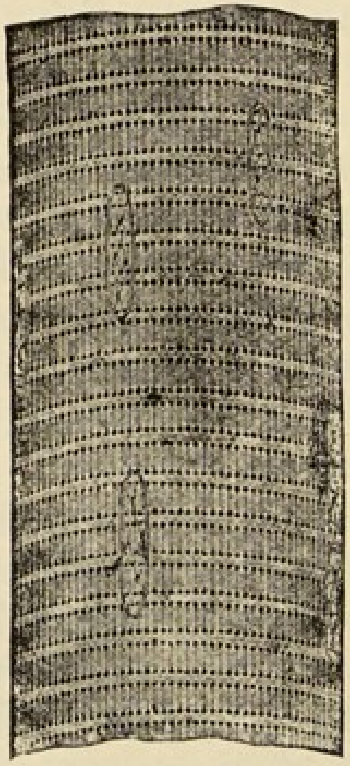


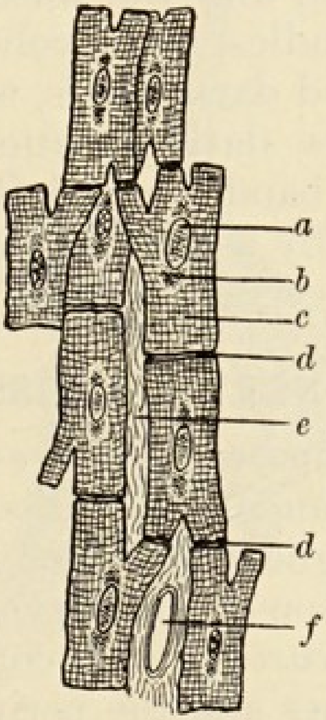
Fig. 27.—Involuntary muscle-cell. The nucleus is somewhat contracted, so as to appear broader and shorter than when in the extended state. (Schäfer.)

Fig. 28.—Portion of a muscle-fibre from a mammal. This figure represents the appearances of the fibre when the surface is in sharp focus. (Schäfer.)

the light band, and a light line (*Hensen's median line*) in the dark band (*Brücke's line*).

The fibres, when treated with certain chemicals, may be made to undergo a longitudinal cleavage into fine fibrillæ or *sarcostyles*, and transversely into disks separating at the membranes of Krause. The ultimate units of which the fibre is composed will thus be seen to be made up of spindles or double prisms, whose ends become extremely thin and terminate in minute spheres. These spindles lie parallel and their thickest parts give rise to the dark lines and their thinner ends to the light lines, while the membranes of Krause or the dark

Fig. 29.



Cardiac muscle: *a*, nucleus of a muscle-cell; *b*, unmodified cytoplasm; *c*, contractile substance with longitudinal and transverse striations; *d*, cement-substance uniting contiguous cells; *e*, areolar tissue (vessels omitted) between the muscle-fibres formed by union of the individual cells; *f*, small bloodvessel within the areolar tissue. (Dunham.)

lines in the light band are formed by the spherical ends of the spindles. The light line, or *median line of Hensen*, in the dark band is the space between the prisms or the centre of the spindles. The separate fibres are held together by a delicate areolar tissue called the *endomysium*. These bundles or fasciculi are also surrounded by a similar sheath called the *perimysium*, and, lastly, the entire muscle is covered by the *epimysium*, through which the bloodvessels and nerves penetrate.

The **cardiac muscle** possesses some of the characteristics of both the preceding varieties, and might be called involuntary striated muscle. It consists of short *branched*, cylindrical cells, with square extremities placed end to end, so that the dividing-line between the ends may only be distinguished with difficulty. The cells contain no sarcolemma, have a single nucleus in the centre of their protoplasm, are transversely striated and faintly marked longitudinally. These cells, after special methods of staining, show dark columns which run parallel to the long axis of the cell, and these are separated by a light or unstained substance. These columns are called *fibril-bundles*, and the unstained substance *sarcoplasm*. The fibril-bundles, as in voluntary muscular tissue, show alternate light and dark bands, and in the centre of the light band is a narrow dark striation, *Krause's membrane*, while the broader dark band is called *Brücke's line*. The rows of cells are separated by a delicate connective tissue rich in capillaries. This variety of muscle is found only in the heart.

THE NERVOUS TISSUES.

These tissues are **composed of** nerve-cells, nerve-fibres, and a connective-tissue framework called the *neuroglia*. The cells, fibres, and neuroglia are **derived from** the ectoderm.

The modern conception of the nervous system is now based upon the *theory of the neuron*, which consists of a single nerve-cell, with all its branches and the peripheral terminations.

The **neuron** constitutes the nerve-unit, and combinations of these neurons make up the whole.

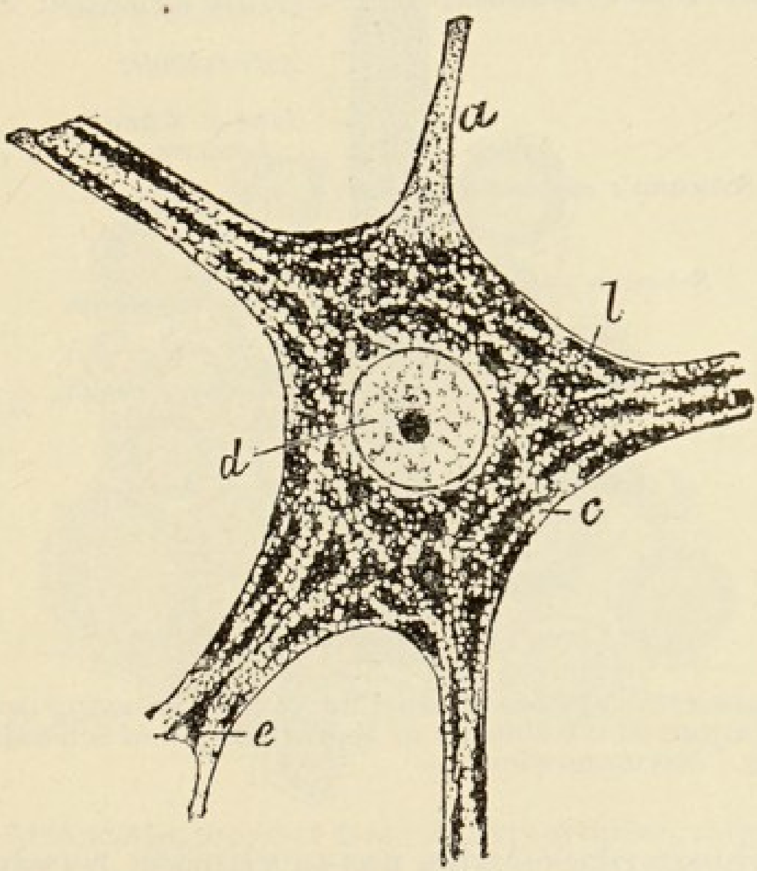
Nerve-Cells.—These vary greatly in size, have a large nucleus containing little chromatin, and a large nucleolus. Protoplasmatic processes are given off from the body of the cell, and we classify the shapes as unipolar, bipolar, tripolar, and multipolar, according to their number of processes. These processes are called dendrites, except the one which becomes the nerve-fibre, called the axis-cylinder process or neuraxon or neurite.

Some authors suppose that the dendrites conduct impulses to the cell, while the neurites convey impulses from the cell to the peripheral nerve-endings.

Nerve-Fibres.—These are essentially prolonged processes of nerve-cells, and are of two kinds, the medullated and the non-medullated.

The *medullated* or *white fibres* are the continuation of the neurite of the cell, and consist of a central core, the *axis-cylinder*, which is a prolongation of the original cell-protoplasm, and runs uninterruptedly from the nerve-cell to the nerve-ending; an enveloping sheath, called the *medullary*

Fig. 30.



Body of multipolar nerve-cell from spinal cord (Nissl's stain), showing details of the structure: *a*, neurite; *b*, *c*, cytoplasm, containing coarse chromophilic granules; *d*, nucleus, with nucleolus; *e*, dendrite. (Ramon y Cajal.)

sheath or *white substance of Schwann;* and lastly an outer covering of a delicate elastic membrane, called the *neurolemma* or *Schwann's sheath.* Between the medullary sheath and the axis-cylinder is *Mauthner's sheath*, or the *inner neurolemma.* Nuclei are scattered along the fibres, just under the neurolemma, but are less numerous in the medullated than in the non-medullated fibres.

Constrictions occur at regular intervals along the fibres, and are called the *nodes of Ranvier*.

The nodes interrupt the white substance, as the constrictions extend down to the axis-cylinder, and the absence of myelin at these nodes allows the axis-cylinder to become joined with the neurolemma by a cement-substance, and

FIG. 31.

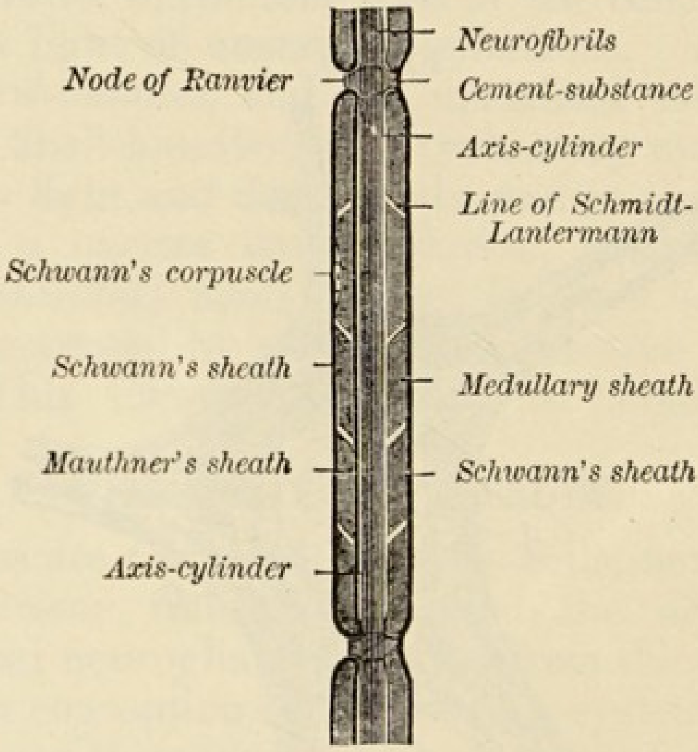


Diagram of the structure of a medullated nerve-fibre, showing two different views concerning the relations of the sheaths of Mauthner and of Schwann. Compare the right and left sides. (Szymonowicz.)

probably at these places the axis-cylinder receives nourishment, as nutritive fluids could pass more easily into the centre of the fibre here than elsewhere.

The *non-medullated* or *gray fibres* differ from the preceding in that they have no medullary sheath, but are surrounded by a covering resembling Schwann's sheath, show a tendency to be branched, and contain more nuclei.

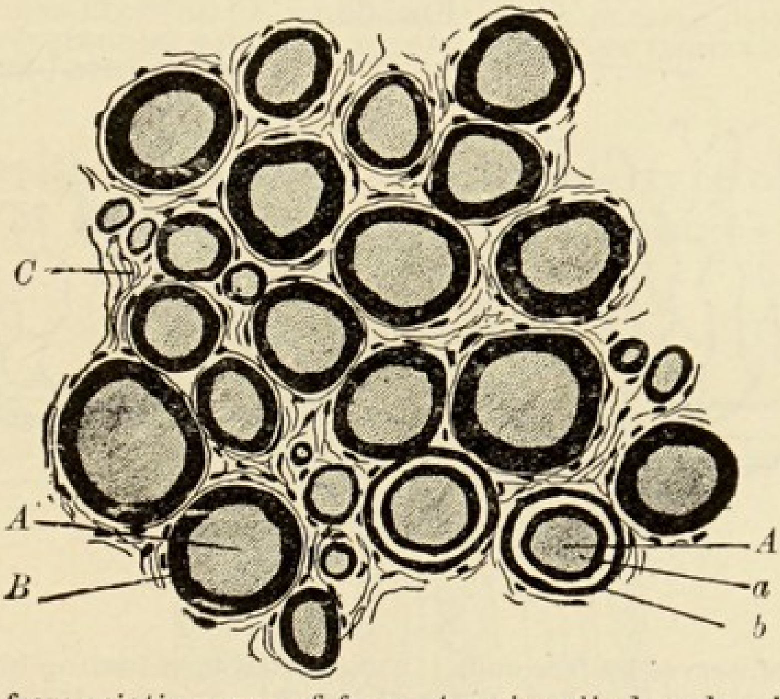
These fibres are found principally in the sympathetic nervous system.

Nerve-Trunks.—The nerve-fibres are surrounded by a delicate connective-tissue sheath called the *endoneurium*, the bundles of fibres or funiculi ensheathed by the *epineurium*, and lastly the *perineurium* covers the nerve-trunk.

Neuroglia.—This is a sustentacular tissue similar to connective tissue (except of ectodermic origin, as the nerve-cells and -fibres), forming the framework of the nervous system, and is composed of extremely branched cells, called *glia-cells*, whose delicate processes extend in all directions, cementing the nervous elements together.

Ganglia are groups of nerve-cells and -fibres in the course of nerve-trunks, as in the sensory roots of the spinal nerves, many cranial nerves, and the sympathetic system.

FIG. 32.



Cross-section from sciatic nerve of frog: *A*, axis-cylinder, showing punctate sections of the fibrillæ; *B*, medullary sheath stained with osmic acid; *a*, *b*, apparent duplication of the medullary sheath, due to the presence of a Lantermann cleft; *C*, areolar tissue between the fibres. (Böhm and Davidoff.)

These enlargements are covered with a fibrous coat, denser than the epineurium, and the nerve-cells are generally spherical, having one or two processes to become continuous with the afferent and efferent nerves.

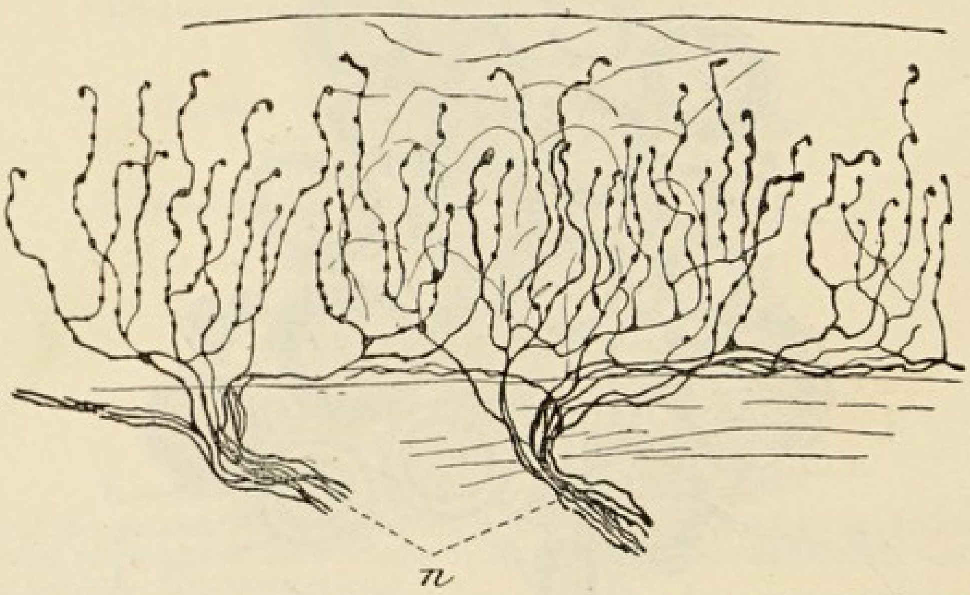
Numerous capillaries surround the individual cells of the ganglia. There are two types of ganglia: the *spinal ganglion type* and the *sympathetic ganglion type*.

The *spinal ganglia* are made up of cells with large cell-bodies, which are unipolar, containing a vesicular nucleus with a distinct nucleolus and often yellowish-brown pigment-granules. A nucleated capsule always surrounds the cells, and this is probably only a continuation of Schwann's sheath.

The *sympathetic ganglia* contain small multipolar cells, having some pigment, often two nuclei, and are surrounded by a capsule.

Nerve-Terminations.—Through these endings the sensory impulses are transmitted to the central nervous system, and motor impulses transmitted from the nervous system to peripheral organs. The nerve-endings are the final terminations of the individual neurons. There are free nerve-endings

Fig. 33.

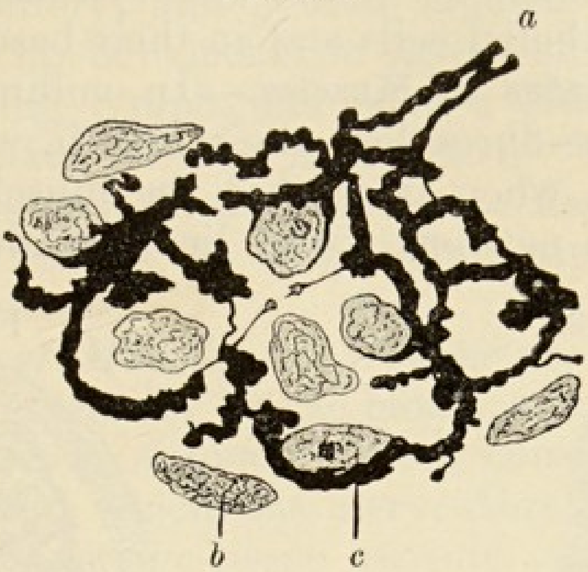


Termination of nerves by free ends. Two nerves terminating in the stratified epithelium covering the vocal cords of the cat. *n*, nerve-trunk. (Retzius.)

which are not connected directly with other tissues in order to give or receive impulses, and other specialized nerve-endings in which the nerve-ending is connected with some other tissue: as epithelial, connective, muscle, and nervous tissues, to form its termination. The nerve-fibres terminate in four ways:

1. The interepithelial arborizations;
2. The motor plates in muscles;
3. The special end-organs in sensory tissues;
4. The tactile corpuscles.

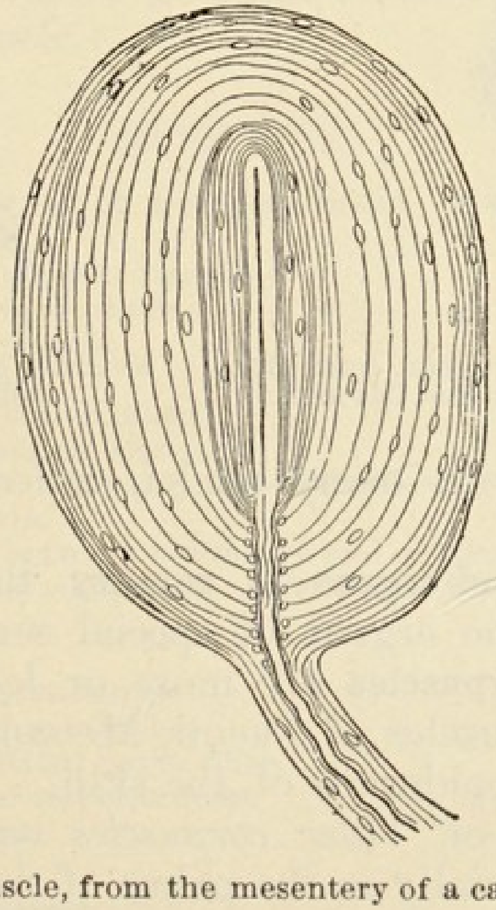
FIG. 34.



Motor plate; tail of a squirrel: *a*, two branches of axis-cylinder terminating in a plexus of varicose filaments; *b*, muscle-nucleus; *c*, nucleus derived from neurilemma. The finely granular substance surrounding these structures has been omitted. (Galcotti and Levi.)

The Interepithelial Arborizations.—This type of nerve-endings occurs in the skin and mucous membrane and consists

FIG. 35.



Pacinian corpuscle, from the mesentery of a cat. (Klein.)

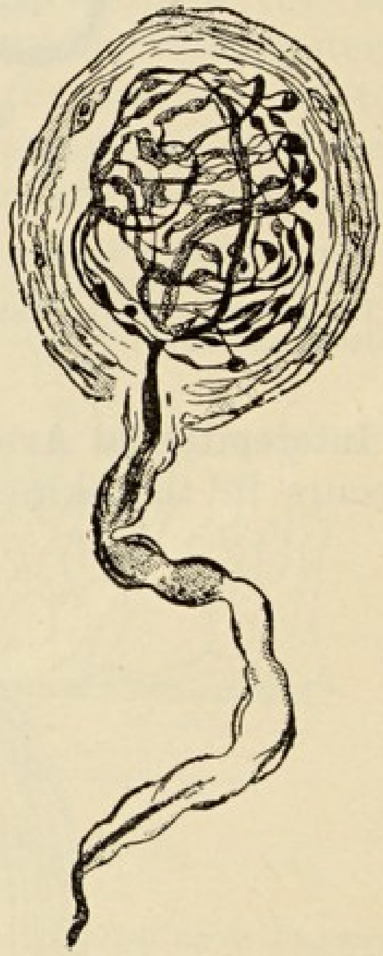
of minute ramifications of the axis-cylinder process passing between the epithelial cells and in their basement-membrane.

The Motor Plates in Muscles.—In voluntary muscles the medullated nerve-fibres lose their sheath, which blends with the sarcolemma when it reaches the muscle, and the axis-cylinder forms a network which lies embedded in a flattened

FIG. 36.

Tactile corpuscle of Wagner, from the human corium. (Böhm and Davidoff.)

FIG. 37.



Krause's corpuscle, from the human conjunctiva. (Dogiel.)

granular mass, with many nuclei, called the *sole* or *motor plate*.

The **special end-organs in sensory tissues** will later be described with the organs of special senses.

The **tactile corpuscles** are more or less encapsulated and embrace the corpuscles of Pacini, Meissner, and Krause, and are found in the epidermis of the skin.

The *Pacinian* or *Vater corpuscles* occur in the subcutaneous tissue, especially in the palms of the hands, soles of the feet, joints, mesentery, and genital organs. They are oval structures made up of concentric layers of fibrous tissue or capsules, containing lymph, and have a clear centre or core into which the axis-cylinder is blended. These corpuscles lie just under the skin in the connective tissue of the palms of the hands and soles of the feet, and are especially abundant in the fingers and toes.

The *corpuscles of Meissner* or *Wagner* are elliptical structures, and found especially in the hands and feet, being associated with the sense of touch. They consist of a group of epithelial cells into which the nerve-fibre is entwined. A thin nucleated connective-tissue capsule, containing a gelatinous inner sheath, surrounds these corpuscles. The nerves when entering the capsule lose their medullary sheath, and the naked axis-cylinder, after taking a spiral course, breaks up into many branches in the inner sheath.

The *corpuscles of Krause*, or *end-bulbs*, are found principally in the conjunctiva, and consist of a spherical structure with a delicate fibrous capsule covered with endothelial cells. The nerve-fibre enters into the formation of a core at the centre of the corpuscle.

QUESTIONS.

Name the three varieties of muscular tissue. From what layer are they derived?
What characterizes muscular tissue?
Describe the non-striated muscle.
Describe the striated muscle.
What is the sarcolemma?
What is the membrane of Krause?
What is the median line of Hensen?
Name the coverings of voluntary muscular fibres.
Describe cardiac muscle.
Name the differences between voluntary and cardiac muscle.
Of what is nerve-tissue composed? From what layer is it derived?
What is a neuron?
Describe a nerve-cell.
Name the kinds of nerve-fibres.
Describe a medullated nerve-fibre.
Describe a non-medullated nerve-fibre.
Name the coverings of nerve-trunks.
What is the neuroglia?
Describe ganglia.
How do nerves terminate?

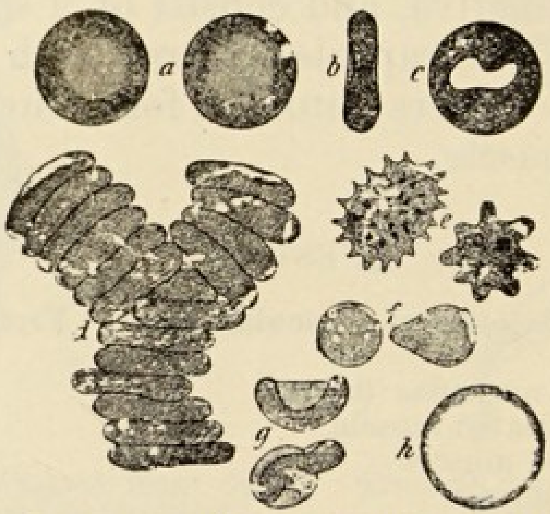
Describe interepithelial arborizations.
What are the motor plates?
Name the tactile corpuscles.
Describe Pacinian corpuscles.
Describe the corpuscles of Meissner.
Where are the end-bulbs of Krause found?
Describe these end-bulbs.

CHAPTER V.

THE CIRCULATORY SYSTEM.

THE circulatory system **consists of** a circulating medium, the *blood;* the *heart,* or pump to propel the blood; the *arteries,* which conduct the blood to the tissues; the *capillaries,* which distribute it through the tissues; and lastly the *veins,* which return the blood to the heart.

FIG. 38.



Red blood-corpuscles of man: *a,* surface view of normal corpuscles; *b,* edge view; *c,* corpuscle with its substance shrunken, forming a vacuole; *d,* rouleaux formation; *e,* crenated corpuscles; *f,* fragments of broken corpuscles; *g,* bent and distorted corpuscles; *h,* swollen and decolorized corpuscle. (Nichols and Vale.)

The **blood** may be classed as a tissue with cells and a fluid intercellular substance.

The cells are the *corpuscles* and the fluid intercellular substance is called the *plasma.*

Corpuscles.—These are the *red,* colored cell or erythrocyte; the *white,* colorless corpuscle or leucocyte; and to these may be added the *blood-platelets* or *plaques.*

The *erythrocytes*, or *red blood-corpuscles*, are non-nucleated, biconcave, circular disks with rounded edges. They seem, under the microscope to be of pale greenish-yellow color, but when many are seen together, as with the naked eye, they appear red. The number of red blood-corpuscles in a cubic millimeter of human blood is about five millions, and the average diameter is about $\frac{1}{3200}$ inch, while the thickness is about $\frac{1}{12000}$ inch. When the erythrocytes are seen in optical cross-section they are biscuit-shaped, and the flat surfaces are depressed in the centre, resembling in form a biconcave lens, while the borders are rounded and much thicker than the centre.

In fresh blood, when examined between slide and cover, the cells arrange themselves in rows, side by side, like piles of coins, which are called *rouleaux*.

When acted upon by reagents the red blood-corpuscles change their forms: in water or dilute acids they swell and lose their hæmoglobin and appear as *blood-shadows*, and in strong salt solution they undergo shrinkage and become crenated.

The red corpuscles are composed of a transparent framework or stroma, infiltrated with a coloring-matter called hæmoglobin, the substance which combines with oxygen and supplies the tissues with this gas, and which gives to the red cells and to thin layers of blood a straw-yellow tint.

The red blood-corpuscles of birds, reptiles, and fishes are oval and nucleated, while all mammals except the camel, whose are oval, have round non-nucleated red corpuscles.

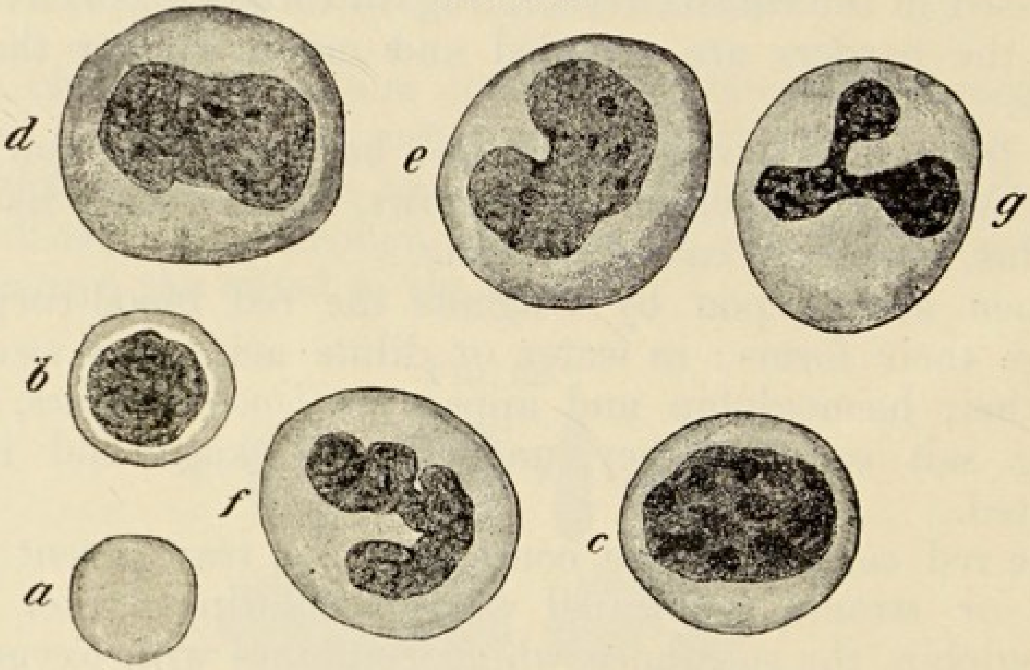
The *leucocytes*, or white blood-corpuscles, are granular cells possessing one or more nuclei, and resemble the amœbæ in appearance and action. They are in the proportion of one to about six hundred of the red, and average $\frac{1}{2500}$ inch in diameter. These corpuscles can squeeze themselves through the endothelial lining of the bloodvessels and make their way out among the tissues, a process called *migration* or *diapedesis*. There are similar cells found in the lymph, bone-marrow, adenoid tissue, and throughout connective tissue and epithelial tissue, in which latter they are called *wandering cells*.

According to their general form and the character of their nuclei leucocytes are *divided into* the following :

1. The polynuclear leucocytes ;
2. The small lymphocytes ;
3. The large lymphocytes ;
4. The eosinophiles ;
5. The basophiles.

The *polynuclear leucocytes* constitute about 72 per cent. of

FIG. 39.



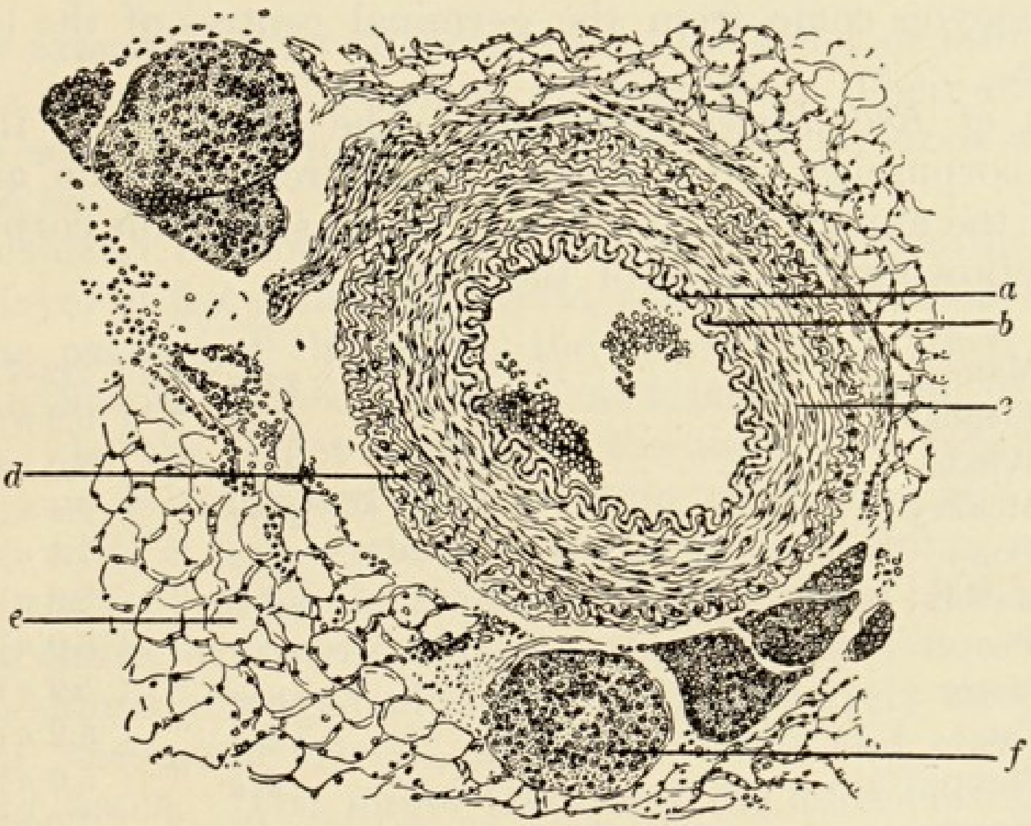
Leucocytes from normal human blood: *a*, red blood-corpuscle, introduced for comparison; *b*, small mononuclear leucocyte (lymphocyte); *c*, large mononuclear leucocyte; *g*, polynuclear leucocyte. These differ in the character of the granules they contain (not represented in the figure). In normal blood these granules are neutrophilic in the vast majority of the polynucleated leucocytes. Occasionally they are acidophilic, "esinophile leucocytes"; sometimes basophilic, "mast-cells" or "plasma-cells." *d, e, f*, intermediate and probably transitional forms between the large mononuclear leucocytes *c*, and the polynucleated leucocytes, or leucocytes with polymorphic nuclei, *g*. (Böhm and Davidoff.)

the total number of leucocytes, and have a large irregular nucleus, often resembling two nuclei connected, contain fine granules which stain especially with neutral anilin dyes, and possess the power of amœboid movements. These cells are found as *wandering cells* everywhere in the tissues, and are especially abundant in inflammatory processes, where they are the main constituent of the exudate and later of the pus. They are supposed to digest bacteria, a process called *phagocytosis*.

The *small lymphocytes* have a single round nucleus in a clear cytoplasm. They are the smallest, and form about 20 per cent. of the white cells. Their nucleus contains much chromatin arranged in areas, called *checker-board nucleus*, and is large in proportion to the size of the cell.

The *large lymphocytes* make up about 6 per cent., and are larger than the preceding, have oval nucleus and clear cytoplasm.

FIG. 40.



Cross-section of artery: *a*, endothelial lining; *b*, internal elastic lamina; *c*, tunica media; *d*, tunica adventitia; *e*, adipose tissue; *f*, small nerve. (Dunham.)

The *eosinophiles* are large cells with several irregular nuclei and large granules which stain especially well with the acid dye eosin. They constitute about 2 per cent. of the leucocytes.

The *basophiles* are sometimes called mast-cells, or plasma-cells, and are quite rare. They stain only with the basic anilin colors.

Blood-plaques or platelets are round or oval, colorless, and about one-fourth the size of red corpuscles. They probably have something to do with the liberation of fibrin.

Origin of the Red Corpuscles.—These are primarily derived from the mesoderm, at first possess nuclei, have no hæmoglobin, and are called *erythroblasts.* In embryonic life the formation of erythrocytes takes place in the liver, lymph-glands, and spleen. Later they are mostly produced in the red bone-marrow.

Origin of the White Corpuscles.—These owe their origin principally to the spleen and the lymphoid tissues. Some authors believe that the polynuclear leucocytes are derived from the myelocytes of the bone-marrow, and that the lymphocytes come from the germinal centres of the lymph-glands.

Size of Red Blood-Corpuscles.—The diameter of the red blood-corpuscles varies greatly in different animals, and the size of the animal has no relation to the size of the corpuscles. The following is a table of the diameters :

Man	$\frac{1}{3200}$	inch	(7.2–7.8 μ)
Elephant	$\frac{1}{2745}$	"	(9.2 μ)
Whale	$\frac{1}{3125}$	"	(8.0 μ)
Monkey	$\frac{1}{3378}$	"	(7.4 μ)
Dog	$\frac{1}{3300}$	"	(7.1 μ)
Rabbit	$\frac{1}{3511}$	"	(7.0 μ)
Pig	$\frac{1}{4166}$	"	(6.0 μ)
Horse	$\frac{1}{4600}$	"	(5.9 μ)
Cat	$\frac{1}{4000}$	"	(6.2 μ)
Sheep	$\frac{1}{5000}$	"	(5.0 μ)
Mouse	$\frac{1}{3511}$	"	(7.0 μ)
Guinea-pig	$\frac{1}{3300}$	"	(7.1 μ)
Goat	$\frac{1}{6250}$	"	(4.0 μ)
Pigeon	$\frac{1}{2317}$	"	(9.5 μ)
Camel	$\frac{1}{3123}$	"	(7.6 μ)
Snake	$\frac{1}{1274}$	"	(19.6 μ)
Bear	$\frac{1}{3511}$	"	(7.0 μ)
Ox	$\frac{1}{5208}$	"	(4.8 μ)
Deer	$\frac{1}{12325}$	"	(2.4 μ)
Toad	$\frac{1}{1043}$	"	(23.9 μ)

The **capillaries** are the smallest vessels, and establish the communication between the arteries and veins. They consist of a single layer of endothelial cells, with little openings between the cells, called the *stigmata,* through which the leucocytes are supposed to pass by diapedesis.

The **precapillary arteries** are composed of only a thin sheath of connective tissue surrounding an endothelial tube. As they approach the larger vessels and heart the coats are thickened and a layer of smooth muscular tissue is arranged circularly around the connective tissue covering the endothelial tube. In these vessels the muscle-cell nuclei are seen to run at right angles to the nuclei of the endothelial cells.

The **arteries** consist of three coats—the inner or *intima,* the middle or *media,* and the outer or *adventitia.* Their structure varies somewhat as to size. Only the medium-sized arteries will be described.

The *intima,* or inner coat, is made up of three parts, the innermost layer of flat endothelial cells, affording a smooth surface for the passage of the blood, the subendothelial layer of a delicate fibrous connective tissue, and, lastly, a band of elastic tissue. In the larger arteries, as the aorta, this subendothelial tissue is composed of a stratum of fibrous and elastic tissue, with a few connective-tissue cells, making a thick layer which is called the *fenestrated membrane of Henle.*

The *media,* or middle coat, is a thick layer of non-striated muscle-fibres arranged circularly or transversely under control of vasomotor nerves, and some white and elastic connective tissue. The larger the artery the more elastic fibres and less muscle. In some arteries the muscle-fibres are arranged longitudinally, as in the subclavian.

The *adventitia,* or outer coat, consists of a fibrous and elastic tissue, between the bundles of which are scattered connective-tissue cells. This coat is the one which gives strength to the artery. In the larger arteries it also contains the small vessels which supply the walls of the vessels, called the *vasa vasorum,* and a few lymphatics.

The **veins** have the same coats as the arteries, except that they have thinner walls, less muscular and elastic tissue, and more of the fibrous element in proportion. Many of the veins have *valves*, made up of the inner coat of the vessels, strengthened by fibrous and elastic tissue.

The **heart** consists of three layers—the endocardium, the muscular tissue, and the pericardium.

The *endocardium* is a continuation of the inner lining of the bloodvessels and similar in structure. The valves of the heart are folds or reduplications of the endocardium, strengthened by bands of fibrous and elastic tissue.

The *myocardium* is composed of typical cardiac muscle and forms the main part of the heart, and is thickest in the wall of the left ventricle. The arrangement of the muscle-fibres in the heart is very complex, and consists of several bands of muscle with tendons at each end, rolled up like a scroll. There is a rich network of capillaries in the heart muscle.

The *pericardium* is the serofibrinous sac which covers the heart, and is lined with flat endothelial cells with a dense fibroëlastic connective tissue beneath. The heart is richly supplied with lymphatics and nerves.

QUESTIONS.

Name the parts composing the circulatory system.
Of what is the blood composed?
Name the kinds of blood-cells.
Describe the red corpuscles.
What are rouleaux?
What is the coloring-matter of the blood?
What is the difference between the red corpuscles of birds and those of mammals?
Describe a leucocyte.
Name the kinds of leucocytes.
Describe the polynuclear leucocytes; the small lymphocytes; the large lymphocytes; the eosinophiles; and the basophiles.
What are blood-plaques?
What is the origin of the red corpuscles?
Name the coats of the arteries.
Describe the inner coat; the middle; and the outer.
What are capillaries?
How do veins differ from arteries in structure?
Describe the construction of the valves.
Name the structures of the heart.
Describe the endocardium.
Describe the pericardium.

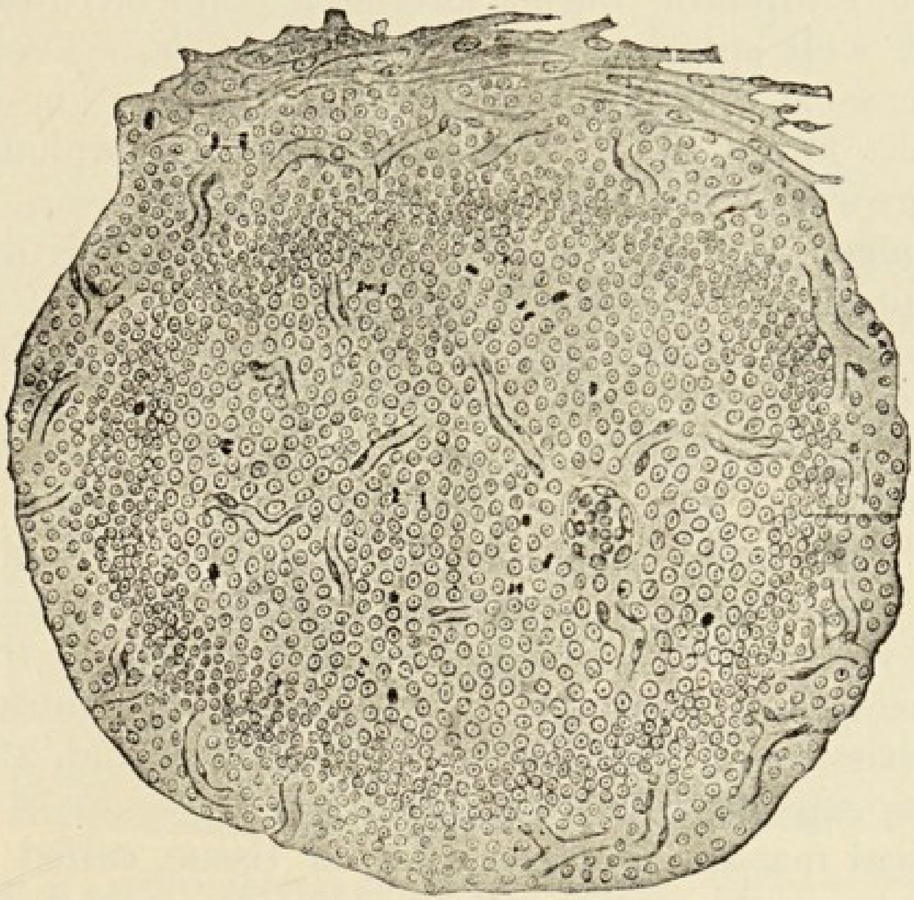
CHAPTER VI.

THE LYMPHATIC SYSTEM.

THE lymphatic system **consists of** a circulating medium, the lymph, its vessels, and the lymphatic tissues, which comprise the diffuse adenoid tissue, the simple lymphatic nodules, and the compound lymphatic glands, as the spleen, the thymus body, and the tonsils.

The **lymph** is a colorless fluid composed of two parts, the cells and the plasma.

FIG. 41.



Lymph-follicle. (Flemming.)

The cells are similar to the leucocytes of the blood, the small lymphocytes predominating.

In the plasma are many fatty granules, and they are most abundant in the lacteals, which absorb the products of digestion and in which it is called the *chyle*.

Lymph-vessels are very similar to the blood-capillaries and veins, having a lining of endothelium, and in the larger vessels muscular and fibrous outer coats.

The **lymph-capillaries** are not, like the blood-capillaries, intermediate structures between the two systems, but they form the lymphatic system which empties into the vascular system.

Lymphoid or **adenoid tissue** is a delicate connective-tissue reticulum containing the small round lymphoid cells and communicating with the lymphatic vessels.

Diffuse adenoid tissue occurs in the mucosæ of the digestive and respiratory tracts.

The *simple lymphatic nodules* or *follicles* consist of spherical masses of lymphatic tissue, having a connective-tissue capsule and well supplied with lymph-vessels. The tissue is most dense at the periphery of the gland. These lymph-glands are found along the course of the lymphatic vessels and are grouped together in the neck, axilla, groin, etc.

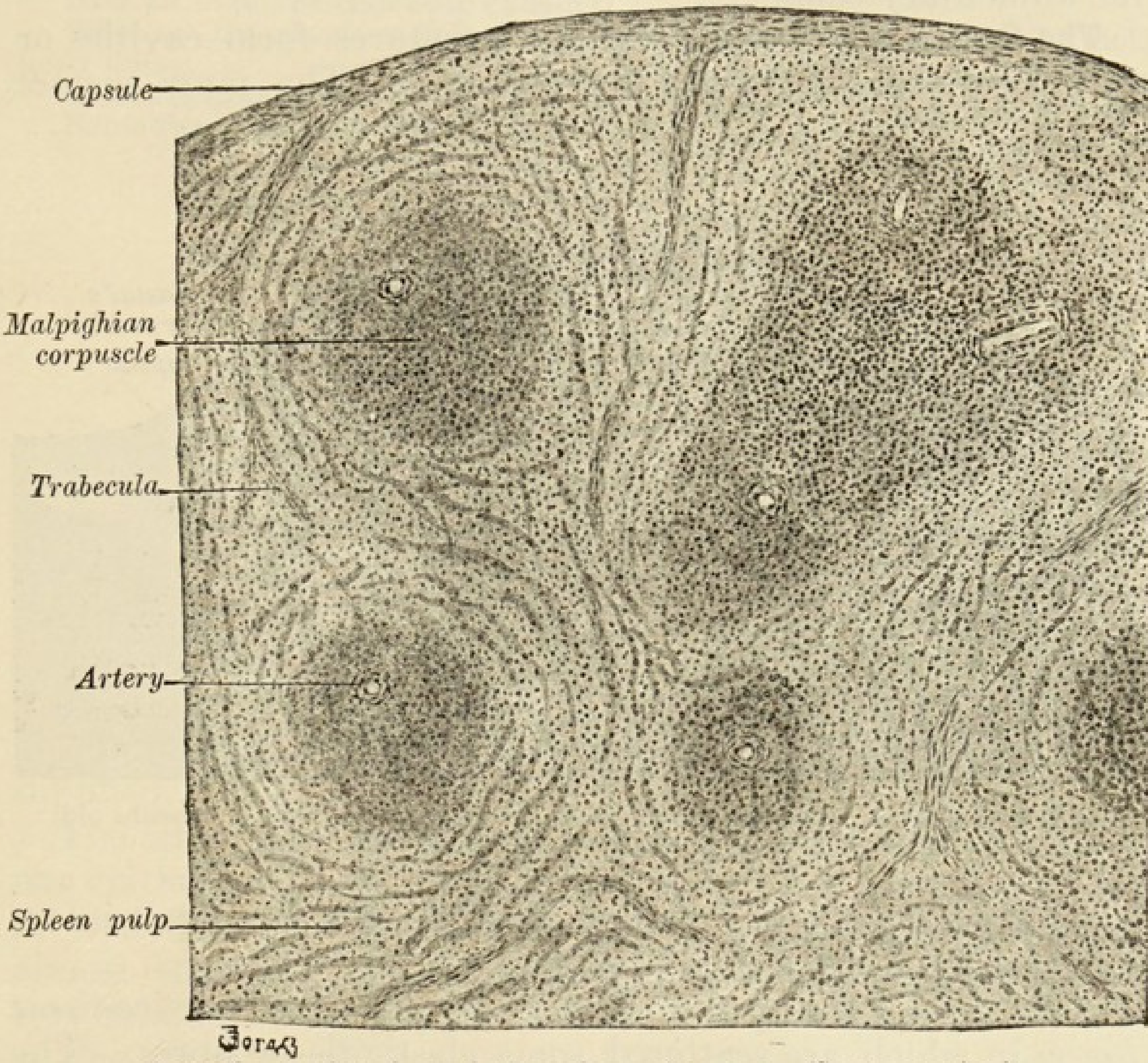
The **spleen** is a compound lymphatic gland with a special blood-supply opening into its reticular spaces.

This organ is often called a ductless gland, as it differs from most of the glands of the body in not having an excretory channel. The gland or organ is covered with a dense capsule, of an outer serous and an inner fibroëlastic coat, from which fibrous bands or trabeculæ are given off, which penetrate the lymphatic tissue or splenic pulp, as it is called.

These trabeculæ constitute the framework of the spleen. This capsule also contains a few non-striated muscle-fibres. The arteries enter the organ at the hilum, and, after penetrating its capsule, follow the trabeculæ.

Spherical masses of dense adenoid tissue, called the *Malpighian corpuscles*, appear throughout the gland, and these ensheath the arteries. The arteries lack the characteristic arrangements seen in other organs, and the blood appears to be emptied into the pulpy structure to be changed or regenerated, and then filtered into the veins of the spleen. The circulation in the spleen is best considered together with the so-called *lobule* (Mall). The spleen is thus divided into sacs, each containing a spleen-lobule. The Malpighian corpuscle is situated at the end of the lobule farthest from the capsule. An artery in the centre of the lobule branches and supplies the compartments formed by the intralobular trabeculæ, and the blood is then collected by the intralobular vein.

FIG. 42.



Part of a section through the spleen of an ape. (Szymonowicz.)

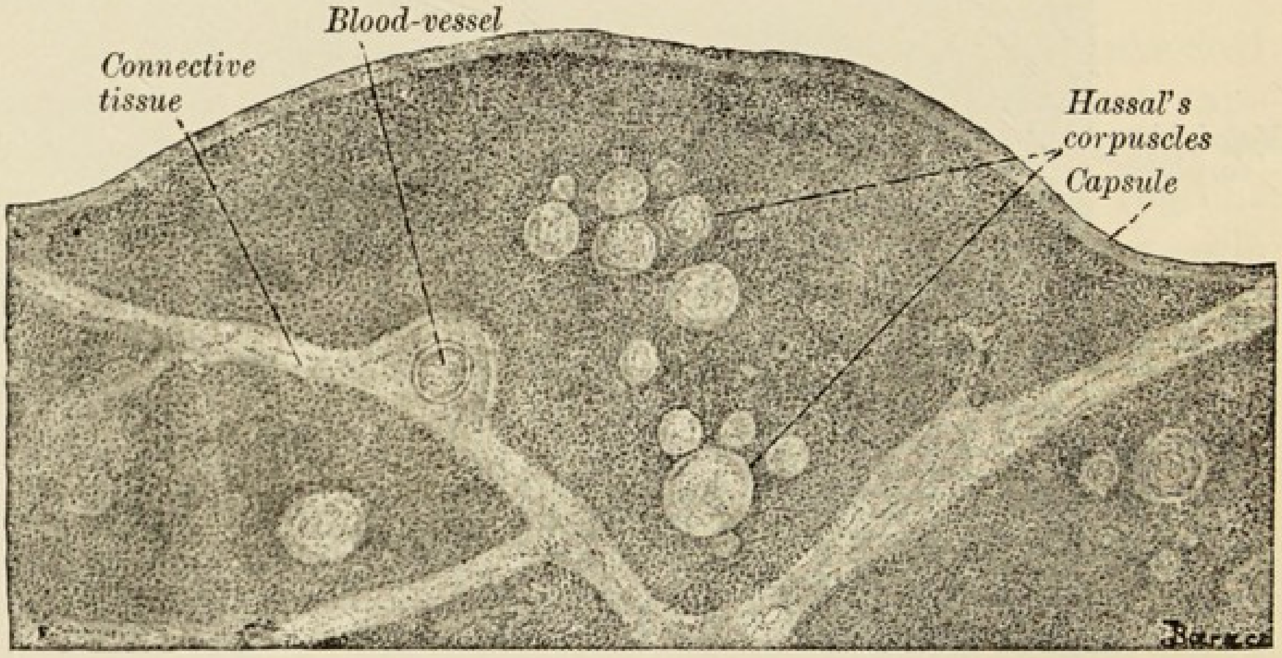
The **thymus body** is a gland of the neck, which in its earliest stages is composed of epithelium, but later is surrounded by lymphoid cells, crowding aside the epithelium, and finally in adult life disappears.

This gland is enveloped in its mature state by a capsule of fibrous tissue sending trabeculæ into its cortical portion, thus dividing this part into lobules. The medulla is a less dense lymphatic reticulum, free from the fibrous trabeculæ, and contains the *corpuscles of Hassall*, which are small spherical bodies of epithelial cells, the remains of the original epithelial structures.

The Tonsils.—These will be described in connection with the alimentary canal.

The Serous Membranes.—These structures form cavities or sacs closely related to the lymph-tracts. The *inner surface*

FIG. 43.



Section through a secondary lobule of the thymus of a child six months old. (Szymonowicz.)

consists of a single layer of endothelial cells, having at intervals small openings called *stomata*.

This layer rests upon an interlacing *fibrous connective-tissue layer*, in which are scattered some elastic tissue fibres. The principal serous membranes are the peritoneum, pleura, pericardium, tunica vaginalis, synovial membranes of joints, tendons, and bursa.

QUESTIONS.

Of what does the lymphatic system consist?
What is lymph? Chyle?
Describe adenoid tissue.
Where do we find diffuse adenoid tissue?
Describe a lymphatic follicle.

What kind of gland is the spleen structurally considered? Describe its capsule.

What are the trabeculæ?

What is the course of the bloodvessels?

Describe the Malpighian corpuscles.

What is the thymus body? Of what is it composed in its early state?

Describe the gland in its mature state. Where is it most dense?

What are the corpuscles of Hassall?

How far in do the trabeculæ extend?

What are the serous membranes structurally considered? Describe their inner lining.

What are stomata?

Name the principal serous cavities.

CHAPTER VII.

THE DIGESTIVE ORGANS.

THESE **consist of** the mouth, salivary glands, teeth, œsophagus, large and small intestine, liver, and pancreas. They are mostly hollow or tubular organs, lined with epithelium of either the mucous or glandular type, each having a different function to perform. The function as a whole is the preparation of the food and digestion of the same—that is, preparing it in such a condition so as to be absorbed or taken up by the bloodvessels and lymphatics with which this system is well supplied.

The **mucous membranes** are made up of squamous or columnar epithelium, with a submucous layer of fibrous tissue, and in this layer are found the glands. These glands consist almost entirely of epithelial tissue, which possesses a secretory function.

The cavities or passages which communicate with the exterior are all lined with mucous membrane.

The **glands** are divided into the tubular, which may be simple or compound, and into the saccular, which are either simple or compound.

The *simple tubular glands* are those of the mucous follicles of the intestine and the peptic glands of the stomach. They consist of a single tube lined with glandular epithelium derived from the cells covering the mucous membrane of stomach and intestine adjacent to the gland, and extend down into the submucous layer.

These tubular glands vary from straight cylindrical tubes to those having a tortuous course, often forming the so-called coiled glands, examples of the same being the sweat-glands.

Compound tubular glands consist of several tubes emptying their contents into one mouth or duct, and are found in the pyloric end of the stomach.

Simple saccular or *alveolar glands* are spherical cavities lined with epithelium, and communicating with the surface by a duct. They are best represented by the smallest sebaceous glands, otherwise they are rare in the human subject, but found often in other mammals of lower type.

Compound saccular or *racemose glands* are made up of a number of sac-like cavities connected, but not communicating with each other, and all opening into a common excretory duct.

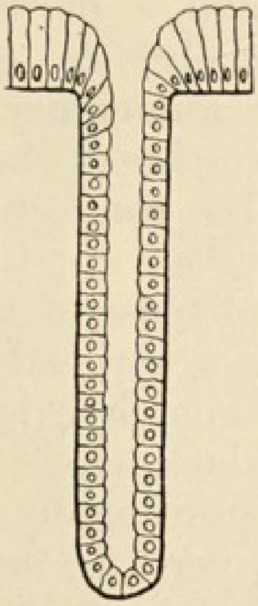
They resemble bunches of grapes, and when the glands are large are divided into groups, these groups forming lobes and lobules. Each lobule has its duct, into which all the saccules forming it empty. Ducts from numerous lobules come together, forming a still larger duct, and these ducts finally empty into a common duct. These glands are best typified in the lungs.

The glands are all richly supplied with bloodvessels, which divide into fine capillaries and surround the tubuli or alveoli. The blood carries with it the materials used in the formation of the secretion, and is only separated from the lumen of the gland by the secreting cells lining the glands.

The **mouth** is lined with stratified squamous epithelium, beneath which is a layer of connective tissue containing some elastic fibres. This layer is called the *tunica propria*, and is covered with numerous papillæ varying in size, the largest being those found on the lips. Beneath this is the submucosa, which is a layer of areolar connective tissue loosely attached, except at certain points, where it is in intimate contact with the periosteum of the bones. This layer contains very numerous racemose glands which secrete mucus.

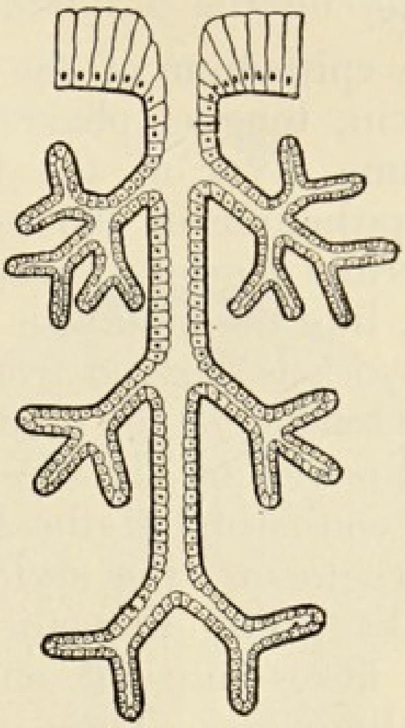
Two plexuses of bloodvessels run parallel to the surface: the deeper, made up of larger vessels, is situated in the sub-

FIG. 44.



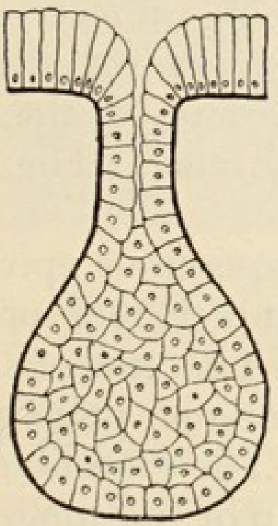
Simple tubular gland.

FIG. 45.



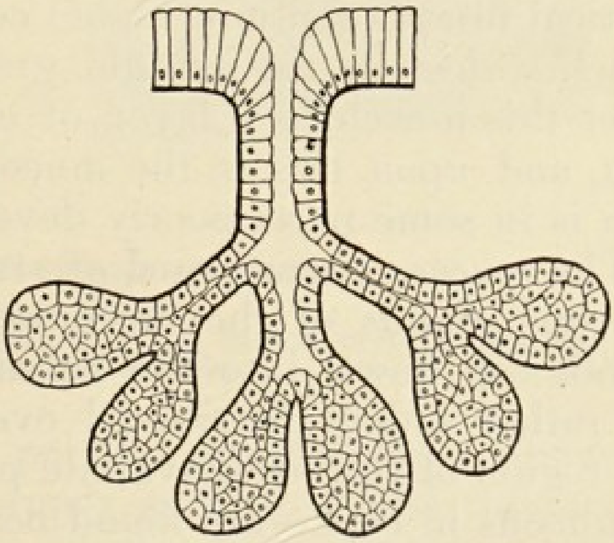
Compound tubular gland.

FIG. 46.



Simple saccular gland.

FIG. 47.



Compound or racemose saccular gland.

Morphologic types of secretory glands, diagrammatically represented. (Dunham.)

mucosa; while the upper, in the tunica propria, consists of a fine meshwork of small vessels. These latter capillaries end in the papillæ, where they form a plexus.

The lymph-vessels are arranged somewhat similarly to the bloodvessels.

The nerves in the papillæ are *Krause's end-bulbs*, while those in the epithelium terminate as fine intraëpithelial nerve-endings.

The epithelium of the mouth is continuous with that of the skin, tongue, pharynx, and nose, and is derived from the same layer of the blastoderm, namely, the ectoderm. The epithelium of the remainder of the alimentary tract is entodermic in origin, except the lower two inches of the rectum, which, like the mouth, is ectodermic. The connective-tissue framework is derived from the mesoderm.

The **tongue** is the organ of the special sense of taste. It is composed of bundles of voluntary or striated muscle-fibres, consisting of the hyoglossus, the geniohyoglossus, the chondroglossus, the styloglossus, the palatoglossus, and the lingualis. The lingualis is divided according to direction of its fibres into the superior, inferior, vertical, and transverse lingualis. These muscle-fibres are arranged in three planes, namely, vertical, transverse, and longitudinal, and separated into equal lateral halves in the median line by a vertical fibrous septum (raphé) composed of connective tissue, which widest in the middle, gradually slopes on either side. Over this muscle is a layer of connective tissue, the *submucosa*, and upon this is the mucous membrane. The submucosa is in some parts poorly developed.

The *mucosa* is composed of stratified squamous epithelium. Mucous glands of the racemose type and Ebner or serous glands dip down into the submucosa. The mucous glands are rather widely distributed over the tongue, principally in the region of the circumvallate papillæ. The glands of Huhn —mucous in type—are found near the tip of the tongue, inferiorly.

The serous glands are found only in the back part of the tongue; their watery secretion, being discharged in the neighborhood of the circumvallate papillæ, is claimed by some to be for the purpose of assisting in dissolving the substances to be tasted.

The mucous membrane is thin on the inner surface, but gradually thickens as it reaches the dorsum, where it is thrown into folds or papillæ by the elevations of the submucosa. These papillæ are divided into the filiform or papillæ minimæ, the fungiform or papillæ mediæ, and the circumvallate or papillæ maximæ.

FIG. 48.

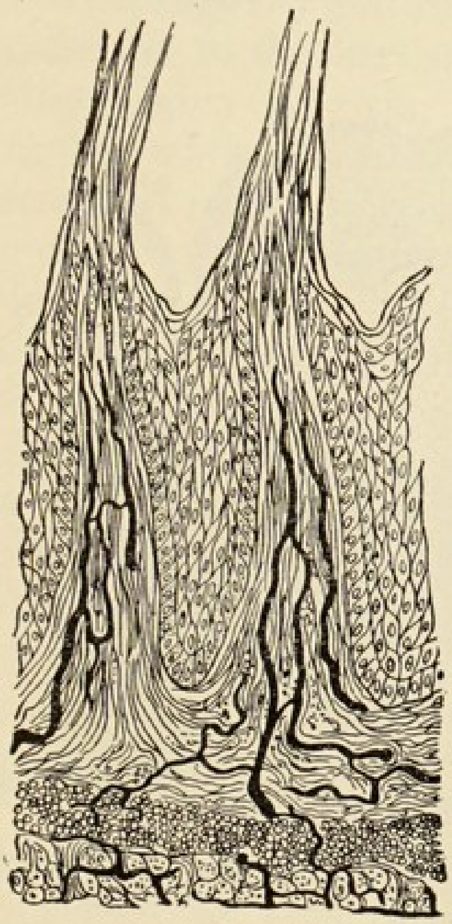
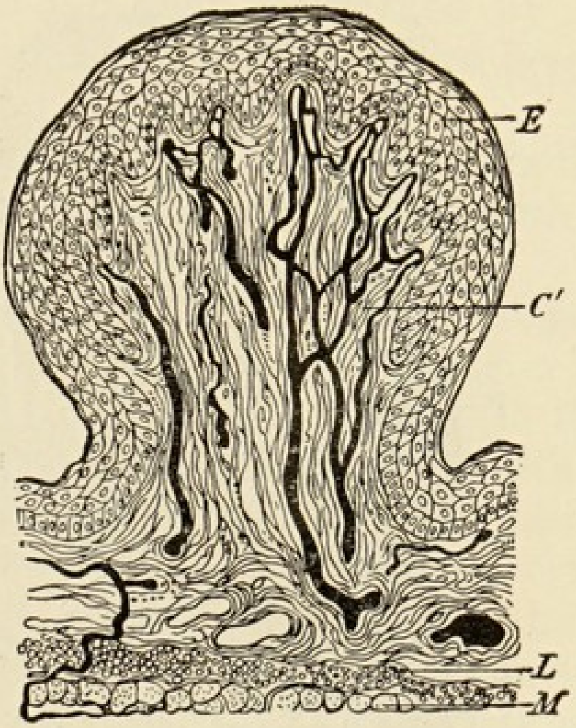


FIG. 49.



Papillæ of human tongue. (Heitzmann.)

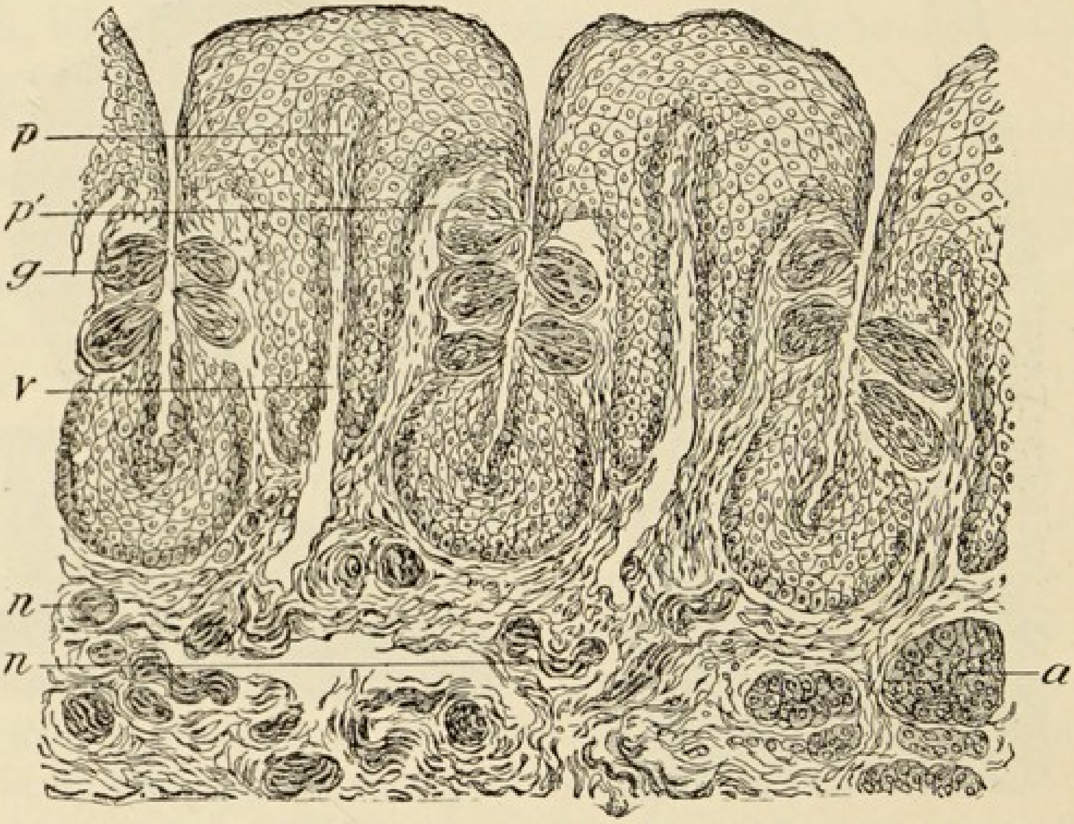
FIG. 48.—Filiform papillæ.

FIG. 49.—Fungiform papilla: *E*, epithelium; *C*, tunica propria, showing capillaries; *L*, lymphoid tissue; *M*, muscle.

The *filiform* or *conical* papillæ are the most numerous, found in all parts of the upper surface of the tongue, and consist of conical processes of the tunica propria covered with a thick layer of stratified squamous epithelium, the cells at the apex presenting a dead or horny appearance. The apex of these papillæ is branched, giving a brush-like appearance, some elastic fibres being present to make them more firm.

The *fungiform* papillæ are less numerous, found on all parts of the upper surface of the tongue, chiefly at the apex and sides. They are lower and broader than the filiform, having a rounded apex covered with secondary projections and attached to the surface by a constricted base. The epithelial covering does not, as in the filiform, become cornified, nor is it quite so thick, but with a rich blood-supply immediately beneath the thin epithelium they are distinguished by their

FIG. 50.



Circumvallate papillæ of rabbit: *p*, fibrous core of papilla; *g*, taste-buds; *n*, nerves; *a*, gland of Ebner. (Ranvier.)

red color, and by their outline, which resembles a mushroom, whence their name is derived.

The *circumvallate* papillæ are eight to ten in number, situated at the base of the tongue, being arranged in a V-shaped fashion just anterior to the foramen cæcum. They resemble the fungiform except that they are larger, are constricted at their base, and more flat on top, lying in a cup-shaped depression in the mucous membrane; the mucous membrane forming a sort of ridge or wall around them. On the side-walls of these papillæ are found the end-apparatus of the nerves of taste, the so-called *taste-buds*.

Taste-buds, or the organs of the special sense of taste, are found within the epithelium on the sides of the circumvallate papillæ and also on the sides of the furrows between the papillæ. At times they are found in the fungiform papillæ as well as in the epiglottis and soft palate. These are oval bodies reaching the entire thickness of the epithelium and perpendicular to the surface. Their base being widest, rests upon the tunica propria, while the apex is marked by an opening known as the *taste-pore*. They consist of two layers of specialized epithelial cells.

The outer or overlapping layer of long flattened epithelial cells, known as the cortical cells, have a pointed apex with a centrally placed nucleus in clear protoplasm.

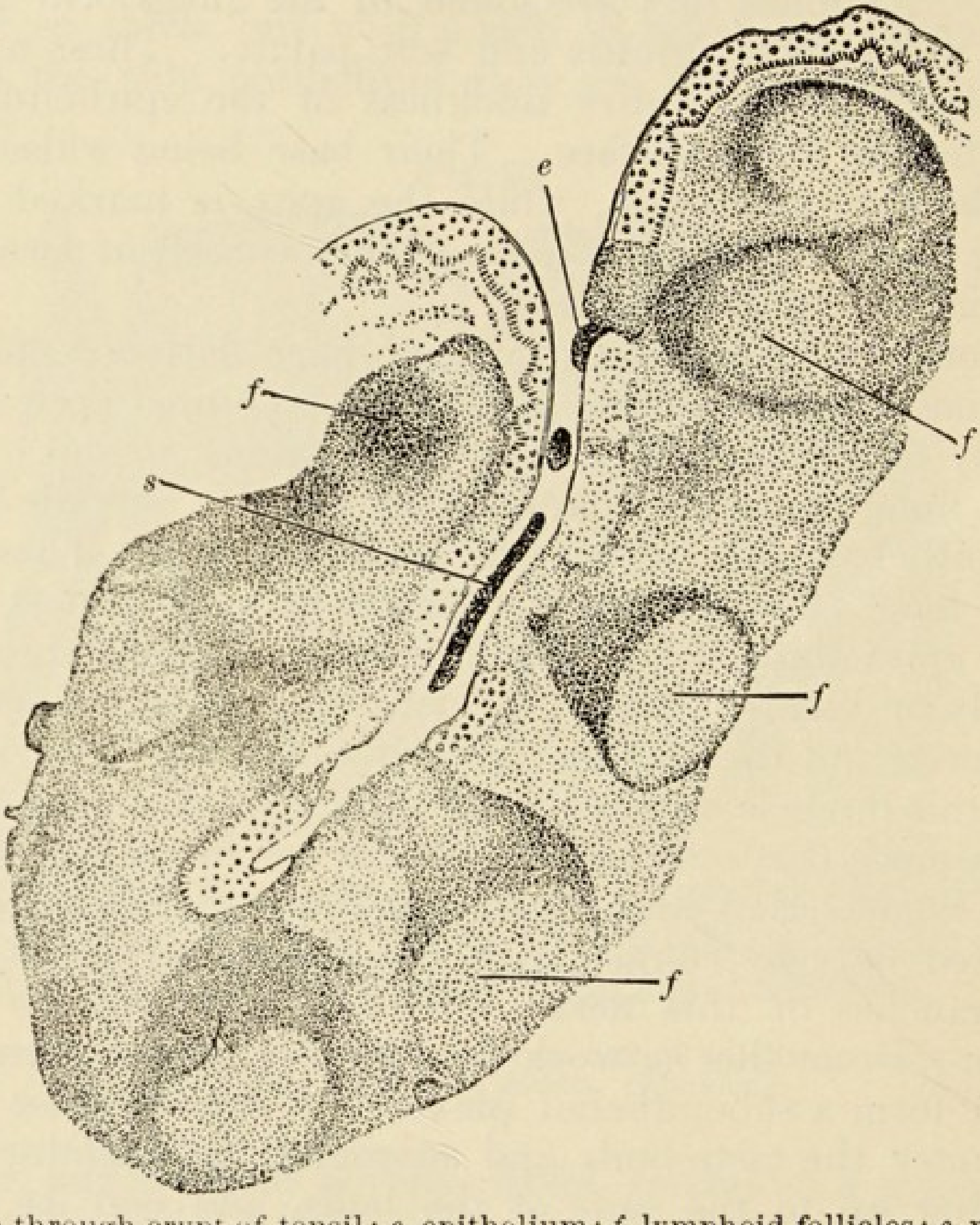
The inner layer is composed of slender spindle-shaped neuroëpithelial cells, called the *gustatory cells*. These cells end in long, hair-like processes which project almost to the surface epithelium of the papillæ. They have a large either centrally or basally situated nucleus in granular protoplasm. Whether or not the terminal branches of the gustatory nerve end in this inner layer of cells is still *sub judice*, some authorities claiming that only sensory nerves are found in the taste-buds. Some recent authors state that the gustatory cells are connected only by contact with the glossopharyngeal nerve. The branches of this nerve form a network in the tunica propria. From this network fine bundles of fibres are given off and form a subepithelial plexus. A few of these nerve-fibres enter the taste-buds and surround the gustatory cells, extending up to the pore of the buds, and end as minute swellings on the gustatory cells.

The tongue is richly supplied with bloodvessels; the larger vessels enter the submucosa and there form plexuses, branches from which reach up into the summit of the papillæ.

The *lymphatics* are also numerous and arranged as a plexus in the submucosa, communicating with those from the bases of the papillæ.

The *nerves* of the mucous membrane are of two kinds, common sensory and special sensory of taste; namely, the lingual branches of the trifacial and of the glossopharyngeal, motion being supplied by the hypoglossal. Sympathetic filaments also enter on some of the bloodvessels.

Fig. 51.



Section through crypt of tonsil: *e*, epithelium; *f*, lymphoid follicles; *s*, material within the crypt, composed partly of escaped lymphoid cells. (Stöhr.)

Tonsils.—The adenoid tissue around the borders of the mouth-cavity is arranged in a group, the *lymphatic pharyngeal ring* (Waldeyer), and comprises the lingual, pharyngeal, and palatine tonsils.

These *palatine tonsils* are the largest and the most important, and are two compound lymphatic glands situated between the pillars of the fauces. They are made up of a number of lymph-follicles surrounded on the attached surface by a fibrous capsule, and on the outer or exposed side by stratified squamous epithelium, the same being a continuation of the mucosa of the mouth.

The *mucous membrane* dips down into the lymphatic tissue and forms follicles or crypts lined with the same stratified squamous and infiltrated by lymphoid cells; no line of demarcation between epithelial and adenoid tissue being present.

The *pharyngeal tonsils* have their crypts lined with ciliated epithelium, and it is these which on hypertrophy form the so-called adenoids of children.

The tonsils, like the tongue, are well supplied with *blood-vessels* and *lymphatics.*

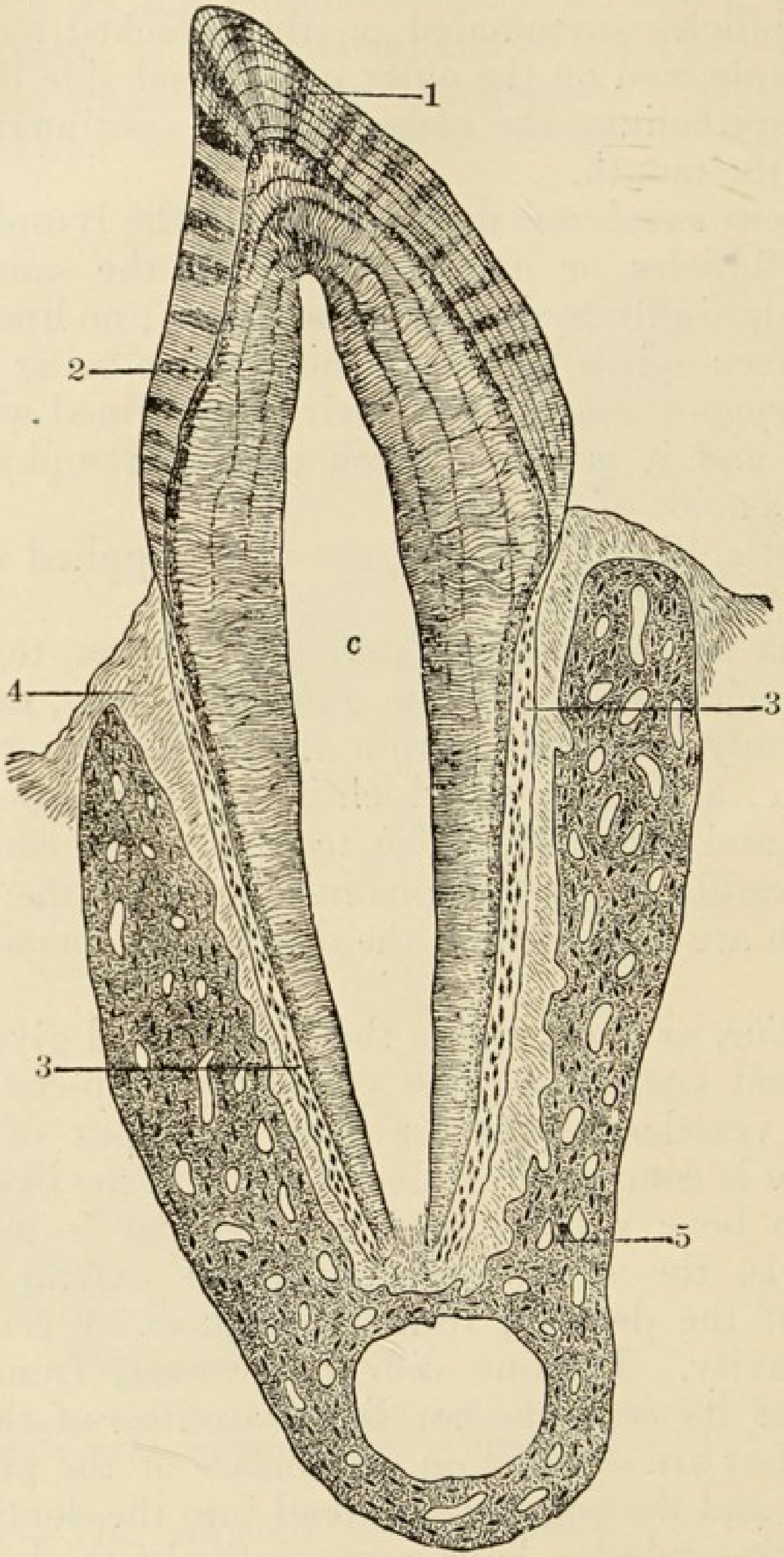
The **teeth** consist of three parts: the *crown,* that part exposed or projecting above the gum; the *fang,* that portion which is firmly implanted within the alveolus and is covered by the gum; and the *neck,* which is the constriction between the crown and the fang. The teeth may be considered as hardened papillæ of the mucous membrane of the mouth.

The teeth are composed of the *dentine,* the *enamel,* and the *cementum.*

The *dentine,* or *ivory,* forms the bulk of and gives shape to the tooth and encloses a space called the pulp-cavity, except where the vessels and nerves enter the apex of the fang. The dentine is composed of a connective-tissue basis impregnated as in bone with lime salts; dentine is made up of small canals, the *dentine-tubules,* which extend the entire thickness of the dentine, from the enamel or cementum to the pulp-cavity. Dentine differs, however, from ordinary bone in that its cells do not lie in cavities of the ground-substance, but are situated on the surface of the pulp next to the dentine and the cell-fibres extend into the dentine.

The dentine-tubules have comparatively thick walls, are wavy in course, and parallel to each other. Small branches or ramifications are given off whereby they communicate with each other. Each tubule contains cylindrical processes from the cells of the pulp-tissue, known as the *dentinal fibres.* The

FIG 52.

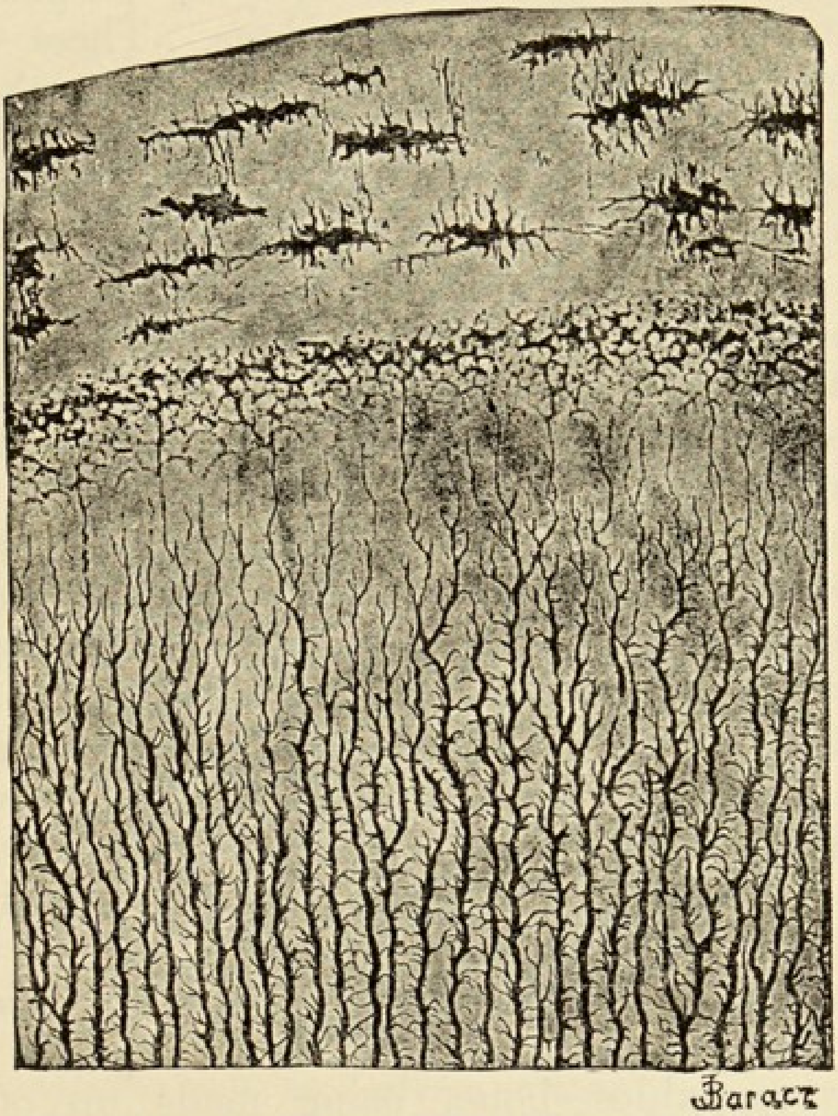


Section of tooth *in situ:* 1, enamel; 2, dentine; 3, crusta petrosa; 4, periodontal membrane; 5, maxillary bone; *c*, pulp-cavity. (Waldeyer.)

dense portion of the dentine matrix surrounding the tubules is especially resistant to acids, and is called the *dentinal sheath* or intertubular tissue. This intertubular tissue is translucent and contains the greater part of the phosphate and carbonate of calcium which go to make up the dentine.

Along the periphery of the dentine many star-shaped spaces are found which communicate with the tubules. They are

FIG. 53.



Part of a cross-section through a human incisor tooth in the region of the root. × 360. (Szymonowicz.)

the result of failure of calcification, and are known as the *dentinal lacunæ* or interglobular spaces. The *lines of Salter* are irregular concentric lines due to imperfect calcification, while the *lines of Shreger* are due to the curvature of the dentinal tubules. Between the dentine and the enamel there is found a layer of irregular *interglobular spaces*. Similar spaces, but smaller, are found between the cementum and the dentine ; these latter being called *Tomes' granular layer*.

The *pulp*, which occupies the cavity surrounded by the dentine, consists of a matrix of immature connective tissue with many stellate and spindle cells, nerves, and bloodvessels. Where the pulp comes into contact with the dentine are layers of elongated connective-tissue cells, lying perpendicular to the dentine and known as *odontoblasts*. These cells send processes into the dentinal tubules, known as the dentinal fibres.

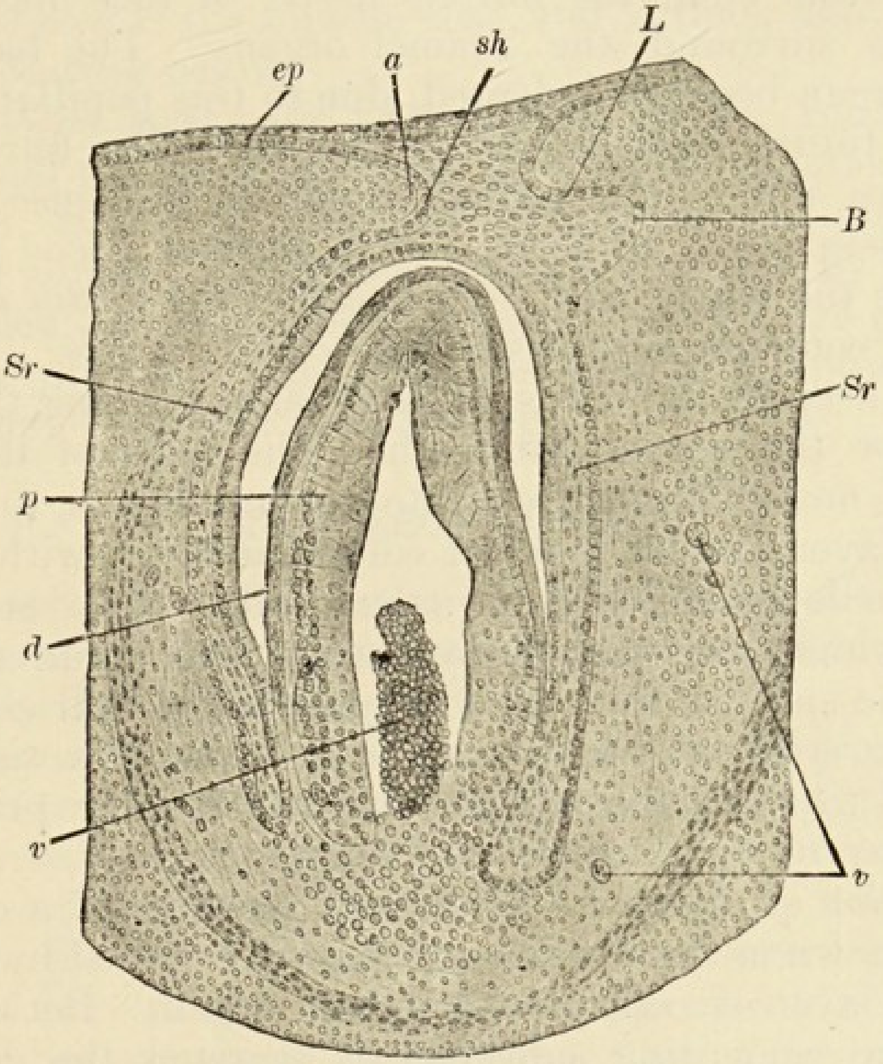
The bloodvessels and nerves supplying the pulp break up to form plexuses which are found under the odontoblasts. The *nerves* enter the pulp-cavity and pass up through its centre, with numerous branches running toward the periphery, and lose their medullary sheath as they pass up among the odontoblasts, ending as small swellings between the dentine and these cells.

The *enamel* is formed of a number of six-sided prisms, composed of a very dense, hard substance containing little organic matter. These columns or prisms are not straight, but present wavy borders, run through the entire thickness of the enamel, and are held together by a delicate layer of cement. A delicate but resistant membrane, known as the enamel cuticle or *membrane of Nasmyth*, which is the remains of the enamel organ, covers the external surface of the enamel, and remains for a short time after birth.

The *cementum*, or *crusta petrosa*, surrounds the fang of the tooth from the end of the enamel to the apex of the fang, and closely resembles bone, being made up of parallel lamellæ or layers of bone-tissue containing lacunæ. Haversian canals are very rarely found. This cementum is in direct contact with a vascular fibrous structure similar to the periosteum of bone, called the *periodontal membrane*, of which it is the product. Unlike the pulp, the dentine is a tissue entirely free from bloodvessels and nerves. The cementum is non-vascular, and the enamel may be considered as a dead substance which needs no nourishment.

Development of the Teeth.—The enamel of the teeth is derived from the epithelium of the mouth and is ectodermic in origin, while the dentine, dental pulp, cementum, and pericementum are of the connective-tissue type and are mesodermic. Morphologically the teeth represent papillæ of the mucous membrane.

FIG. 54.



Section of developing tooth, from embryo of rabbit: *ep*, epithelium of gum; *sh*, epithelial cells forming outer layer of the enamel-pulp of the temporary tooth; *L*, similar layer belonging to the rudiment of the permanent tooth; *Sr*, enamel-pulp; *p*, dental pulp of the tooth-cavity; *d*, dentine; *v*, bloodvessels; *B*, rudiment of second or permanent tooth; *a*, embryonic connective tissue of the alveolar process. (Freund.)

About the seventh week of embryonal life a thickening of the epithelium covering the jaw occurs due to activity of the germinal epithelial layer. This thickening forms not only an elevation of the mucous membrane, but also sinks down into the submucosa. The ridge thus formed is known as the *dental ridge.* From the inner side of this ridge epithelial cords or *dental bulbs* arise which will form the temporary teeth. These bulbs continue to grow into flask-shaped bodies, their interior being mature cells, while externally they are covered with germinal cells. Later on, these become the *enamel organs.*

About this time the fibrous tissue of mesoblastic origin begins to surround the enamel organs. The base of the enamel organ becomes indented, due to this papillary growth, and the future tooth is being shaped. The fibrous tissue which lies under the enamel organ is condensed and the bloodvessels begin to form. This fibrous tissue gradually surrounds the whole cord and is called the *dental sac,* which with its contents comprises the *dental follicle.* From the sides of the epithelial cords, buds develop forming the enamel organs for the permanent teeth. The cells of the enamel organ are now differentiated into several layers, an outer or cuboidal layer, and an inner or columnar layer, with a middle or stellate layer called the enamel jelly. The mesodermic papillæ which are capped by the enamel organ now push toward the surface, their blood-supply being well established, while the cells of the surrounding connective tissue have elongated to form the *odontoblasts,* which later produce the dentine.

Formation of Enamel.—Gradually globules of a calcareous nature, known as the enamel-prisms, are secreted by the inner columnar layer of cells of the enamel organ. Between these prisms the cementing substance is secreted, the deposit of enamel occurring from within out.

Formation of Dentine.—The odontoblasts take from the blood the material for making the dentine, which they secrete, the same being deposited in layers from without in.

The cementum has its origin from the *dental sac,* being a layer of bone adherent to the dentine and covering the fang. The central portion of the dentinal papillæ is changed into pulp after a sufficient amount of dentine has been deposited. The permanent teeth develop from the secondary enamel organs which are left as remnants of the original dental ridge, development taking place in the same manner as described under the temporary teeth.

THE PHARYNX.

The pharynx is a fibromembranous tube surrounded by voluntary muscular tissue and lined with mucous membrane. The *fibrous coat* is the middle coat, and is thick above, gradually disappearing below.

The *mucous membrane* is composed above, in the naso-pharynx and region of the nasal cavities, of columnar ciliated epithelium, below of stratified squamous, continuous with that of the mouth. Numerous crypts surrounded by lymphoid tissue, which comprises the *pharyngeal tonsils*, are present in the tunica propria. The *muscular coat* is composed in the outer layers of striated muscle-tissue.

THE ŒSOPHAGUS.

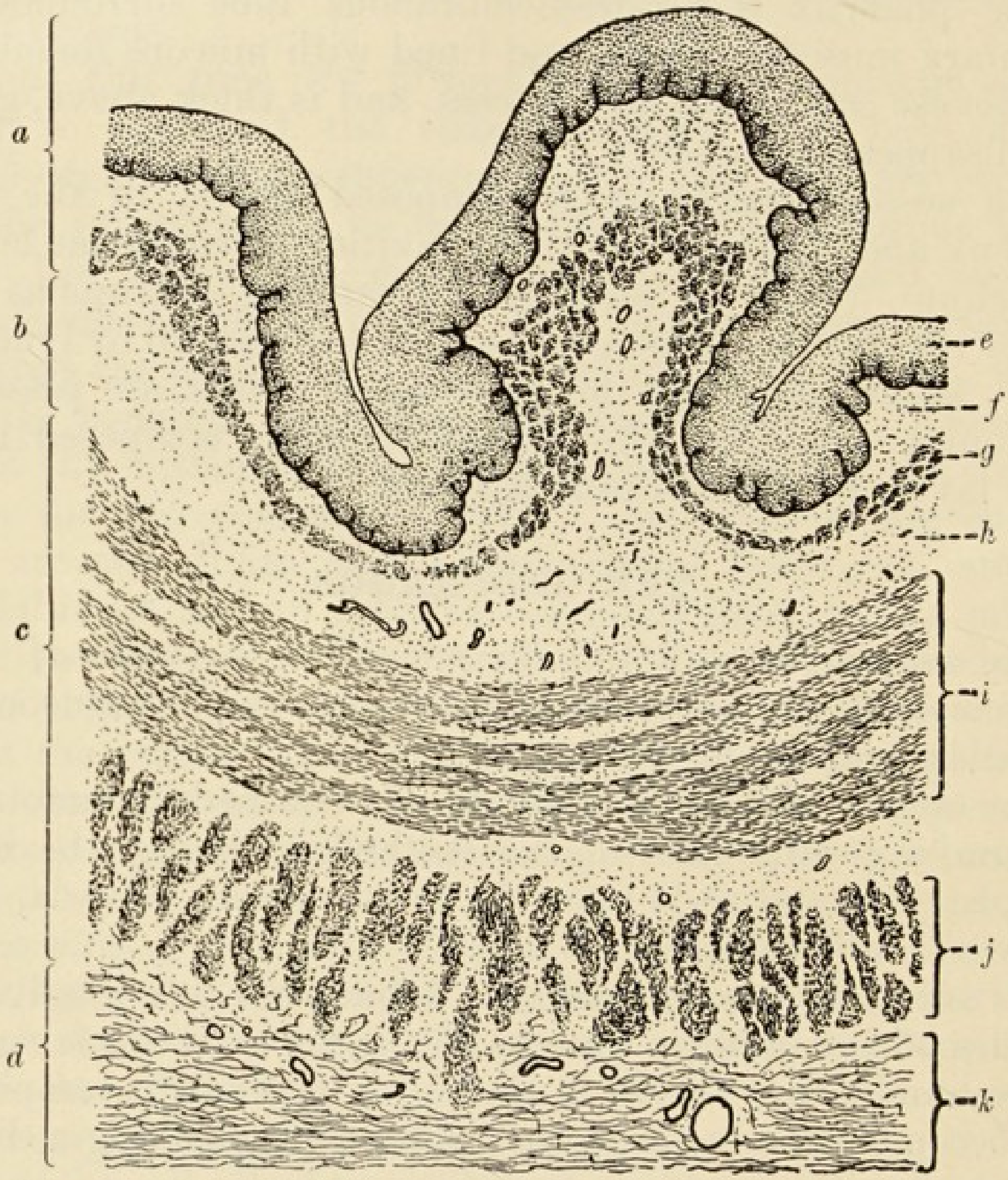
The œsophagus is a tubular structure, the walls of which are composed of four coats, the mucous, the submucous, the muscular, and the fibrous.

The *mucous membrane* consists of stratified squamous epithelium, a continuation of the epithelium lining the mouth and pharynx, and rests upon the fibrous tunica propria, which is thrown into papillæ.

Between the mucosa and the submucosa are longitudinal bundles of involuntary muscle-fibres, the *muscularis mucosæ*. These bundles are absent in the upper part of the œsophagus, but become prominent in the lower part, forming a distinct layer.

The *submucous coat* is made up of loose connective tissue containing many bloodvessels, lymphatics, and mucous glands. These mucous or œsophageal glands are small compound racemose glands widely scattered throughout the whole length, being most numerous in the lower third. These glands have a long excretory duct which passes through the muscularis mucosæ and empties its secretion on the free surface of the mucous membrane. Another type of glands, distinct from the mucous glands, are described by some authors. These occur in small groups in the upper part of the œsophagus and at or near the junction of the stomach and œsophagus. They are situated superficially to the muscularis mucosæ.

FIG. 55.



Part of a cross-section of the œsophagus of a dog: *a*, mucous membrane; *b*, submucous coat; *c*, muscular coat; *d*, fibrous coat; *e*, stratified epithelium; *f*, subepithelial areolar tissue (sometimes called the "tunica propria" of the mucous membrane); *g*, muscularis mucosæ; *h*, areolar tissue of the submucosa, containing the chief branches of the arterial and venous vessels; *i*, internal, encircling layer of the muscular coat. (Böhm and Davidoff.)

The *muscular coat* is composed of an inner circular coat and an outer longitudinal coat. In the upper third of the œsophagus the fibres are striated muscle continuous with the inferior constrictor of the pharynx, in the middle third they are mixed, and in the lower third non-striated.

The *fibrous coat* consists of dense white fibroëlastic tissue and surrounds the muscular layer externally. Bloodvessels and lymphatics are abundant in the submucosa, and the larger arteries and veins are situated in the submucosa, with branches passing upward to the mucosa and downward to the muscle. *Nerve*-fibrillæ are traced from the submucous coat to the epithelial cells of the mucosa. These nerves are derived from two large plexuses of sympathetic fibres, one between the muscle-coats and one in the submucosa like those found in the intestines.

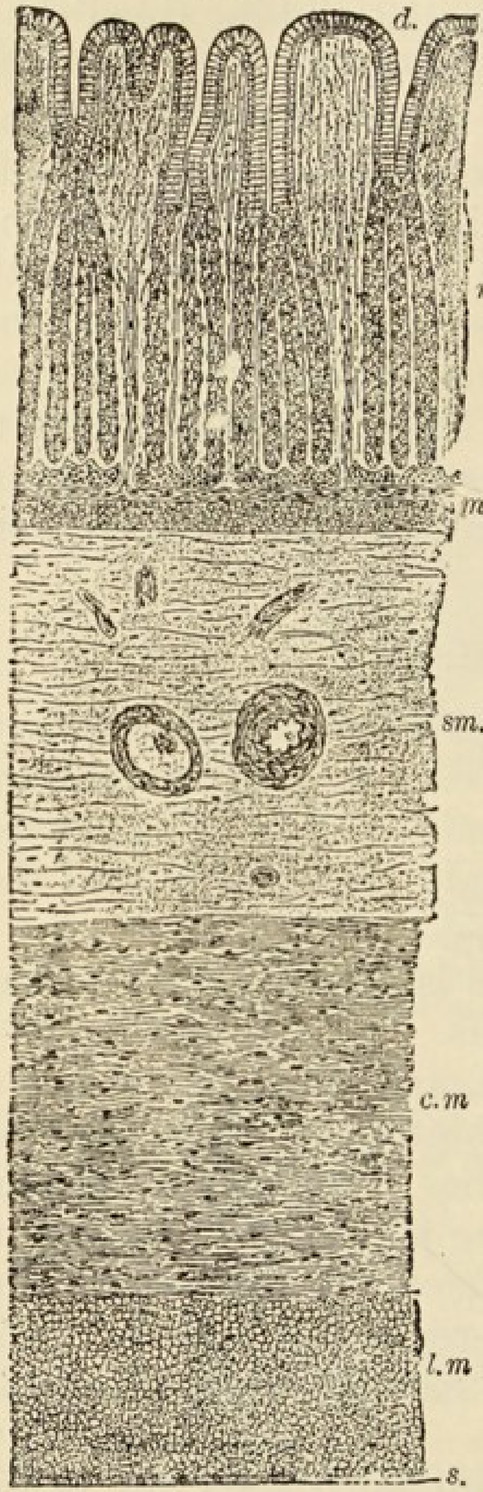
THE STOMACH.

The stomach is a sac-like dilatation of the alimentary canal composed of four coats which from without inward are the fibroserous, the muscular, the submucous, and the mucous. It is divided into two parts for study, the *cardiac* and the *pyloric* ends.

The *mucous coat* consists of a single layer of simple columnar epithelium with some goblet-cells. Hexagonal depressions are separated by elevated ridges, and give the surface a honey-combed appearance. In the bottom of these depressions are seen the mouths of the tubes forming the gastric glands. These glands differ according to whether located in the cardiac or pyloric end of the stomach. The mucosa in a recent state is of a gray or grayish-red color, and in addition to the hexagonal depressions has many conspicuous folds or rugæ.

The *cardiac end* contains simple tubular glands, the *peptic glands*, consisting of a short duct lined with columnar epithelium into which empty two or more tubes. Where the duct and the tubes join, the columnar cells change into another type, so that the tubules are lined with two varieties of cells. Along the periphery is found a layer of large spheroidal cells having a granular protoplasm and containing a large oval nucleus called the *parietal* or *acid cells*. They cause a bulging of the

FIG. 56.



Diagrammatic section through coats of stomach: *m*, mucosa; *e*, epithelium; *d*, outlet of peptic gland; *mm*, muscularis mucosæ; *sm*, submucosa; *cm*, inner circular muscular layer; *lm*, outer longitudinal muscular layer; *s*, peritoneum. (Mall.)

basement-membrane giving the tubule a beaded appearance. Those parietal cells not located directly on the lumen of the gland communicate with it by a secretory duct, which in turn breaks up into a number of secretory capillaries surrounding the cells in a network and penetrating its interior. The cells located on the edge of the lumen do not have a duct, but empty into the lumen directly through their secretory capillaries.

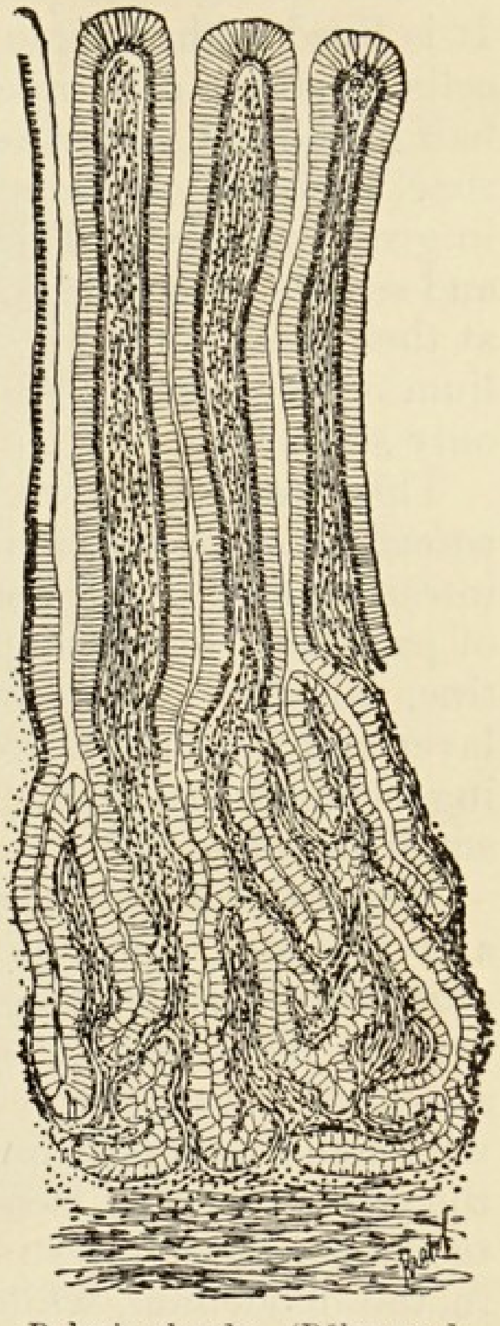
Along the lumen of the tubule are found the *chief* or *peptic cells*, which are composed of short columnar cells containing a finely granular protoplasm. These small columnar cells are supposed to secrete the digestive ferment pepsin, and also mucus, while the large parietal cells are the acid-forming cells.

The glands of the *pyloric* end are less numerous than those of the cardiac. They consist of several short tubules emptying into a long, wide excretory duct. The duct is lined with columnar epithelium while the tubules have a lining of short columnar cells. The *parietal cells* of the cardiac end are absent. These glands secrete a ferment, *rennet*, but no acid.

Both the cardiac and pyloric glands secrete mucus and pepsin, the acid being secreted by the cardiac while the enzyme rennet, which precipitates the casein of milk, is secreted by the pyloric.

The *submucous coat* is composed of a thick layer of fibro-elastic tissue loosely connecting the mucosa and the muscular coat, giving much movement to the mucous membrane. It is thrown into folds or elevations over which the mucosa with its glands is reflected. It contains many bloodvessels, lymphatics, and nerves, also some diffuse adenoid tissue. The nerves form the *plexus of Meissner* and send numerous fibres to the glands of the mucosa. The nerves are mainly from the sympathetic system.

Fig. 57.



Pyloric glands. (Böhm and Davidoff.)

The *muscular coat* consists of two layers of involuntary muscular fibres—an inner *circular* and an outer *longitudinal*. At the cardiac end are also found some irregular or *oblique* bundles, constituting a third layer. At the pyloric end the circular and middle layers are very prominent, causing a valve-like projection of the mucosa and submucosa forming the pyloric valve. Some fibres of the outer layer pass through the sphincter pylori and may be traced into the submucosa.

Between the circular and longitudinal layers of muscle-fibres is a nerve-plexus made up of both medullated and pale fibres, known as the *plexus of Auerbach*.

The *fibroserous coat*, next to the muscle, is a dense fibro-elastic tissue, which in turn is covered with the endothelial cells of the peritoneum.

THE SMALL INTESTINE.

The small intestine has four coats, the mucous, the submucous, the muscular, and the fibroserous. It is divided into three parts, the duodenum, the jejunum, and the ileum.

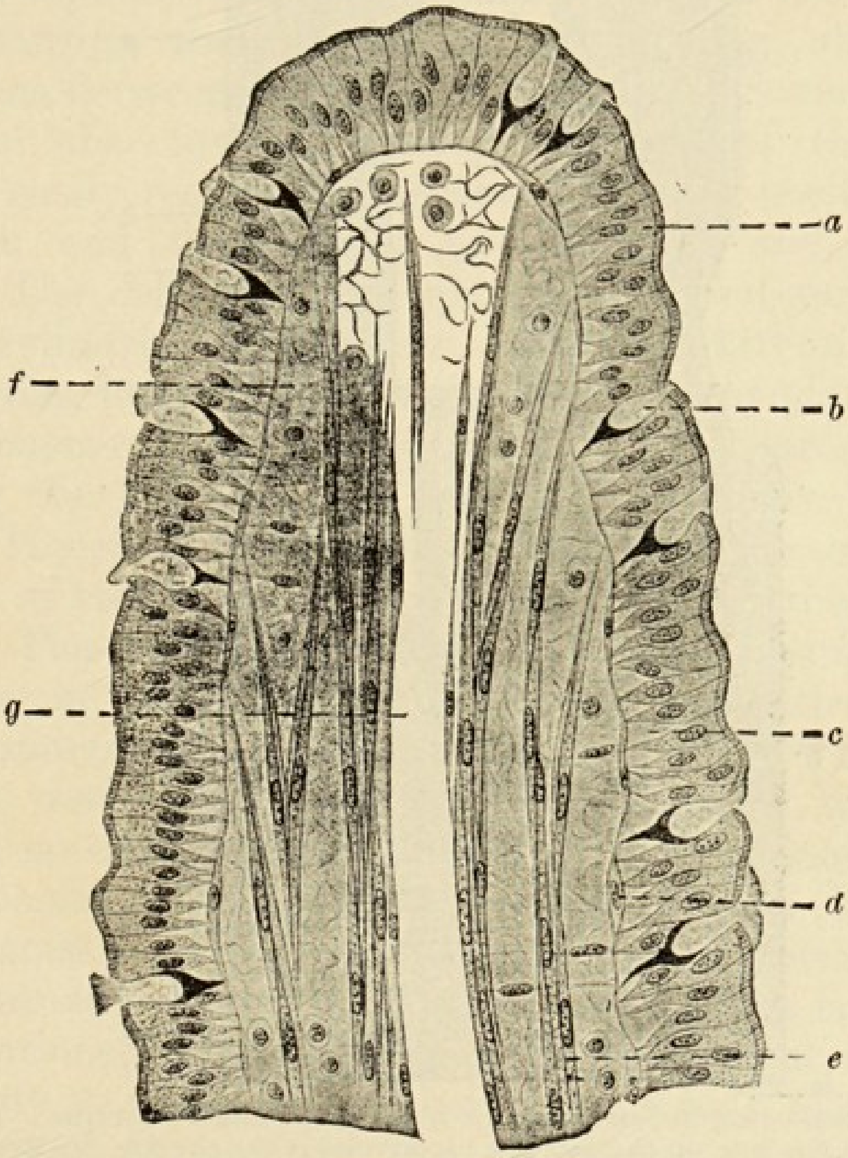
The *mucous coat* is continuous with that of the stomach. It is lined with a single layer of columnar epithelium. These cells have an oval nucleus, which usually lies in the lower half of the cell, embedded in granular protoplasm. A striated zone is found on their free surface. Goblet-cells are found in great number. They are formed from the columnar cell and secrete mucus, which is poured out of an elliptical opening at their free surface. The principal function of the epithelium of the small intestine is absorption, the secretion being only secondary.

This coat is thrown into transverse or oblique folds, the *valvulæ conniventes*, found especially in the upper part of the intestine, and its free surface is characterized by the presence of papillary elevations projecting into the lumen of the intestine, called the *villi*, which are folds simply of the epithelial layer and the tunica propria, the muscularis mucosa continuing straight below them. The villi are found only in the small intestine.

The *valvulæ conniventes*, most numerous in the duodenum and jejunum, are composed of the submucous and mucous coats only, and are ring-like folds of the whole mucous membrane. The *villi* are small vascular projections made up of a fibrous reticulum resembling adenoid tissue and covered with columnar epithelium. The centre or core of each contains the chyle-vessel or lacteal. The villi vary in form according to the region of intestine in which they occur, being leaf-like in the duodenum, while in the jejunum and ileum they are cylindrical and thickened at the free extremity.

The *lacteals* are tubes lined with endothelial cells and end above in a blind extremity. Below they empty into the lymphatic vessels in the submucosa. Along the sides of the lacteals are found involuntary *muscle-fibres* derived from the muscularis mucosæ, and next to this comes the capillary network of bloodvessels, the whole being covered with the columnar epithelium resting on a basement-membrane. The matrix or fibrous reticulum, which holds these different tissues together, has also in its meshes lymphoid cells. The villi increase the surface area of the intestine for the absorption of its contents. Fat or, better, oils undergo absorption

FIG. 58.



Axial section of villus: *a*, epithelium; *b*, goblet-cell; *d*, connective-tissue cell of basement-membrane; *e*, smooth muscle-cells; *f*, reticulum of tunica propria; *g*, central lacteal. (Kultschitzky.)

through the lacteals of the villi. It is probable that this occurs not as an emulsion, but as fatty acids formed by combination with the bile salts. The epithelial cells again convert the fatty acids into neutral fats. The glands of the intestine are the *glands of Lieberkühn* and the *glands of Brunner*.

The *crypts* or *follicles of Lieberkühn* consist of thin tubes extending down into the submucosa, and lined with a columnar

FIG. 59.

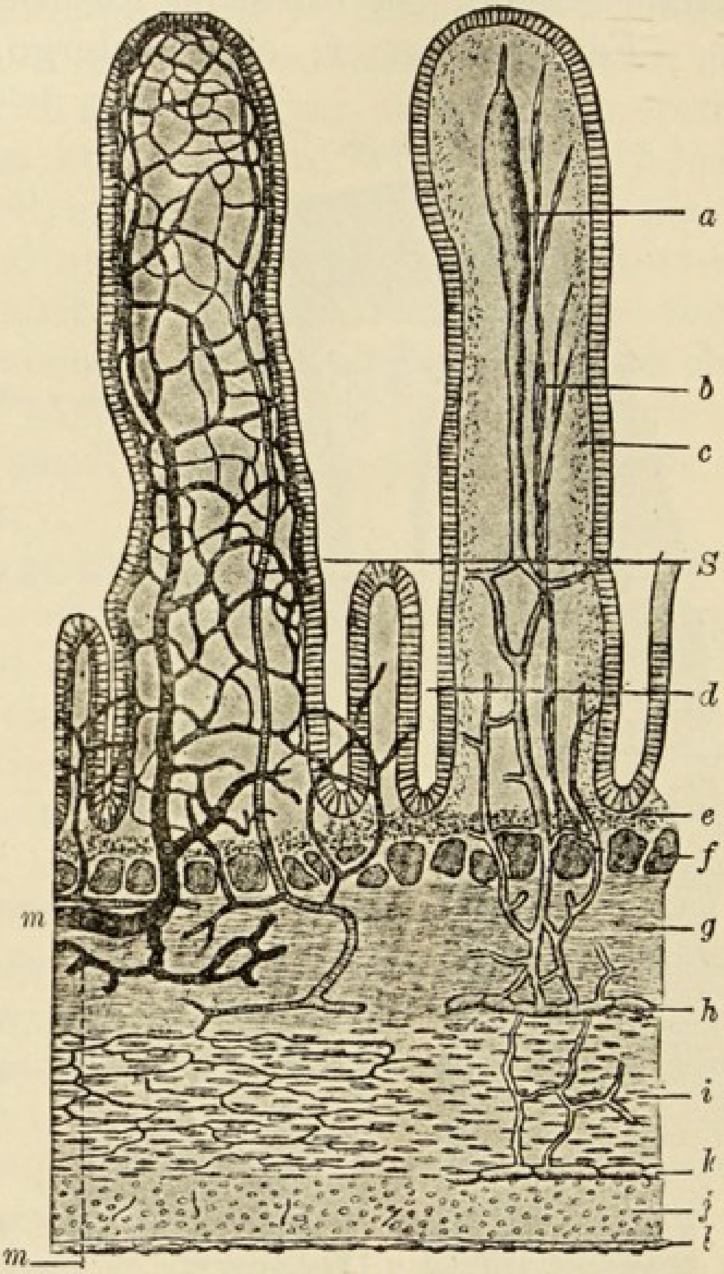


Diagram representing the structure of the human small intestine. Two villi are represented. In the one on the left the bloodvessels are shown; in the one on the right, the lymphatics. The line *S* indicates the surface of the mucous membrane between the villi. *a*, central lacteal vessel; *b*, smooth muscular fibres extending into the villus from the muscularis mucosæ; *c*, lymphadenoid tissue beneath the epithelial covering of the villus; *d*, crypt of Lieberkühn; *e*, tunica propria of lymphadenoid tissue, and continuous with that of the villus; *f*, muscularis mucosæ, forming the deepest portion of the mucous membrane; *g*, submucosa containing the larger bloodvessels and the lymphatic plexus, *h*; *i*, encircling layer of the muscular coat; *j*, longitudinal layer; *k*, lymphatic plexus within the muscular coat; *l*, serous coat; *m*, vein. The crypts are lined, and the villi covered, with columnar epithelium. (Böhm, Davidoff, and Mall, slightly modified.)

epithelium due to the dipping down into some of the epithelium lining the free surface of the intestine. These glands are found between the bases of the villi in the small intestine and also in the large intestine, in which latter place they are somewhat longer. They are regularly arranged in a continuous row and have an ampulla-like widening of their lamina.

The *glands of Brunner* are special secretory structures found in the duodenum and first part of the jejunum. These are compound tubular or racemose glands lying in the submucosa and discharging their secretion into a long, slender duct which opens between the bases of the villi. Sometimes these glands are also found in the pyloric end of the stomach. They are easily recognized because of their position in the submucosa, and their ducts pass through the muscularis mucosa. The cells of these glands are composed of finely granular cylindrical epithelium, and the extremities of the gland-tubules, being dilated, resemble alveolar glands.

The *submucous coat* is made up of a loose areolar tissue, containing the larger blood- and lymph-vessels, the nerve-plexus of Meissner, and lymphatic glands. These lymphatic glands are of two kinds, the *solitary glands* and the *agminated glands*. The *solitary glands* are isolated lymph-follicles found lying in the submucosa throughout the entire intestine, but most numerous near the ileocæcal valve. They consist of a dense reticular tissue, closely filled with lymph-cells. They have no ducts and communicate with the lacteal system through the aid of large lymph-spaces at their base, which are continuous with the interspaces of the retiform tissue.

The *agminated glands*, or *Peyer's patches*, are large groups or aggregations of lymph-follicles, usually oval in outline, from twenty to thirty in number, from a half to four inches in length, and situated in the submucosa of the intestine, especially in the lower part of the ileum. Their free surface is usually devoid of villi.

The *muscular coat* consists of a thick inner or circular, and a thinner outer or longitudinal layer of involuntary muscle-fibre. Between these is the nerve-plexus of Auerbach.

The *fibroserous coat* is similar to the same layer of the stomach, and is composed of fibroëlastic tissue covered with the endothelial cells of the peritoneum.

THE LARGE INTESTINE.

The large intestine consists of the cæcum, colon, and rectum. It, like the small intestine, has four coats, the glands of Lieberkühn, and the solitary follicles, but has no villi or Peyer's patches.

The *mucous coat* is raised into folds, due to the arrangement of the muscular coat. It contains the crypts of Lieberkühn, which have a large lumen, are deeper, more numerous, and more abundantly supplied with goblet-cells for the secretion of mucus than in the small intestine.

The *submucosa* is the same as in the small intestine.

The *muscular coat*, consisting of two layers, has a special arrangement. The longitudinal fibres are arranged in three bundles, which are shorter than the real length of intestine, thereby causing the formation of pockets in the intestine. The circular fibres form a continuous layer, and in the lower end of the rectum form the internal sphincter ani.

The *appendix vermiformis* is of the same general structure as the colon, except that the glands of Lieberkühn are shorter and not so numerous, lymphoid tissue more abundant, and the muscular coat well developed. The relatively large number of solitary lymph-follicles, occasionally forming a continuous layer, so encroach upon the glands of Lieberkühn that many are obliterated. The lymphoid tissue penetrates into the glands and causes a very close admixture of epithelial and adenoid tissue. (These histological conditions may account for the frequent inflammation of this structure.) It is especially favored with a large blood-supply considering the fact that it is an organ without apparent function.

The *anus* has a mucosa of stratified squamous epithelium in place of the columnar type which lines the digestive tract directly above it.

The *blood-supply* to the large intestine is abundant; the vessels entering through the muscular and serous coats, break up into a capillary network in the submucosa. From here small capillaries extend to and surround the glands.

The *lymphatics* of the intestine begin in the apex of the villi and in the mucosa around the villi, and from here extend to the submucosa, where plexuses are formed which combine to form large lymph-vessels. The nerves, as in the stomach, are arranged to form the *plexuses of Meissner* and of *Auerbach.*

QUESTIONS.

What are mucous membranes?
Name the kinds of glands.
What are simple tubular glands? Compound?
What are simple saccular glands? Compound?
Describe the coverings of the mouth.
From what embryonal layer is the epithelium derived?
Describe the muscle of the tongue.
Name the papillæ of the tongue.
Where are the taste-buds found?
Describe the tonsils.
Name the parts of a tooth.
Describe dentine.
What is pulp?
Describe the enamel.
From what embryonal layers are the teeth developed?
Describe the development of the teeth.
Name the coats of the œsophagus.
Describe the mucous coat; the submucous; the muscular; the fibrous.
Into what two parts is the stomach divided for consideration?
Describe the mucous coat.
Describe the cardiac glands.
Describe the pyloric glands. What points of difference between the two?
Describe the submucous, the muscular, and the fibroserous coats.
Where is the plexus of Meissner?
Name the coats of the small intestine.
What are the valvulæ conniventes?
Describe the villus.
Where are the glands of Lieberkühn situated?
What are the solitary glands?
Describe Peyer's patches.
Name the points of difference between the large and small intestine.
Describe the anus.

CHAPTER VIII.

THE DIGESTIVE ORGANS (Continued).

THE LIVER.

THE liver, the largest gland of the human economy, is of the compound tubular variety. It is surrounded or enveloped by a fibrous tissue called *Glisson's capsule.*

Glisson's capsule is a fibroëlastic tissue investing the liver, and covered on its free surface by endothelial cells. At the transverse fissure Glisson's capsule dips down into and enters into the formation of the *interlobular connective* tissue, which forms a wall between the lobules of which the liver is composed. These *lobules* are hexagonal in shape and are surrounded by the *interlobular septa*, which contain the larger

FIG. 60.

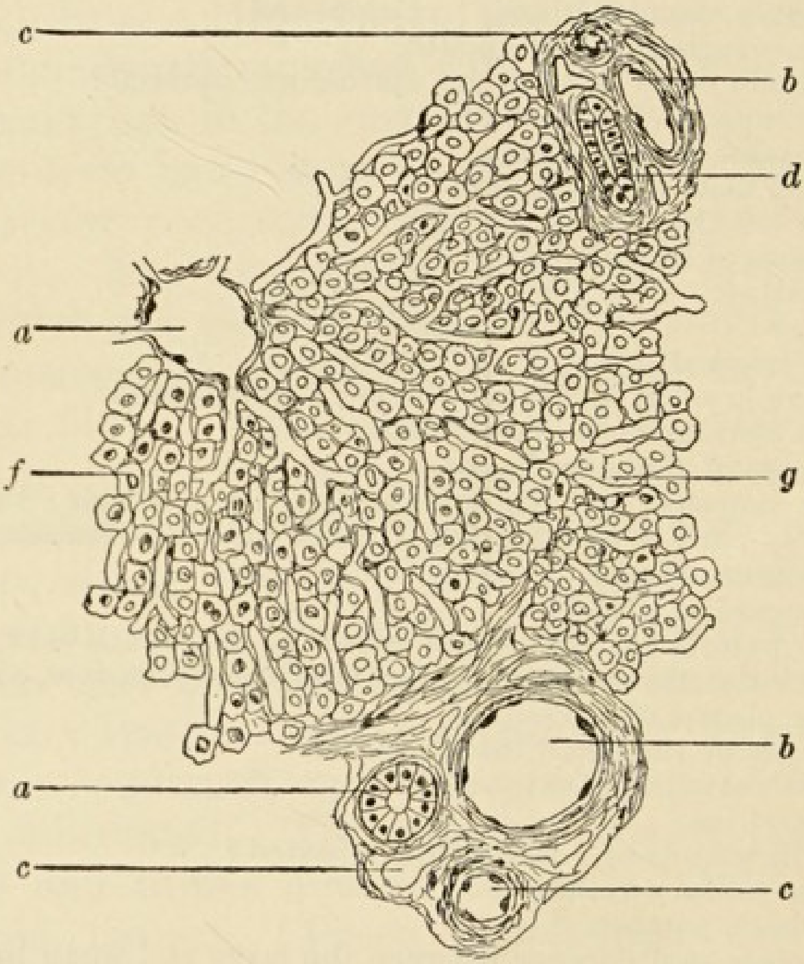


Diagram of portion of a lobule of the liver: *a*, intralobular vein, receiving intralobular capillaries; *b*, branches of portal vein; *c*, branches of hepatic artery; *d*, bile-ducts; *e*, lymph-vessel; *f*, liver-cells; *g*, junction of two lobules. (Dunham.)

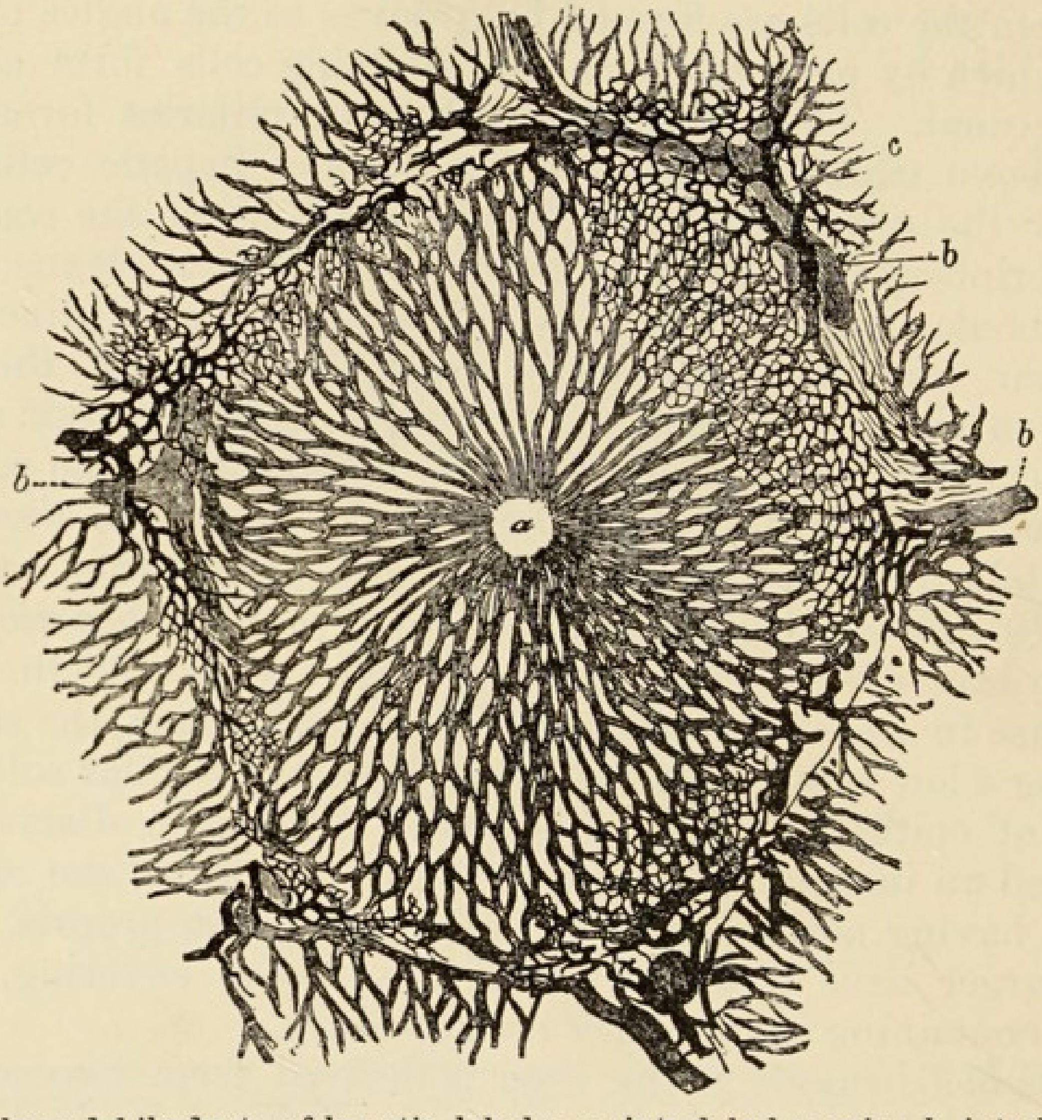
blood- and lymph-vessels as well as the bile-ducts and nerves. Each lobule consists of a collection of secretory cells—the *hepatic cells*, which, due to pressure, are polyhedral in shape, and have either one or more nuclei embedded in a granular protoplasm. The cells contain the coloring-matter of the bile in the form of yellow pigment-granules and also oil-globules. The character of the protoplasm differs according to whether digestion is going on or not. In the latter case, during fasting, the cells look small and dense, while in the former case they are larger, clearer, and have along the periphery a granular appearance. They are arranged in irregular rows, resembling cords, from the centre of the lobule to the periphery.

Separating these various rows or cords of cells are found spaces filled on one side by capillary bloodvessels, while a small bile-duct separates them on the other side. The spaces between the cells are formed by grooves in the angles of each cell which by pressure from the adjoining cells form a complete canal. The small bile-ducts or capillaries formed in the above manner consist of two rows of hepatic cells, and follow the direction of the hepatic cords from the centre to the periphery of the lobule, where they form a plexus in the interlobular spaces. The *bile-capillaries* have no distinct wall of their own, and are made up of the walls of the cells between which they pass. They begin in the interior of the hepatic cells just as do the secretory capillaries in the parietal cells of the fundus of the stomach. These *interlobular ducts* later join, forming larger vessels, until, finally, they are surrounded by Glisson's capsule, and form the *hepatic duct*, which leaves the liver at the transverse fissure. As the ducts increase in size so does the epithelium lining them, the smaller having a low type, while the larger have the regular columnar type of epithelial cells. Also with increase in diameter do we find an increase in construction of the walls, the smaller ducts having nothing more than a membrana propria, while the larger have a distinct connective-tissue covering, some even containing involuntary muscle-fibres.

The *blood-supply* to the liver is derived from two sources, the *hepatic artery*, an indirect branch of the abdominal aorta, and the *portal vein*, the latter bringing the blood containing the products of digestion from the alimentary canal. This vein plays the part of an artery in the liver and should really be considered as such, because its blood is the most nutritious in the body. The hepatic artery is much smaller than the portal vein, and has only to supply the connective-tissue framework of the liver, while the portal vein is the main artery, and supplies the parenchyma or bulk of the liver.

Both enter the liver at the transverse fissure. The *hepatic artery* after its entrance breaks up into several branches, each of which again divides and ramifies in the connective tissue surrounding the portal vein and hepatic ducts, and also in the interlobular septa, where it forms a plexus to supply the walls

FIG. 61.



Vessels and bile-ducts of hepatic lobule: *a*, intralobular vein; *b*, interlobular veins, breaking up into intralobular capillaries; *c*, bile-duct with bile-capillaries (shown only at periphery of lobule). (Cadiat.)

of the lobules. The *portal vein* takes the same course as the hepatic artery, gradually forming an interlobular plexus between the lobules. From here small capillaries pass in between the cells of the lobules, radiating toward the centre. Each capillary has for its walls the hepatic cells, and by this arrangement the blood in passing from the periphery to the centre bathes a row of hepatic cells on either side, and allows the cells to filter the bile through into the biliary duct, which is separated from the blood-capillary by only a single cell. When these capillaries reach the centre of the lobule they empty into one vein, the *intralobular vein*. To understand this better, the lobule should be considered as a cylinder, with a core in the centre, the intralobular vein. This vein, after receiving the above blood, empties into the *sublobular vein* found at the base of the lobule. The sublobular veins unite to form the radicals of the *hepatic veins*, which finally unite to form three trunks, emptying into the vena cava. In the connective tissue between the lobules we find the *portal canals*, made up of the interlobular bile-ducts, the hepatic artery, the portal vein, and a lymph-vessel, all enclosed in areolar tissue.

The *lymph-vessels* accompany the portal vein and hepatic artery and form a plexus in the capsule of the liver, sending branches into the interlobular connective tissue. Fine lymph-vessels extend from between the lobules along with and surrounded by the intralobular capillaries and form lymph-spaces.

The *nerves* of the liver are branches from the lymphatic system, and are probably from ganglia situated outside of this organ. They form plexuses in the interlobular connective tissue around the bloodvessels and bile-passages, and are in every respect like the vascular nerves in other organs.

The **gall-bladder** and its **cystic duct** are composed of a *serous*, *fibromuscular*, and a *mucous coat*.

The *mucous coat* is covered with a single layer of columnar epithelium containing many mucous glands and is raised into rugæ. There are no goblet-cells present.

The *fibromuscular coat* contains plain muscle-fibres with dense fibrous tissue. Some authors claim that there are three definite layers of muscle in the bladder wall. In this coat are present solitary lymph-follicles and many blood- and lymph-vessels.

The *serous coat* is covered with the endothelial cells of the peritoneum, being continuous with that covering the external surface of Glisson's capsule.

THE SALIVARY GLANDS.

The principal *salivary glands,* three in number, are the *parotid,* the *sublingual,* and the *submaxillary,* named according to their situation. They are classified according to their secretions, as *serous, mucous,* and *mixed* glands. These glands are all of the tubular type and their ducts open into the cavity of the mouth.

The **parotid,** the largest of the three, is a compound racemose gland surrounded by a fibrous capsule, from which dense connective tissue extends into the same, dividing it into lobes which are subdivided into lobules, and these into groups of cellular glands called *acini.* The *acini* are lined with a single layer of irregular glandular epithelium resting upon a basement-membrane. These cells just before discharging their secretion appear large, clear, and granular with a rounded centrally placed nucleus, but after emptying their secretion are small and dark.

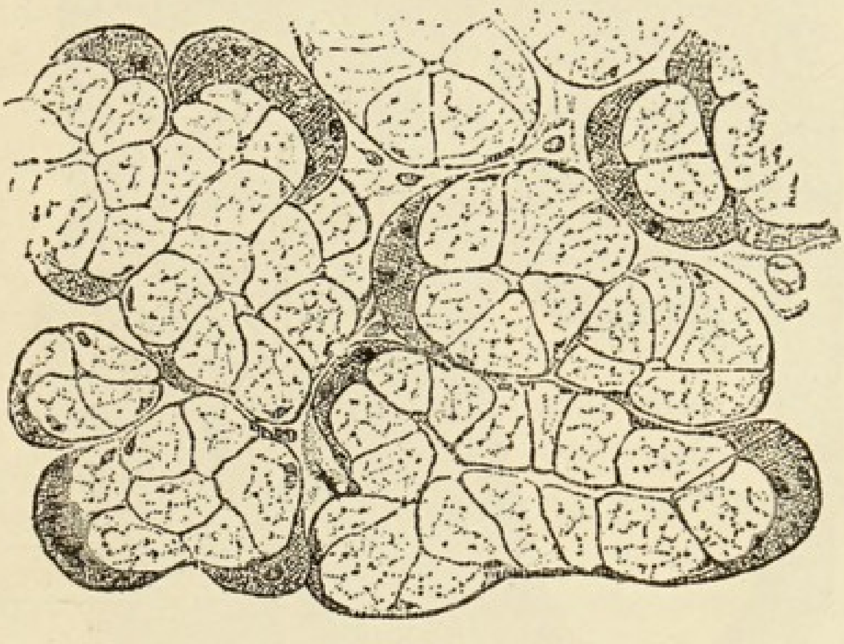
Between the cells are narrow spaces marking the beginning of the excretory *duct of Stenson.* This large excretory channel is lined with a single layer of low columnar epithelium surrounded by a thick wall of fibroëlastic tissue. As this duct diminishes in size the columnar cells gradually become elongated and a striated zone appears on the outer margin of the cells. As the ducts continue to diminish in diameter, the epithelium changes to a low, flat cell which finally passes into the cells lining the acini. This is a typical *serous gland* and secretes a thin albuminous fluid.

The **sublingual,** the smallest of the three, is a *mucous* gland and secretes a thick, viscid fluid. The acini are larger than in the serous glands and are lined with spheroidal cells having a clear translucent protoplasm when filled with mucus. The nuclei are flat and placed next to the basement-membrane. Quite often half-moon-shaped groups of cells having a granular protoplasm and placed immediately next to the basement-membrane at the periphery of the acini are found. These are the *demilunes of Heidenhain* and are supposed to be of the serous type. The excretory duct of the sublingual gland is the *duct of Bartholin*, and is similar in structure to Stenson's duct of the parotid gland.

The **submaxillary** is a mucoserous or mixed gland possessing some of the characteristics of both the mucous and serous types. The excretory channel or the *duct of Wharton*, resembles the duct of the parotid gland, its wall, however, having a thin layer of longitudinal muscle-fibres externally.

The *blood-supply* of the salivary glands is very abundant, the vessels entering along with the excretory ducts and giving

FIG. 62.



Mucous alveoli from submaxillary gland, showing mucinogenous cells and demilunes of Heidenhain. (Ranvier.)

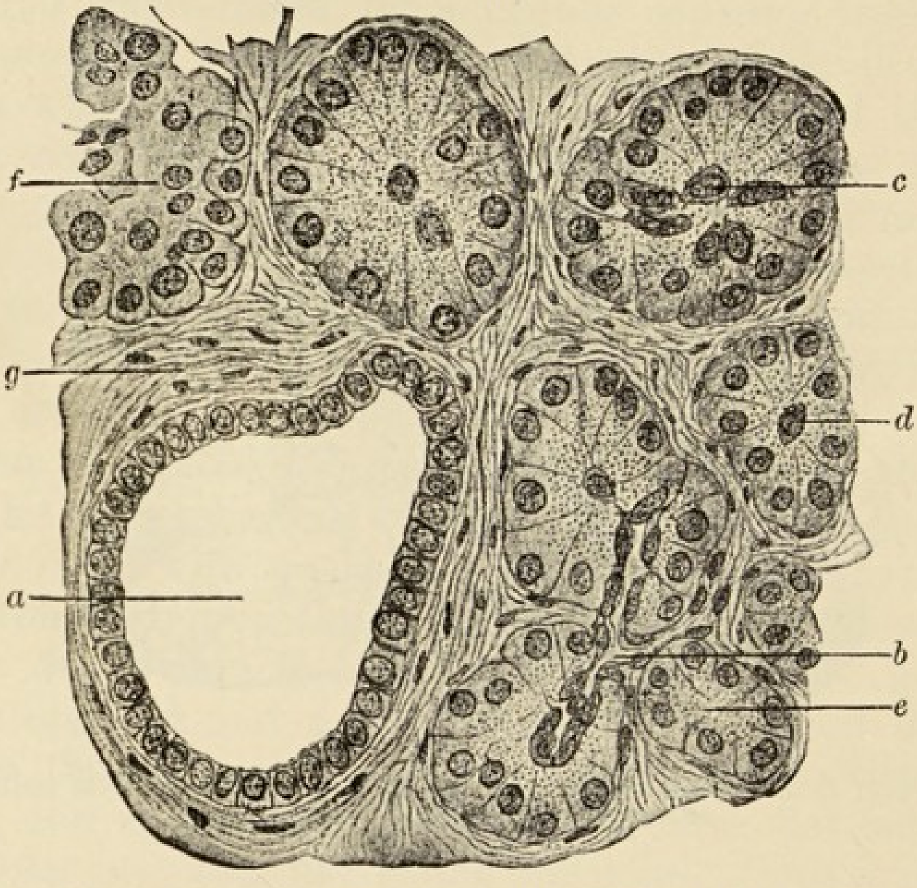
off branches within the interlobular septa. These branches form a capillary network in the basement-membrane and surround the acini, lying next to the secretory cells.

The *lymph-vessels* are arranged in a like manner. The nerve-trunks enter with the bloodvessels and consist of medullated and non-medullated fibres. They gradually break up into smaller bundles until they reach the acini. These they surround in the form of a plexus, and from here small branches enter the secretory cells after having penetrated the basement-membrane.

THE PANCREAS.

The pancreas has been called "the abdominal salivary gland" as its secretion is of the same type—serous—as that of the parotid gland. It is a compound acinotubular gland, and is divided into lobes and lobules by a connective-tissue framework, the whole being invested by a connective-tissue capsule.

FIG. 63.



Portion of pancreas: *a*, large duct; *b*, beginning ducts; *c*, *d*, *e*, secreting alveoli; *g*, sustentacular connective tissue. (Böhm and Davidoff.)

The *pancreatic duct*, or *duct of Wirsung*, is lined with a single layer of columnar cells surrounded by fibrous connective tissue. After entering the gland it breaks up into several tubules; its lining epithelium also gradually changing until the acini are reached. Here the epithelium consists of thin columnar cells containing highly refractive granules called *zymogen granules*, next to the lumen of the acini, while the outer half of the cell contains the nucleus in a clear protoplasm. The relation between these zones depends on the amount of secretion contained in the cell. Just prior to digestion the clear zone is the greater, while during and after digestion the granular zone is in excess. Round or oval areas, the *bodies of Langerhans*, which are undeveloped acini, appear throughout the gland. They are richly supplied with capillary bloodvessels, and are most numerous in the splenic end of the pancreas and situated in the centre of each lobule. As they have no ducts, it is probable that they are concerned with the internal secretion of the gland. Some authors (Opie) suppose that they are concerned with the control of the storing up and excretion of sugar. The bloodvessels, as well as the lymphatics and nerves, are distributed throughout the pancreas very similarly to the distribution of same in the parotid gland.

DEVELOPMENT OF THE DIGESTIVE ORGANS.

The organs of digestion originate from all three layers of the blastoderm, but the entoderm and mesoderm furnish the greater part. The epithelium of the entire tract and of the glands connected with the same is derived from the entoderm, with the exception of the oral cavity and the anus, which derive their lining membrane from the ectoderm. The connective and muscle tissue are from the mesoderm. The primary gut is formed by the folding off and closing together of the ventral body-plates. The tube thus formed is separated from the oral cavity by a partition, the *pharyngeal plate*, dividing these ectodermic and entodermic structures. A similar process takes place at the anus. These plates later rupture and complete the tract. The tube begins to divide into separate organs about the fourth week in the human embryo; the *stomach* being first formed, due to a dilatation of a portion of this primary gut, followed by a proliferation of the entodermic cells and the formation of the peptic and pyloric glands. The mesoderm also increases and two layers, the submucosa and muscular coats, are formed. Next the intestinal villi and glands are formed from the entoderm in that portion destined to become the *intestine.* Villi appear in both large and small intestine, but those in the large intestine soon atrophy, while those in the small intestine increase in size. Entodermic or ectodermic projections are sent into the surrounding mesoderm, whose cells proliferate rapidly and form the primary glands, such as the salivary glands, pancreas, and liver.

The *liver* makes its appearance as a ventral longitudinal outgrowth of the endodermal epithelium of the intestine as a solid mass into the substance of a horizontal shelf, the septum transversum, which is attached to the ventral wall of the body.

The *gall-bladder* is also formed from part of the original outgrowth, and later constrictions appear separating the organs from the intestine, until they are united only by the ductus communis choledochus. Later the *pancreas* appears as three separate outgrowths, extending from the duodenum into the primitive mesentery. The pancreas at first lies parallel to the long axis of the body and afterward becomes transversely situated.

The *connective tissue*, which forms the division between the lobules, is derived from an ingrowth of the surrounded mesoderm. The endothelial cells covering the fibroserous surfaces of the intestinal tract are derived from the mesothelium, which is differentiated mesoderm.

QUESTIONS.

What kind of organ is the liver?
What divides the liver into lobes and lobules?
Describe a lobule.
Describe a liver-cell. How are liver-cells arranged?
Where is the bile-duct situated?
Name the two sources of blood-supply to the liver.
Give the course of the portal vein.
Describe the structure of the bile-ducts.
Describe Glisson's capsule.
Describe the structure of the gall-bladder.
Name the salivary glands.
Describe the parotid gland, the sublingual gland, and the submaxillary gland.
Which are mucous and which serous glands?
What are the demilunes of Heidenhain?

What kind of gland is the pancreas? Describe its acini.

What are the bodies of Langerhans?

How does the pancreas differ in structure from the parotid gland?

Describe the structure of the pancreatic duct.

What parts of the alimentary canal are derived from each layer of the blastoderm.

Describe the primitive gut, and tell how the parts are separated.

Whence is the endothelium derived?

CHAPTER IX.

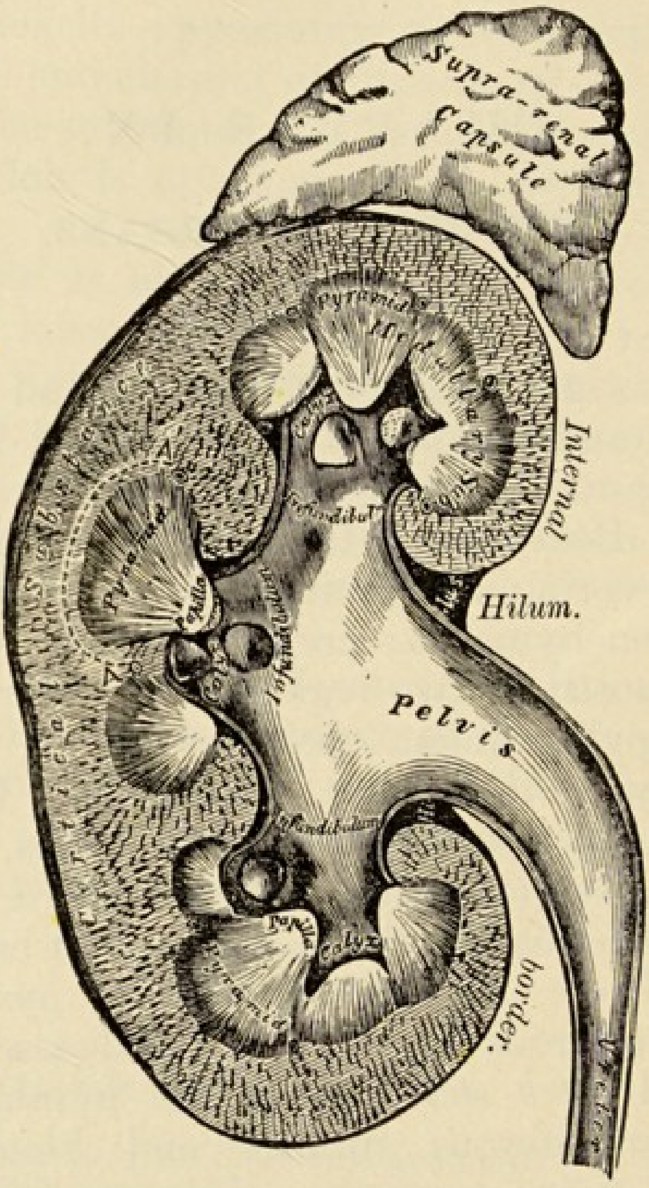
THE URINARY ORGANS.

THE KIDNEY.

The *kidney* is a compound tubular gland covered with a fibrous capsule and composed of pyramidal shaped lobules. This fibrous capsule covering the kidney is made up of dense fibrous tissue. Beneath this is found a network of unstriped muscle-fibre covering the entire organ. Upon longitudinal section the parenchyma or secretory portion of the kidney is seen to be composed of two regions, the outer *cortex*, a granular zone occupying about one-third of the gland, and the medulla occupying the inner two-thirds. The *medulla* is composed of from 8 to 18 pyramidal bodies, each having a papillary eminence projecting into the pelvis or sinus of the kidney, while their base is the meeting-point between medulla and cortex. These are the *Malpighian pyramids* and are made up of uriniferous tubules and bloodvessels.

The *light* and *dark striations* in the pyramids are due to the alternate uriniferous tubules and bloodvessels. The masses of renal tissue separating the pyramids which convey the blood- and lymph-vessels as well as nerves are known as the *columns of Bertini*. Occasionally the striations of the pyramids extend into the cortical portion, consisting of straight tubules arranged in conical masses, their apices pointing toward the periphery and bases toward the medullary portion. These formations are known as the *pyramids of Ferrein*, or the *medullary rays*. The space between the medullary rays is known as the *labyrinth* containing the convoluted tubules. The arrangement of the uriniferous tubules which constitute the bulk of the gland or organ are best understood by tracing their course from the beginning of the secretion of the urine, along the various passages or tubes

FIG. 64.

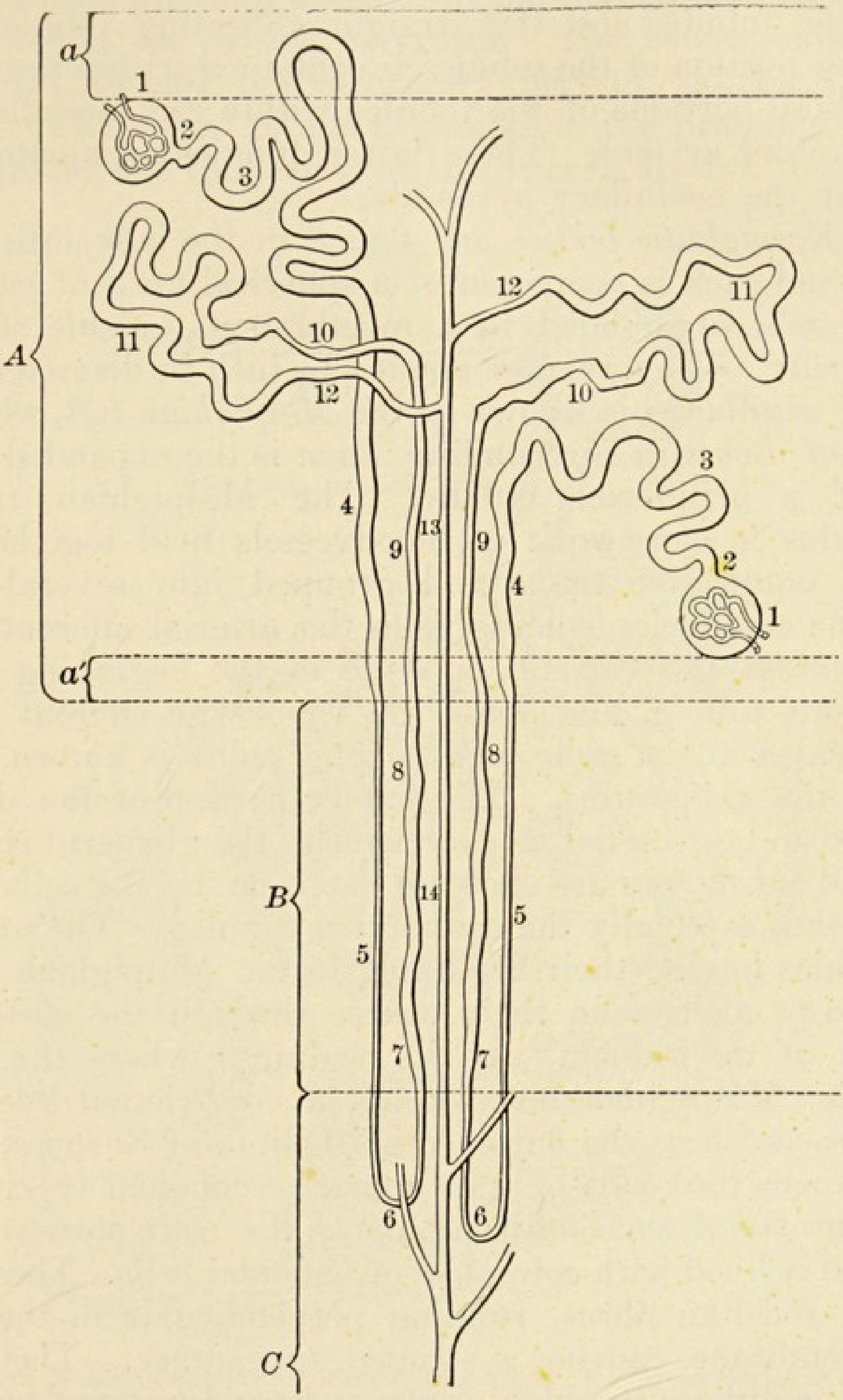


Vertical section of kidney. (Gray.)

until it is poured into the renal pelvis through the openings found in the apices of the renal papillæ.

A complete *uriniferous tubule* is made up of the following parts, namely, the Malpighian body or glomerulus, the proximal convoluted tubule, the spiral tubule, the descending Henle's tubule, Henle's loop, the ascending Henle's tubule,

Fig. 65.



Diagrammatic representation of uriniferous tubules: *A*, cortex of kidney; *B*, boundary zone, and *C*, papillary portion of Malpighian pyramid; *a*, subcapsular portion, and *a'*, inner portion of cortex destitute of Malpighian bodies; 1, Malpighian body, capsule of Bowman, and glomerulus; 2, neck; 3, proximal convoluted tubule; 4, spiral tubule; 5, descending limb of Henle's loop; 6, Henle's loop; 7, 8, 9, ascending limb of Henle's loop; 10, irregular tubule; 11, distal convoluted tubule: 12, curved tubule; 13, 14, collecting tubule. (Klein.)

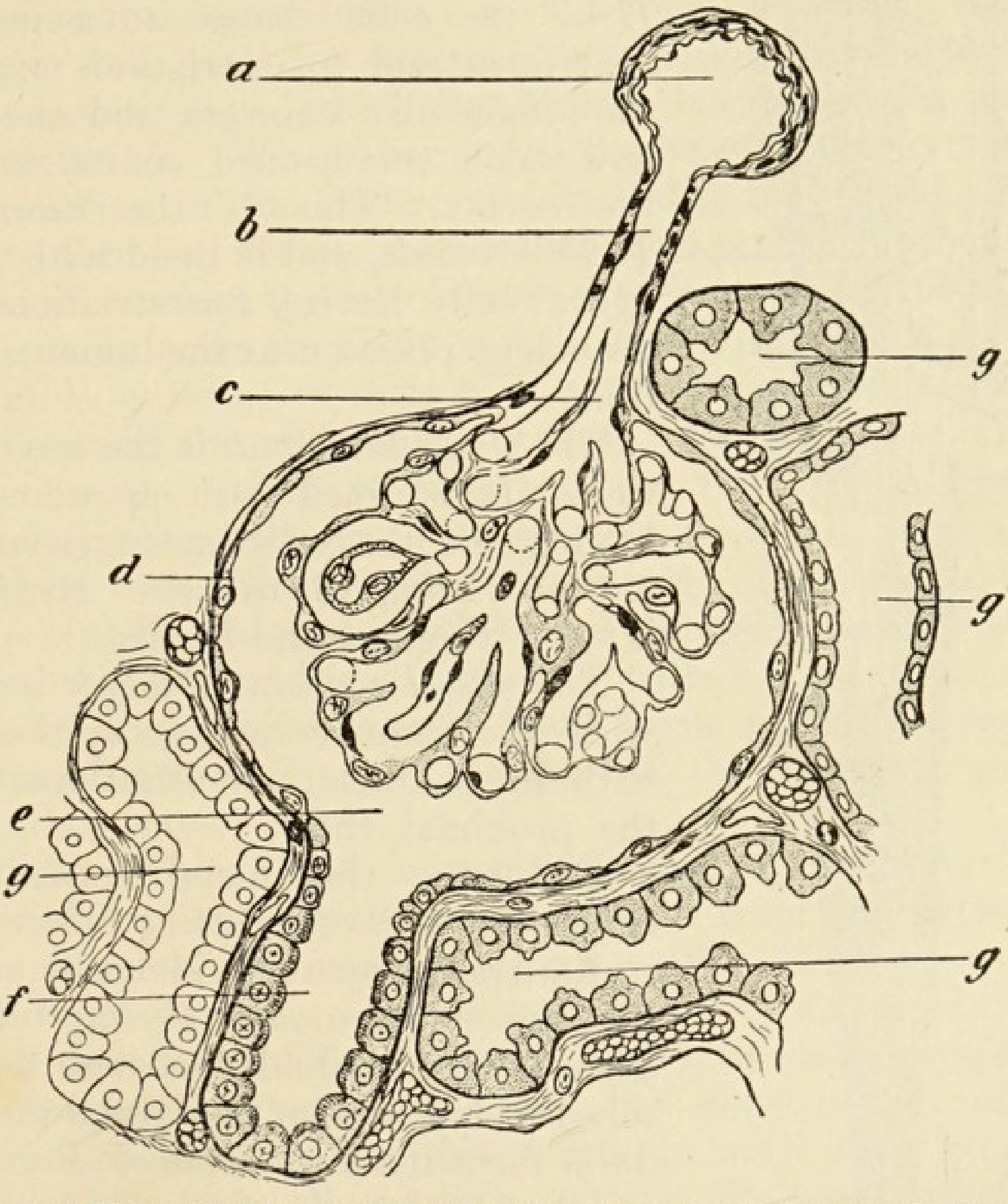
the irregular tubule, the distal convoluted tubule, the arched collecting tubule, and the straight collecting tubule. The secreting portion of the tubules is contained within the cortex, while those portions of the tubules within the medulla form the excretory system. These latter tubules terminate at the apices of the medullary pyramids.

The *Malpighian bodies* are found in the labyrinth of the cortex, and each is composed of a spherical mass of capillary bloodvessels surrounded by a membranous capsule of endothelial cells. They average about $\frac{1}{120}$ inch in diameter. The mass of capillaries is known as the *Malpighian tuft*, while the *capsule of Bowman* surrounding them is the expanded beginning of a uriniferous tubule. The Malpighian tuft or glomerulus is a network of bloodvessels held together by a delicate connective tissue and grouped into several small lobes, the capillaries coming from the arterial afferent vessel which enters the capsule opposite to the beginning of the uriniferous tubule, and from the venous or efferent vessel, which leaves at the same point. This point is known as the *stalk* of the glomerulus. The watery portion of the urine is supposed to be secreted or excreted by the glomerulus, while the solid substances are excreted later on by the cells lining the tubules, especially the convoluted tubules. The uriniferous tubules having their beginning in the Malpighian bodies show many changes in their course through the cortex and medulla of the kidney. At the beginning where the tubule joins the Malpighian body occurs a constriction known as the neck, and here the flattened epithelium of Bowman's capsule changes into cells of a columnar or cuboidal type.

The *proximal convoluted* tubule is the next portion to the neck and is lined with columnar or cuboidal cells. These cells contain rod-like fibres, running perpendicular to the basement-membrane, causing a striated appearance. Their protoplasm is either granular or clear, depending upon stage of secretion.

The diameter of the proximal and distal portions of the convoluted tubules is greater than that of the other portions of the uriniferous tubules. These two segments of the convoluted tubules are both situated in the interpyramidal portion of the cortex or in the labyrinth. The tubule now turns downward toward the medullary portion, taking a spiral course. This *spiral* tubule is similar to the proximal convoluted tubule, but the striations in the cells are not so marked.

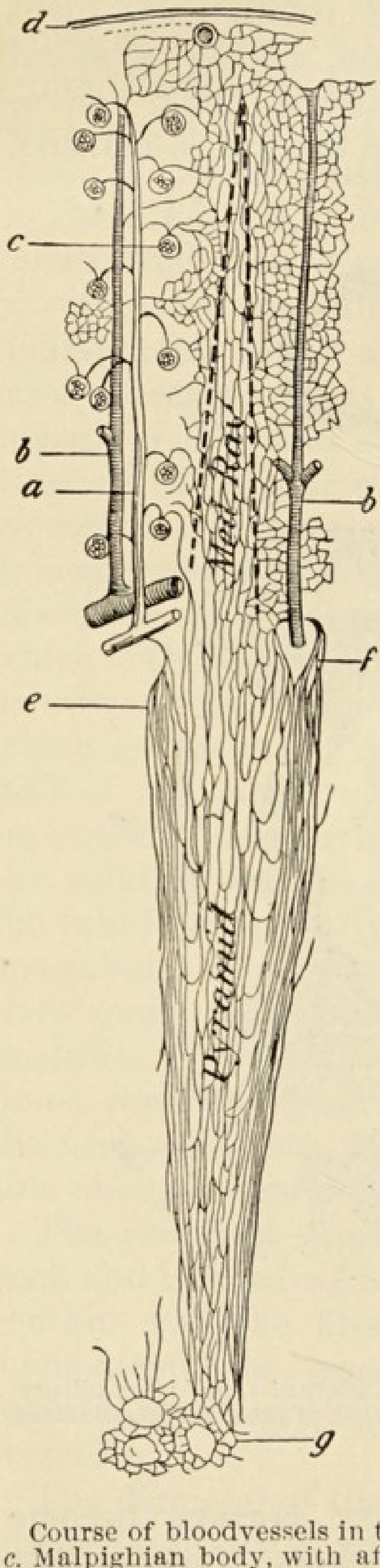
FIG. 66.



Sketch of Malpighian body: *a*, interlobular artery; *b*, afferent vessel; *c*, capillary; *d*, capsule of Bowman; *e*, cavity of the capsule; *f*, beginning of proximal convoluted tubule; *g*, portions of convoluted tubules. (Dunham.)

The tubules now enter the medullary portion, become smaller in calibre and straight in their course, forming the *descending Henle's tubule.* The lining epithelium is composed

Fig. 67.



Course of bloodvessels in the kidney: *a*, interlobular artery; *b*, interlobular vein; *c*. Malpighian body, with afferent and efferent vessels and glomerulus; *d*, stellate vein; *e*, arteriæ rectæ; *f*, venæ rectæ; *g*, capillaries about mouths of oultet-ducts. (Ludwig.)

of flattened, transparent plates, with large nuclei. These nuclei, being very prominent and due to the arrangement of the cells, give a wavy appearance to the lumen of the tubule. Just before the tubules bend upon themselves to form the *loop of Henle* the cells change to a polyhedral form and fine striations appear; the lumen also enlarges and the tube now takes an upward course toward the cortex. This is the *ascending Henle's tubule,* and is lined with polyhedral cells having fine striations and a nucleus placed near the lumen of the tube.

The *irregular tubule* is the next portion. It is lined with angular cells having the most distinct striations of any cells lining the tubules. Its lumen is very irregular and small.

The *distal convoluted tubule* is lined with the same columnar epithelium, with its characteristic striations, as in the proximal end.

Following this distal convolution comes the *arched collecting tubule* with its low transparent cuboidal cells, which also line the *straight collecting tubules.* These cells gradually change as the tubes widen, and as they reach the medulla form the *large tubes of Bellini.*

The *bloodvessels* of the kidney are branches of the renal artery, which enters at the hilum, and after giving off several branches to supply nutrition to the structures of the renal pelvis, divides into a number of large branches which penetrate the glandular tissue along the columns of Bertini, between the Malpighian pyramids. Some authors claim that about three-fourths of the blood entering the hilum of the kidney, by four or five arterial branches, flows through the anterior subdivisions, while about one-fourth flows through the posterior divisions. There is no anastomosis between the large anterior and posterior arteries, thus making a comparatively non-vascular zone, which fact Brödel has noted for surgical consideration. When they reach the base of the pyramid, at the junction of the cortex and medulla, they bend in their course, forming arches from which two sets of branches are given off, namely, the *interlobular arteries* and the *arteriæ rectæ.* The *arteriæ rectæ* are short vessels supplying the Malpighian pyramids, entering at their base and forming a capillary network around the collecting tubules. The interlobular arteries enter the cortex, passing between the pyramids of Ferrein and going directly to the periphery, where they form a capillary network beneath the capsule. In their course to the periphery they give off lateral branches, which are the *afferent* vessels to the Malpighian tufts. After leaving the tufts by the *efferent* vessels they break up into a capillary network surrounding the tubules of the labyrinth and the medullary rays.

Veins.—This blood is now collected by the interlobular veins, which also receive venous blood from the network of veins beneath the capsule, known as the *stellate* veins. The *venæ rectæ* gather up the blood carried to the medulla and follow the course of the arteries. Later, by anastomosing with the interlobular veins, they run the same course with the arteries, down between the pyramids until they reach the sinus, where they all combine to form the *renal veins,* which leave the kidney at the hilum.

A superficial and a deep set of *lymphatics* terminating in the lumbar plexus are found in the kidney, and lymphatic spaces are found forming an anastomosis between the two plexuses.

As far as the ultimate termination of the *nerves*, which are of the non-medullated variety and which follow the blood-vessels to the tubules, little is known. They are supposed to form plexuses around the uriniferous tubules, and penetrate the *membrana propria*, ending in knob-like thickenings on the surface of the epithelial cells.

The *pelvis* of the kidney is the dilated upper part of the ureter, and occupies the greater part of the renal sinus.

The *ureter* is the excretory duct of the kidney, extending from the bladder, and beginning as the *pelvis*, which is divided into a number of short truncated branches, the *calices* or cups.

The *calices* have projecting into them the papillæ of the Malpighian pyramids. The pelvis and ureter proper are composed of three coats, the mucous, the muscular, and the fibrous.

The *mucous coat* consists of stratified squamous epithelium often termed transitional because of the rapid change from the columnar cells of the deeper layer to the flat cells on the surface. This epithelium rests upon a basement-membrane of fibroëlastic tissue and which also separates it from the muscular coat. The cells of transitional epithelium differ in the various layers. The outer layer is made up of large flattened cuboidal cells, with processes extending between the neighboring cells and often with more than one nucleus. The middle layer of cells is cylindrical or polygonal, while the deepest layer is composed of small cubical or oval cells.

The *muscular coat* of the pelvis has an inner longitudinal and an outer circular layer of involuntary muscle-fibres, while this same coat in the ureter proper has an additional layer of longitudinal fibres external to the circular layer.

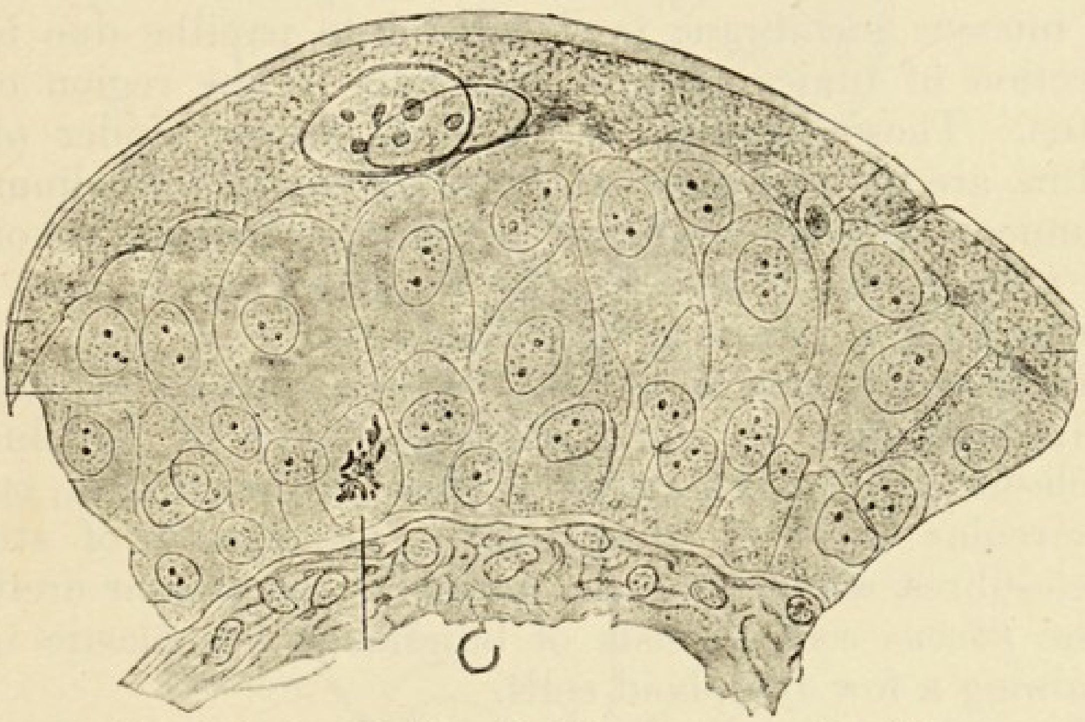
The *fibrous coat* is the outer and consists of dense fibrous tissue, being continuous with the fibrous capsule surrounding the kidney. The *blood-* and *lymph-vessels* lie in the tunica propria in a capillary network, while the *nerves* are principally confined to the muscular coat with a few fibres to the epithelium.

THE BLADDER.

The *bladder*, like the ureter, has three coats making up its walls, namely, the *mucous*, the *muscular*, and the *fibrous*, with an additional covering on its posterior and superior surfaces, which is the *serous* coat and is formed by a reflected portion of the peritoneum.

The *mucous coat* is continuous with that lining the ureters, being composed of the same stratified squamous or transitional epithelium, and is loosely connected with the muscular coat by a layer of areolar tissue. When the bladder is empty, it

FIG. 68.



Transitional epithelium, bladder of mouse. (Dogiel.)

is thrown into folds. At the base of the bladder a few small racemose glands and lymphatics are found.

The *muscular coat* consists of three layers of involuntary muscle-fibre, an outer longitudinal, a middle circular, and an inner longitudinal layer. The circular layers increase in thickness toward the base of the bladder and here form the *sphincter vesicæ*.

The *fibrous coat* is a thin layer composed of areolar tissue. The bloodvessels and lymphatics are abundantly distributed throughout the walls of the bladder. The nerves are mostly sympathetic filaments, both medullated and non-medullated; small ganglia are found along the course of these nerves.

THE URETHRA.

The *urethra* of both the male and female is composed of the same three coats as the bladder, namely, the *mucous*, the *muscular*, and the *fibrous*.

The **female urethra** is lined with transitional epithelium, like the bladder, in the upper part, but lower down becomes a single or double layer of columnar cells, and finally at the lower or external end becomes stratified pavement epithelium. The mucous membrane is elevated into papillæ due to the projection of tunica propria, especially in the region of the meatus. These papillæ, as well as the remainder of the urethra, are covered with stratified pavement epithelium. A few mucous follicles are found surrounding its external orifice. The mucosa has a rich supply of bloodvessels, the veins forming a thick plexus in the submucosa.

The *muscular coat* is a thick tunic composed of an inner longitudinal and an outer circular layer of involuntary muscle-fibres. In the upper portion of the urethra, outside the circular layer of muscle-fibres, are strands of striated muscle-fibres, which form the musculus compressor urethræ.

The *fibrous coat* consists of bundles of fibroëlastic tissue, containing a few lymphoid cells.

The **male urethra** is lined with different types of epithelium, varying with the different portions of this canal. In the *prostatic* portion is found the stratified squamous, in the *membranous* the stratified columnar, and lastly in the *penile* is the simple columnar epithelium.

The *fossa navicularis* is lined with epithelium of the same type as that covering the *glans penis*, namely, stratified squamous epithelium. The small racemose *glands of Littré* are found throughout the male urethra, especially in the spongy or penile portion.

The *muscular coat* is arranged the same as in the female urethra. In the anterior part of the penile portion, however, this layer is not found. Blood- and lymph-vessels as well as nerves are quite numerous in the urethra, being found especially beneath the mucous coat.

DEVELOPMENT OF THE URINARY ORGANS.

All these structures are of mesodermic origin, with the exception of the epithelium of the bladder and urethra, which

FIG. 69.

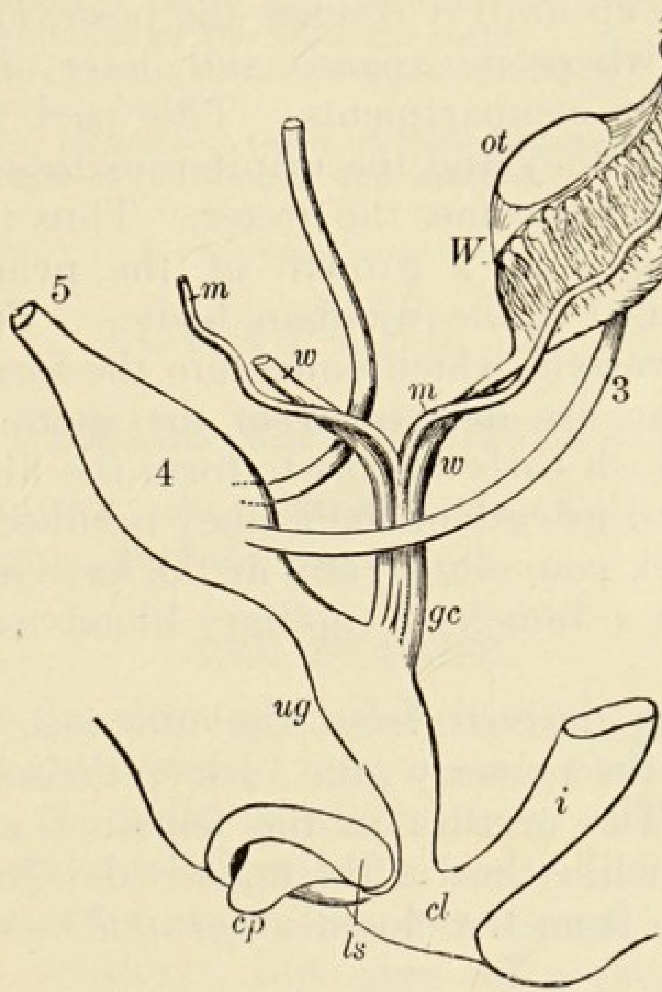


Diagram of the primitive urogenital organs in the embryo previous to sexual distinction. The parts are shown chiefly in profile, but the Müllerian and Wolffian ducts are seen from the front. 3. Ureter. 4. Urinary bladder. 5. Urachus. *ot*, The mass of blastema from which ovary or testicle is afterward formed; *W*, left Wolffian body; *w*, *w*, right and left Wolffian ducts; *m*, *m*, right and left Müllerian ducts uniting together and with the Wolffian ducts in *gc*, the genital cord; *ug*, sinus urogenitalis; *i*, lower part of the intestine; *cl*, common opening of the intestine and urogenital sinus; *cp*, elevation which becomes clitoris or penis; *ls*, ridge from which the labia majora or scrotum are formed. (Gray.)

are entodermic. The permanent kidney is preceded by the *Wolffian body* in the embryo.

The *Wolffian body*, as well as its duct which carries its secretions into the intestinal canal, are embryonic structures arising from the mesoderm, which lines the body cavity. These outgrowths form tubes from which secondary tubules arise, the whole forming the *Wolffian body*. The *Wolffian body* is composed of a long tube, the *Wolffian duct*, extending parallel to the vertebral axis in the lower part of the body-cavity, and the transverse *Wolffian tubules*, attached to the duct at right angles. A tube known as the *primitive kidney tube* grows out from the dorsal surface of the *Wolffian duct*. This tube grows up until it reaches the posterior part of the Wolffian body, where it expands and later divides into a number of tubular compartments. This part later becomes the pelvis of the kidney and the uriniferous tubules, while the unexpanded portion becomes the ureter. Thus the permanent kidney is developed as a growth of the primitive ureter, posterior and dorsal to the Wolffian body. The connective tissue and bloodvessels, which enter into the formation of the kidney and ureter, are derived from the surrounding meso-dermic tissue, which early begins to form the fibrous capsule, limits the outward growth of the kidney tubules, thus making those of the cortex convoluted, and at the extremities of these tubules develops a bunch of capillary bloodvessels to make the glomeruli.

The *bladder* is derived from the *allantois*, which is an outgrowth from the primary gut. Its epithelium is of ento-dermic origin. The urethra in the female is also a remains of the allantois, while that in the male is developed from the allantois and also from the closed *urogenital sinus*.

QUESTIONS.

What type of gland is the kidney?
What is the cortex? The medulla?
What are the columns of Bertini?
Describe the medullary rays and the labyrinth.
Name the parts of a uriniferous tubule.
Describe the Malpighian bodies.
Of what is Bowman's capsule composed?
Describe the cells of the proximal convoluted tubule.
Describe the descending limb of Henle.
How does the epithelium differ in the ascending limb of Henle?
Describe the epithelium of the collecting tubules.

What are the large tubes of Bellini?
What is the blood-supply to the kidney?
Where are the arches found?
What are the two sets of branches from the arches?
Trace the blood which goes to the glomerulus.
What is the pelvis of the kidney? What are its divisions called?
What empties into the calices?
Name the coats of the pelvis and ureter. Describe the mucous coat.
What are the coats of the bladder wall?
What portion does the serous coat cover?
Describe the muscular coat.
Describe the female urethra.
Name the kinds of epithelium found in the male urethra.
Describe the glands of Littré, and tell where they are found.
What is the peculiarity of the muscular coat?
From what layers are the urinary organs developed?
What is the Wolffian body?
From what is the connective tissue of these organs derived?
Describe the origin of the bladder and urethra.

CHAPTER X.

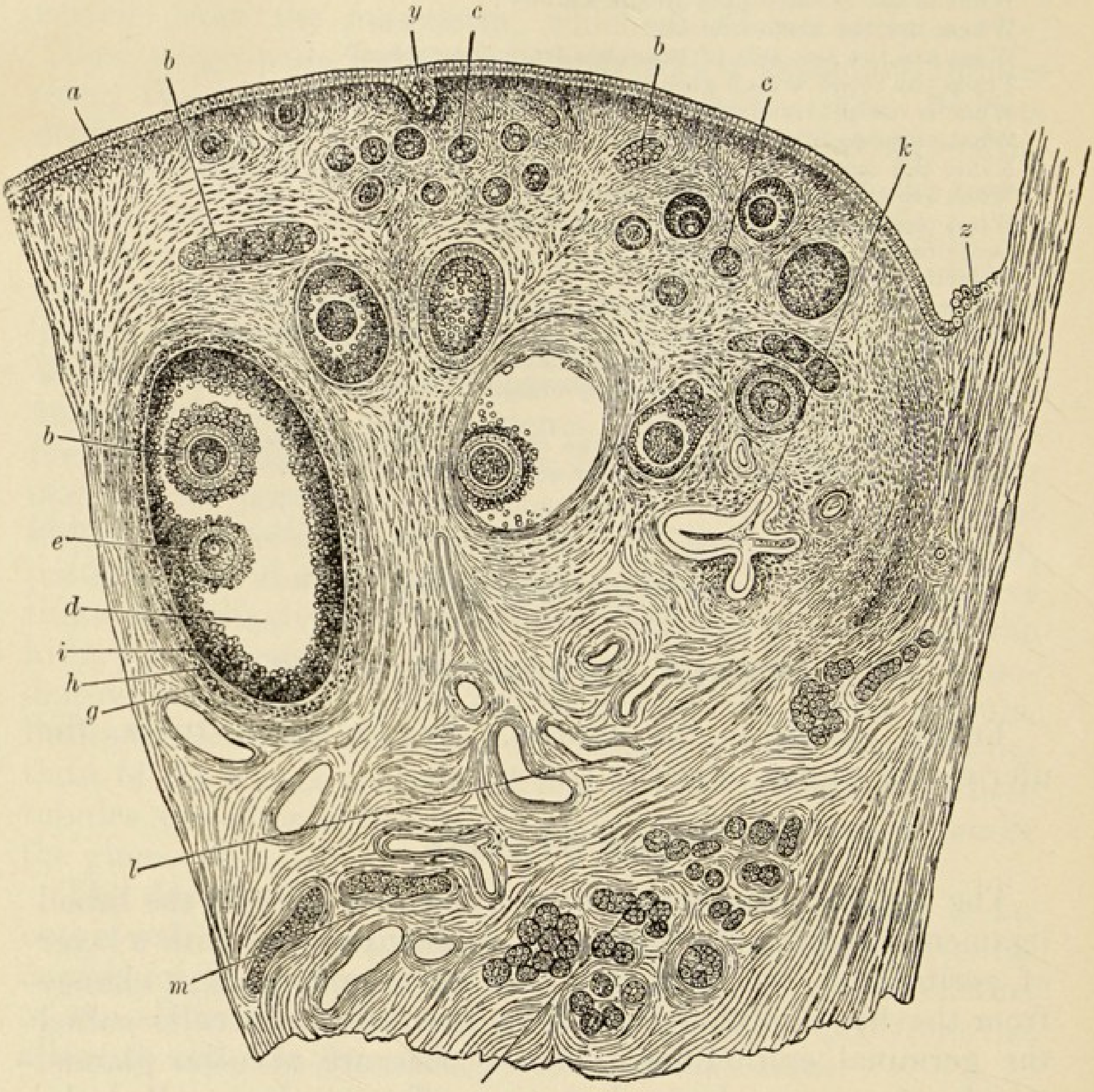
THE FEMALE REPRODUCTIVE ORGANS.

THESE comprise the ovaries, the Fallopian tubes, the uterus, the vagina, and the vulva.

THE OVARIES.

The ovaries are situated in the posterior part of the broad ligaments, and are flattened oval masses, covered with a layer of peritoneum, the cells of which have undergone a change from the flat endothelial cells to low columnar cells called the germinal epithelium. The ovaries are alveolar glands, which possess no ducts, but give off a product called the *ovum*. Each ovary is divided into the cortex or periphery, in which lie the *Graafian follicles* and ova, and into the medulla or centre, composed of a fibrous stroma containing the bloodvessels. The boundary between these two parts is not clearly defined. The stroma of the cortex of the ovary is a peculiar connective tissue, made up of a large number of spindle-shaped cells with little intercellular substance. The nuclei of these cells have a characteristic appearance, being long and oval, with a distinct nuclear membrane and a

FIG. 70.



Section from the ovary of an adult bitch : *a*, germinal epithelium ; *b*, *b*, columns of germinal epithelium within the stroma : *c*, *c*, small follicles ; *d*, much more advanced follicle ; *e*, discus proligerus and ovum ; *f*, second ovum in same follicle (a rare occurrence) ; *g*, fibrous coat of the follicle ; *h*, basement-membrane ; *i*, membrana granulosa of the epithelium ; *d*, liquor folliculi ; *k*, old follicle from which the ovum has been discharged ; *l*, bloodvessels ; *m*, *m*, sections of the parovarium ; *y*, ingrowth from the germinal epithelium ; *z*, transition from the germinal epithelium to the peritoneal endothelium. (Waldeyer.)

well-marked chromatin network, which, being larger than the ordinary connective-tissue nuclei, gives to them a resemblance to smooth muscle. Just beneath the germinal epithelium, at the periphery of the cortical portion of the ovary, this stroma is condensed, forming the *tunica albuginea,* the latter, however, being no distinct layer, as is the coat by the same name covering the testicle.

Many immature *Graafian follicles* in different stages of development are found in the stroma of the cortex. Only a small proportion of the ova in the ovary are ever matured, and it has been estimated by Henle that only about 400 of a possible 72,000 ova ever reach maturity; the rest undergo a degeneration or physiological process called *follicular atresia.* Some of the follicles are surrounded by one or more layers of polygonal cells derived from an ingrowth of the cells from the germinal epithelium and also by a condensation of the stroma arranged in concentric layers. This is the early stage of their development toward the large mature Graafian follicle, which in diameter spans the entire cortex and projects on the free surface of the ovary.

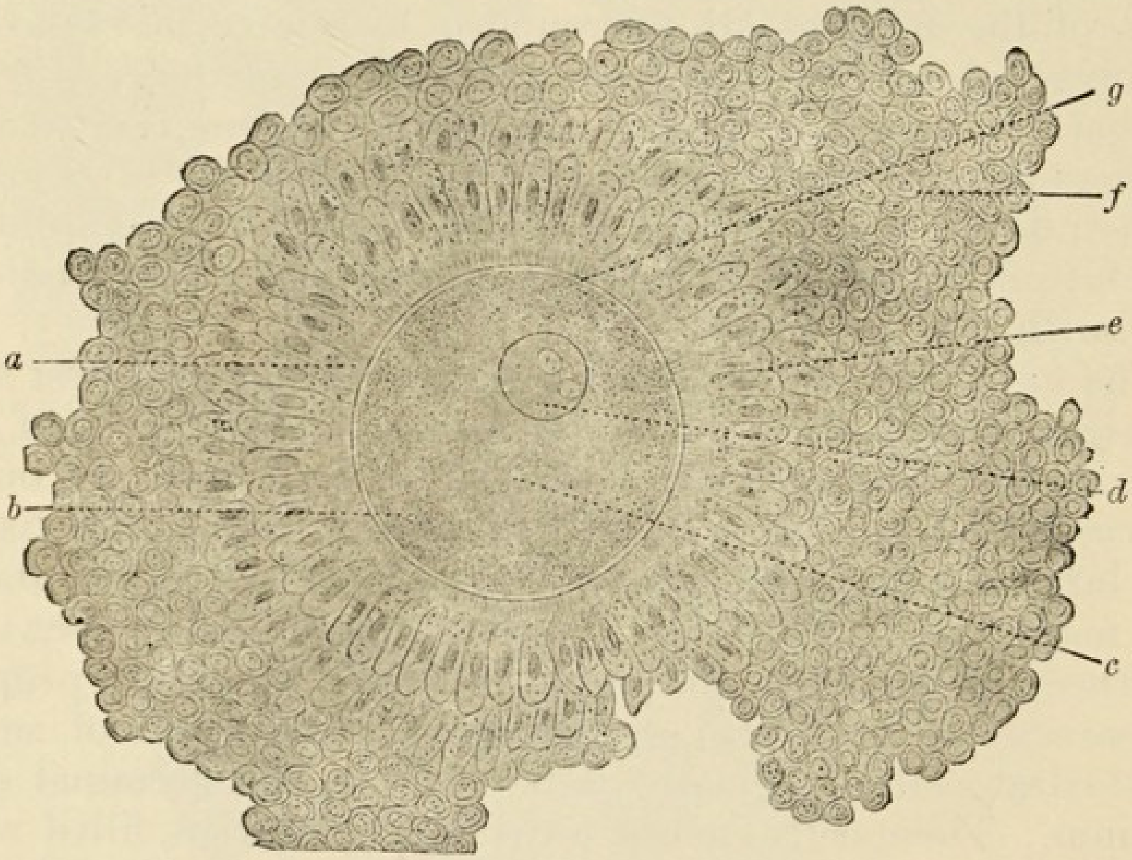
The mature *Graafian follicle* is a spherical or oval cyst and is surrounded on its outer border by a condensed layer of the stroma, the *theca folliculi,* composed of two parts, an outer *tunica fibrosa,* consisting mostly of fibrous connective tissue and large bloodvessels, and an inner *tunica propria,* containing many cells and small capillary bloodvessels. Next to the theca internally is the outer layer of the follicle proper, the *membrana granulosa,* consisting of many layers of small polyhedral cells, originally derived from the germinal epithelium. These cells enclose a cavity, the *antrum,* filled with an *albuminous* fluid, the *liquor folliculi,* and at one side the cells of the membrana granulosa which here have formed a thick mass, the *discus proligerus.* The discus proligerus has embedded within it the *ovum,* a spherical body about $\frac{1}{100}$ inch in diameter.

The inner layer of cells of the discus proligerus are arranged vertically to the surface of the ovum and form the *corona radiata,* inside of which is a membrane having delicate radial striations, the *zona pellucida.* Within this zone is the ovum proper, enclosed within its own cell-wall, the *vitelline membrane.* The ovum is composed of its cell-wall, the *vitelline membrane*, the protoplasm or *vitellus*, and a nucleus and a nucleolus.

The *vitellus*, or yolk, is granular, having embedded within it, especially near the periphery, fat-globules.

The *germinal vesicle* corresponds to the nucleus of a cell, and consists of a delicate, structureless membrane containing a clear matrix in which is found the *germinal spot*, or nucleolus, which is of a yellow color and finely granular.

Fig. 71.



Human ovule and its surroundings in the ovary: *a*, *g*, vitelline membrane (zona pellucida and zona radiata); *b*, *c*, vitellus or cytoplasm of ovule; *d*, nucleus or germinal vesicle; *e*, corona radiata; *f*, cells of cumulus ovigerus. (Nagel.)

The formation of the mature Graafian follicle begins before puberty, and some nearly mature follicles have even been found in the ovaries of the fœtus. The ovum as described above has to undergo another change, or *ripening process*, before it is ready for fertilization. This will be described in a later chapter.

After the Graafian follicle ruptures and the ovum is discharged, the remaining cavity is filled with blood and cells from the membrana granulosa. These contents undergo a change or degeneration, giving the mass a yellow appearance, and this structure is called the *corpus luteum*, which finally is absorbed and results in a mere scar or cicatrix. If an ovum which is discharged has become fecundated, the corpus luteum is supposed to become larger and remain longer than one remaining after an unfecundated ovum has escaped, thus giving rise to the terms true (fecundated) and false corpora lutea.

The medulla is composed of fibrous connective tissue with fewer spindle-shaped cells than are found in the cortex. Involuntary muscle-fibres are also present surrounding the bloodvessels, with which this part is richly supplied. The bloodvessels are derived from branches of the ovarian artery, a direct branch of the abdominal aorta. They enter at the hilum and penetrate to the medulla, from here sending off capillary twigs to the cortex, forming a network around the Graafian follicles. Lymphatics surround the Graafian follicles in a network and leave the ovary through the hilum.

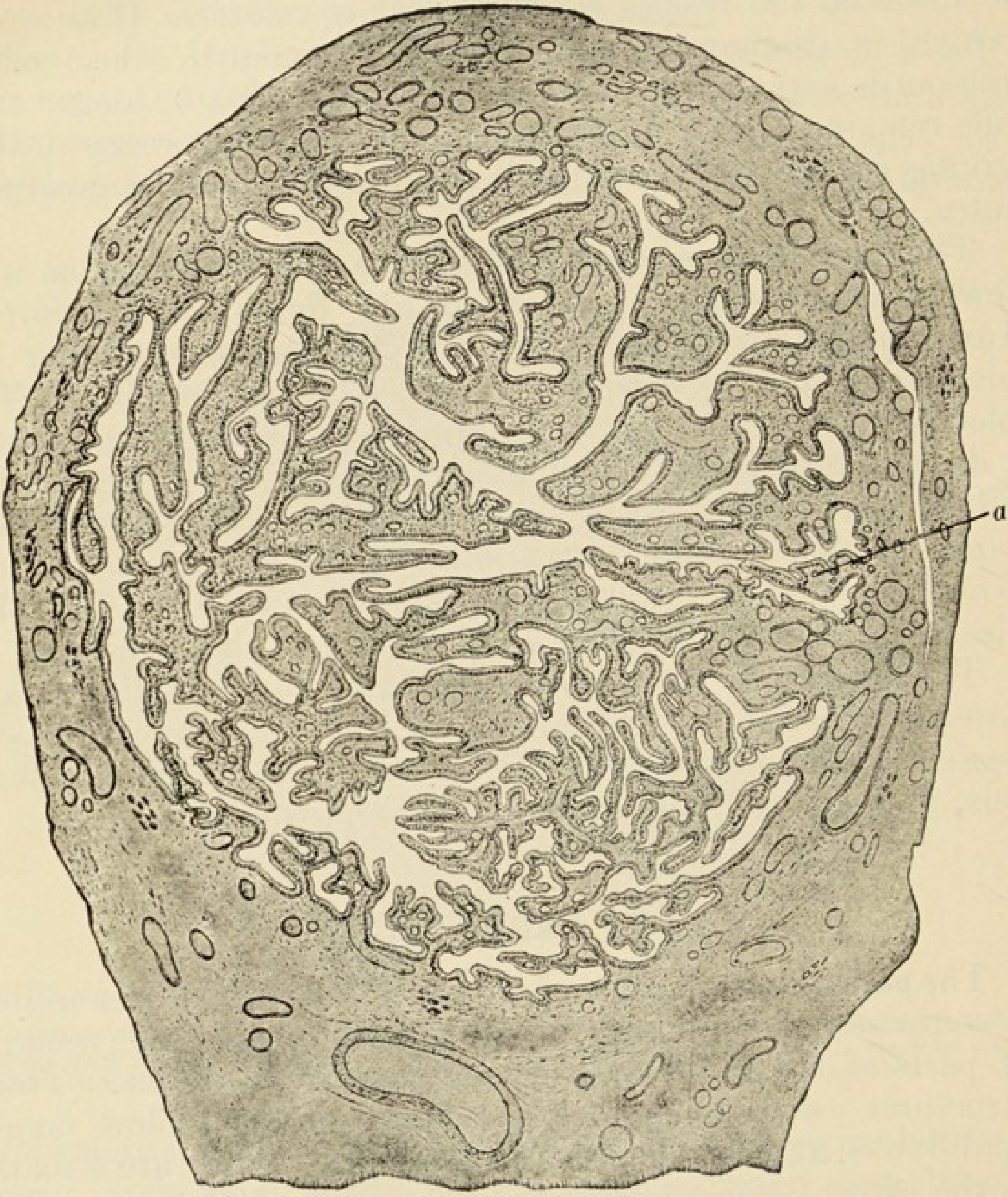
The *nerves* are both medullated and non-medullated, and entering through the hilum, follow the course of the bloodvessels. The nerve-fibres end in the walls of the bloodvessels, the germinal epithelium, and surround the follicles.

THE PAROVARIUM.

The **parovarium**, the epoöphoron or the organ of Rosenmüller, is composed of a number of tubular structures, the remains of parts of the Wolffian body and duct in the fœtus. These structures correspond to the tubules of the globus major, epididymis, and vas deferens in the male. They are situated in the broad ligament, between the ovary and Fallopian tube, and are lined with low columnar epithelial cells similar to those lining the original embryonic canals. Other rudimentary tubules constituting the paroöphoron, homologous with the paradidymis in the male, are almost constantly present in the broad ligament.

The *hydatid of Morgagni*, a pedunculated vesicle lined with cuboidal epithelium and the remains of the Müllerian duct, is frequently present. When the Wolffian duct does not com-

FIG. 72.



Transverse section of the Fallopian tube near its free end. Numerous branching villous projections of the wall, covered by ciliated columnar epithelium, extend into the lumen. The open spaces in these villous projections are sections of the bloodvessels. (Orthmann.)

pletely atrophy and remains as a canal in the broad ligament and vagina, to open occasionally near the urinary meatus, it is known as the *duct of Gärtner*.

THE FALLOPIAN TUBES.

The **Fallopian tubes**, or **oviducts**, which carry the ova from the ovaries to the uterus, lie between the folds of the broad ligaments and extend from the cornua of the uterus out toward the ovaries, ending with the fimbriated extremities, which open into the peritoneal cavity. Each tube consists of three coats, the inner mucous, the middle muscular, and the outer serous.

The *mucous coat* is thrown into deep longitudinal folds especially toward the fimbriated end, where they are highest and have many branched accessory folds, causing the lumen to be filled, and this gives to a cross-section the characteristic labyrinthine appearance. The epithelial cells lining the oviduct are in a single layer and of the columnar ciliated type, resting upon a firm tunica propria containing connective-tissue cells.

Beneath the tunica propria are found some scattered bundles of involuntary muscle-fibre, constituting a muscularis mucosæ, and below this a submucous layer made up of areolar connective tissue. The cilia of the columnar cells wave from the ovarian end toward the uterus. There are no glands present in the mucous membrane of the tube.

The *muscular coat* is composed of a thick inner circular layer and a thinner outer longitudinal layer of involuntary muscle-fibre, both of which layers are thicker near the uterus than at the fimbriated extremity.

The *fibroserous coat* consists of a fibroëlastic connective tissue covered by the flat endothelial cells of the peritoneum. Bloodvessels, lymphatics, and nerves are found situated in the submucosa.

THE UTERUS.

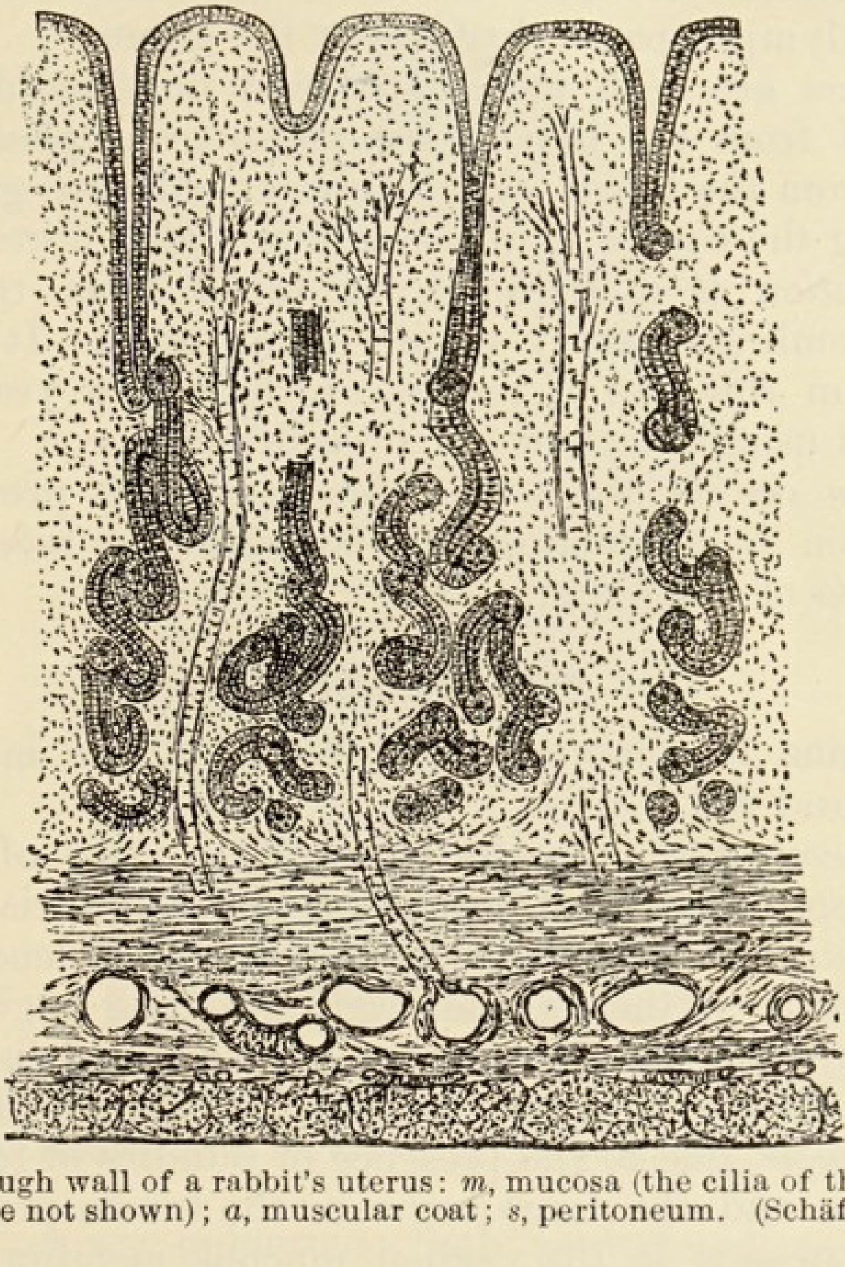
The **uterus**, like the Fallopian tube, is composed of three coats, the mucous, the muscular, and the serous. It is an organ made up mostly of the muscular layer, having a thin external serous coat and an inner mucous coat.

The *mucous coat* consists of a single layer of columnar ciliated epithelium resting upon a basement-membrane, the tunica propria, which is made up of bundles of fibrous and elastic tissue, containing many lymphoid cells in its meshes. Embedded within the tunica propria are the uterine glands. These are slightly wavy tubular glands, unbranched and placed perpendicular to the surface of the mucous membrane. They extend to the muscular layer and are lined with a single layer of columnar ciliated epithelium. The submucosa is absent in the uterus and the epithelium is almost in direct contact with the muscular layer. The mucous membrane appears different at the various stages of a woman's life. During the virgin state after puberty, the mucosa is from 1 to 2 mm. thick, and is covered with columnar ciliated epithelium. During the menstrual period the mucosa thickens, due to an increase in connective-tissue cells and of leucocytes and to an increased blood-supply. Following this stage we have a degeneration of the mucosa with rupture of some of the vessels, leaving only connective tissue and bloodvessels present. Regeneration now begins and the mucous membrane resumes its normal appearance. Should pregnancy, however, occur, characteristic changes take place and there occurs the formation of the *deciduæ*, which are intimately connected with the development of the ovum in the uterus. The mucous membrane of the cervix is thicker than that of the uterus proper, and in the lower third is thrown into papillæ covered with stratified squamous epithelium containing numerous short mucous crypts, the mouths or ducts of which occasionally become occluded and the gland distended with a thick, glairy mucus. These retention-cysts are known as the *Nabothian follicles*, and may be seen as yellow vesicles by the naked eye. The uterus has no submucous coat and the mucous membrane lies directly in contact with the muscularis, with the uterine glands extending down into the muscle coats.

The *muscular coat* makes up the bulk of the organ and is divided into three strata composed of bundles of involuntary muscle-fibre, separated by a small amount of connective tissue. The muscle-fibres are made up of spindle-shaped cells containing one or more nuclei. The size of the cell increases greatly during pregnancy; in the non-pregnant uterus they are about 50 μ long, while at full-term pregnancy they may reach a length of 500 μ.

These layers of muscle are the inner, which is longitudinal and next to the mucosa; the middle, which is arranged circu-

Fig. 73.



Section through wall of a rabbit's uterus: *m*, mucosa (the cilia of the epithelium are not shown); *a*, muscular coat; *s*, peritoneum. (Schäfer.)

larly, is the thickest and contains numerous bloodvessels; and the outer which is longitudinal and next to the serous coat. In the cervix the layers of the muscular coat are more distinct. The serous coat consists of a layer of fibrous tissue resting upon the outer muscular layer, and covered on its outer surface by the endothelial cells of the peritoneum.

The *blood-supply* to the uterus is especially abundant, and consists of branches from the ovarian and uterine arteries, which penetrate the serous coat and form a capillary network in the muscular layer, around the glands, and under the mucosa. The veins form a plexus in the deeper parts of the mucosa and a still larger plexus in the middle muscle-layer.

The *lymphatics* are also numerous and form a network of canals and lymph-spaces throughout the organ.

The *nerves* are both medullated and non-medullated, and are derived from the hypogastric and ovarian plexuses, with branches from the lower sacral nerves. Minute ganglia are found along the course of the non-medullated fibres.

Menstruation is a discharge of blood from the uterine mucous membrane every twenty-eight days. It occurs in women from the ages of fourteen to forty-five years, and at each period usually lasts from three to four days.

Ovulation occurs about this time, and it is probable that menstruation has something to do with the reception and preservation of the ovum.

THE VAGINA.

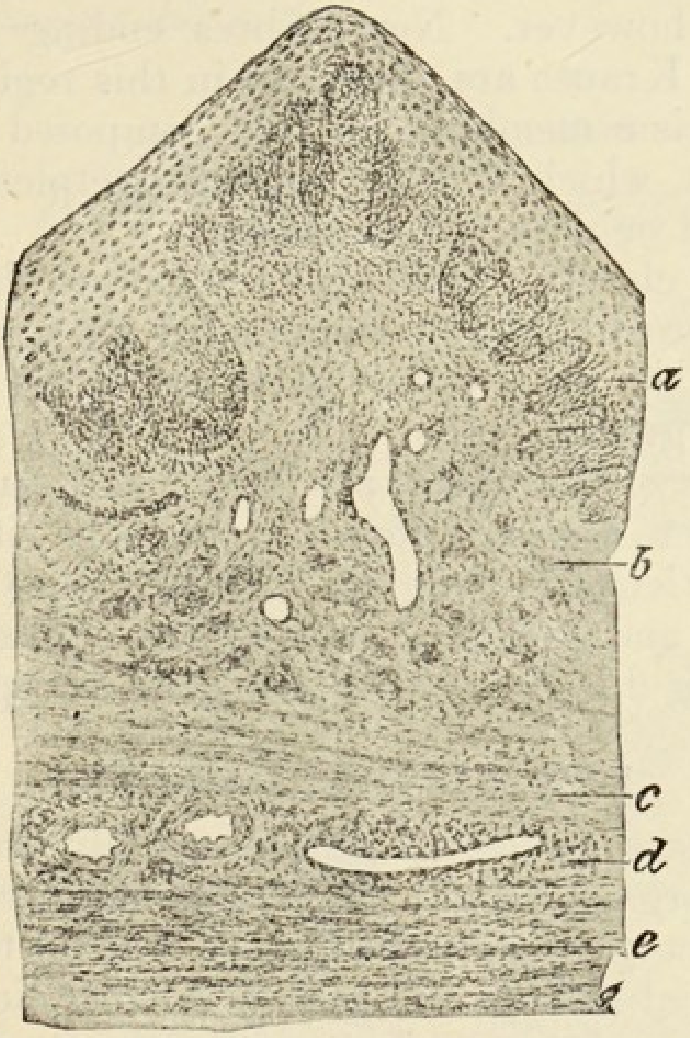
The **vagina** is composed of three coats, the mucous, the muscular, and the fibrous.

The *mucous coat* consists of a thick layer of stratified squamous epithelium resting upon a tunica propria composed of fibroëlastic tissue rich in leucocytes. The leucocytes are very abundant in the anterior wall near the vaginal orifice and cause the mucous tissue to resemble adenoid tissue. The mucosa is thrown into papillæ and into larger longitudinal folds, the *rugæ*, due to the presence of bundles of involuntary muscle-fibre and the large veins in the tunica propria. No glands are present in the vaginal mucous membrane, but an acid watery solution is produced which is probably the product of the mucosa.

The vascular submucosa separates the mucosa from the *muscular layer*, which consists of an inner circular and an outer longitudinal layer of involuntary muscle.

The *fibrous coat* consists of a dense fibrous tissue rich in yellow elastic fibres, which give great strength to the vaginal walls. The *blood* and *lymphatic* vessels are very abundant and form a network between the mucous and muscular coats. Large venous channels lie between the muscular layers, giving it the characteristic cavernous tissue appearance.

FIG. 74.



Portion of a longitudinal section of the vaginal wall: *a*, stratified epithelium; *b*, subepithelial areolar tissue; *c*, muscularis mucosæ; *d*, areolar submucosa containing vascular trunks; *e*, muscular coat. Outside of the latter is the ill-defined fibrous coat, not represented in the figure. (Benda and Günther's *Atlas.*)

The *nerves* are numerous, both medullated and non-medullated. Special end-bulbs, the *genital corpuscles of Krause*, are found within the mucous membrane.

THE VULVA.

The **vulva** is covered with stratified squamous epithelium continuous with that of the vagina and skin. Numerous mucous and sebaceous glands open upon the surface of the integument, the deeper layers of which are pigmented. The *labia majora* consists of adipose, areolar, and muscular tissue, with glands, nerves, and bloodvessels, the whole being surrounded by the integument. The *labia minora* contain a rich network of blood-sinuses, surrounded by areolar tissue, constituting an erectile tissue. Sweat-glands, hair, and fat are not present, however. Nerve-fibres ending in the genital corpuscles of Krause are abundant in this region.

The *hymen* is a membranous fold composed of the mucosa of the vagina, which it more or less completely closes. It may be absent or very rudimentary.

The *clitoris* closely resembles in structure the penis. It is made up of erectile tissue, surrounded by a dense layer of fibrous tissue, the nerves to its *glans* ending on its free surface in the special genital bulbs.

The *glands of Bartholin* are two small racemose glands corresponding to *Cowper's glands* in the male, situated at either side of the outlet of the vagina. These glands are lined with mucous cells and secrete a mucoserous substance, emptying through a long duct lined with low cuboidal epithelium.

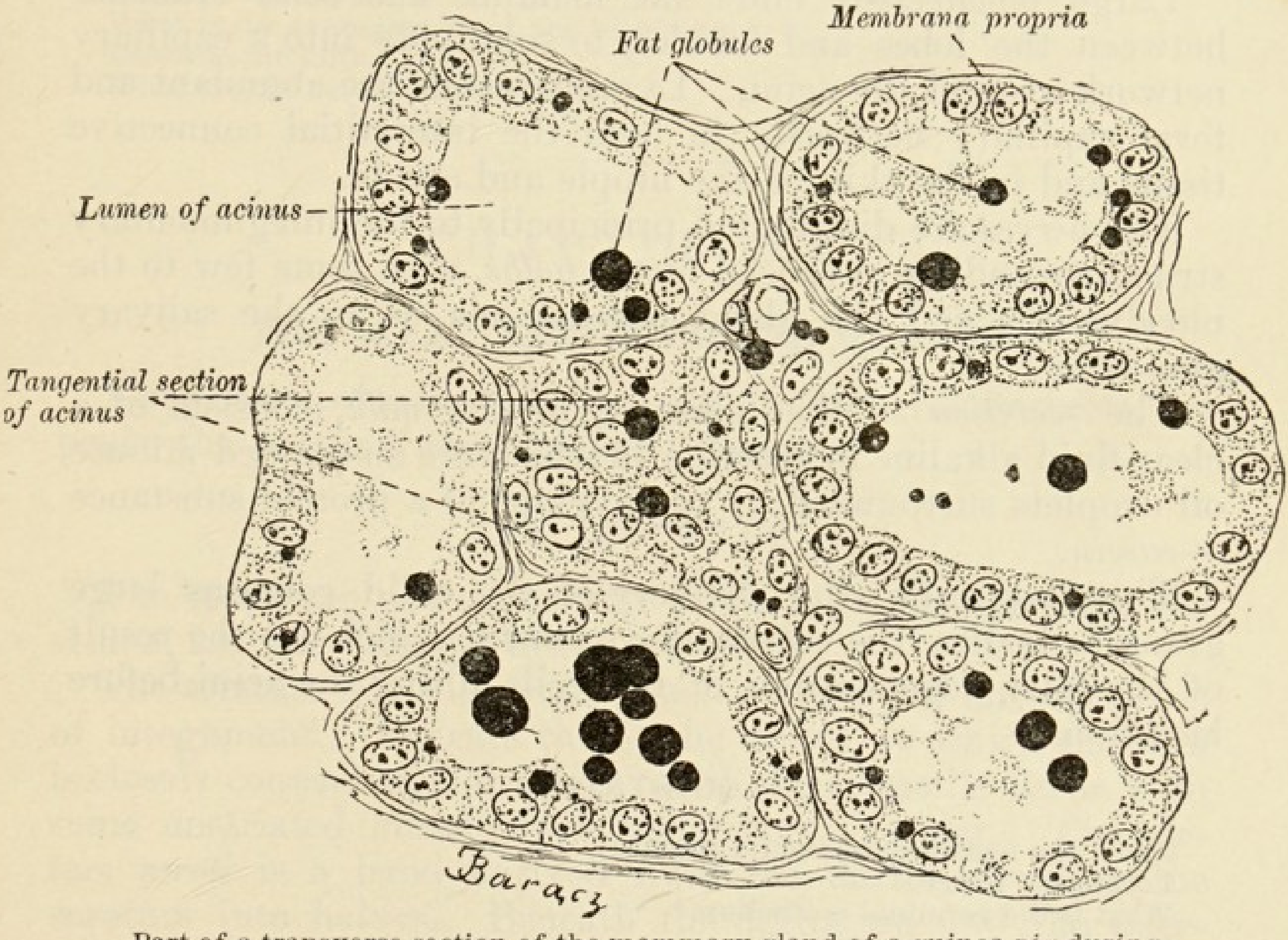
THE MAMMARY GLANDS.

The **mammary glands**, which are usually classed with the reproductive organs, should be more properly considered with the skin. They occur in both sexes, but up to puberty they remain identical in boys and girls. At that time, in the male they begin to undergo a retrograde metamorphosis, while in the female they develop to maturity. They are best studied in their fully developed state, during the period of lactation, for at other times they are in an atrophic condition.

The *mammæ* are compound tubular racemose glands, divided by fibrous septa into fifteen or twenty lobes, and these again into lobules, which in turn are composed of the alveoli or *acini*. The whole is held together by connective tissue, its interspaces being filled with adipose tissue.

The *acini* are lined with a single layer of columnar or polyhedral epithelial cells resting upon a basement-membrane, which when in the active or secreting stage are composed of a granular protoplasm filled with minute oil-drops. These globules become larger, and after nearly filling the cells are discharged into the lumen of the acini. Here they are mixed with an albuminous fluid and form the *lactiferous secretion.* This secretion is then carried by means of the secretory duct, which is lined with simple cuboidal epithelium, to the large *galactophorous ducts.*

FIG. 75.



Part of a transverse section of the mammary gland of a guinea-pig during lactation. × 500. (Szymonowicz.)

These ducts, about twenty in number, are lined with columnar epithelium until they reach a point near the nipple, when the stratified squamous epithelium appears, continuous with the epidermis of the skin. They converge toward the areola and become dilated, forming the *ampullæ* or *reservoirs* for the milk.

The *nipple* is made up of the milk-canals and bloodvessels, surrounded by fibroëlastic tissue and some few involuntary muscle-fibres, and covered with skin which is richly supplied by nerves terminating in its papillæ. The skin is perforated for the escape of the lactiferous secretion, and contains some pigment which varies in amount according to the color of the subject and stage of activity of the glands.

Small racemose glands, the *glands of Montgomery*, are found scattered around the base of the nipple.

Large *bloodvessels* enter the mammæ and send branches between the lobes and lobules, to subdivide into a capillary network around the acini. Lymph-vessels are abundant and form capillary networks in both the interstitial connective tissue and in the skin of the nipple and areola.

The *nerves* are distributed principally to the integumentary structures ending in special *tactile bulbs*, with some few to the bloodvessels and the gland parenchyma, as in the salivary glands.

The *secretion* of the mammæ, or the *milk*, consists of a clear fluid alkaline in reaction in which are suspended minute oil-droplets surrounded by an envelope of a proteid substance —*casein*.

The first milk after delivery of the child contains large granular bodies, the *colostrum corpuscles*, which are the result of the fatty degeneration of the cells filling the acini before lactation.

QUESTIONS.

Name the female reproductive organs.
Locate the ovary.
What is the germinal epithelium?
Describe the ovarian stroma.
What is the tunica albuginea?
Describe a mature Graafian follicle.
Describe the ovum.
What is the corpus luteum?
Describe the ovarian blood-supply.
What is the parovarium?
To what do these structures correspond in the male?
What is the paroöphoron?
Describe Gärtner's duct.
Locate the Fallopian tube. Name the coats.
Describe the mucous coat.

Name the coats of the uterus. Which is the thickest?
Describe the mucous coat.
What is the peculiarity about the relation of the mucous and muscular coats?
Describe the uterine glands.
Name the blood-supply to the uterus.
What are the Nabothian follicles?
Name the coats of the vagina.
Describe the mucous coat.
What are the glands of Bartholin?
Describe the labia minora and labia majora.
Describe the hymen and clitoris.
Describe the mammary glands.
Describe the acini.
Describe the nipple.
What is the arrangement of the blood-supply?
Describe the milk.
What are the colostrum corpuscles?

CHAPTER XI.

THE MALE REPRODUCTIVE ORGANS.

THESE comprise the testicles, with their excretory ducts, the penis, the prostate, and Cowper's glands.

THE TESTICLES.

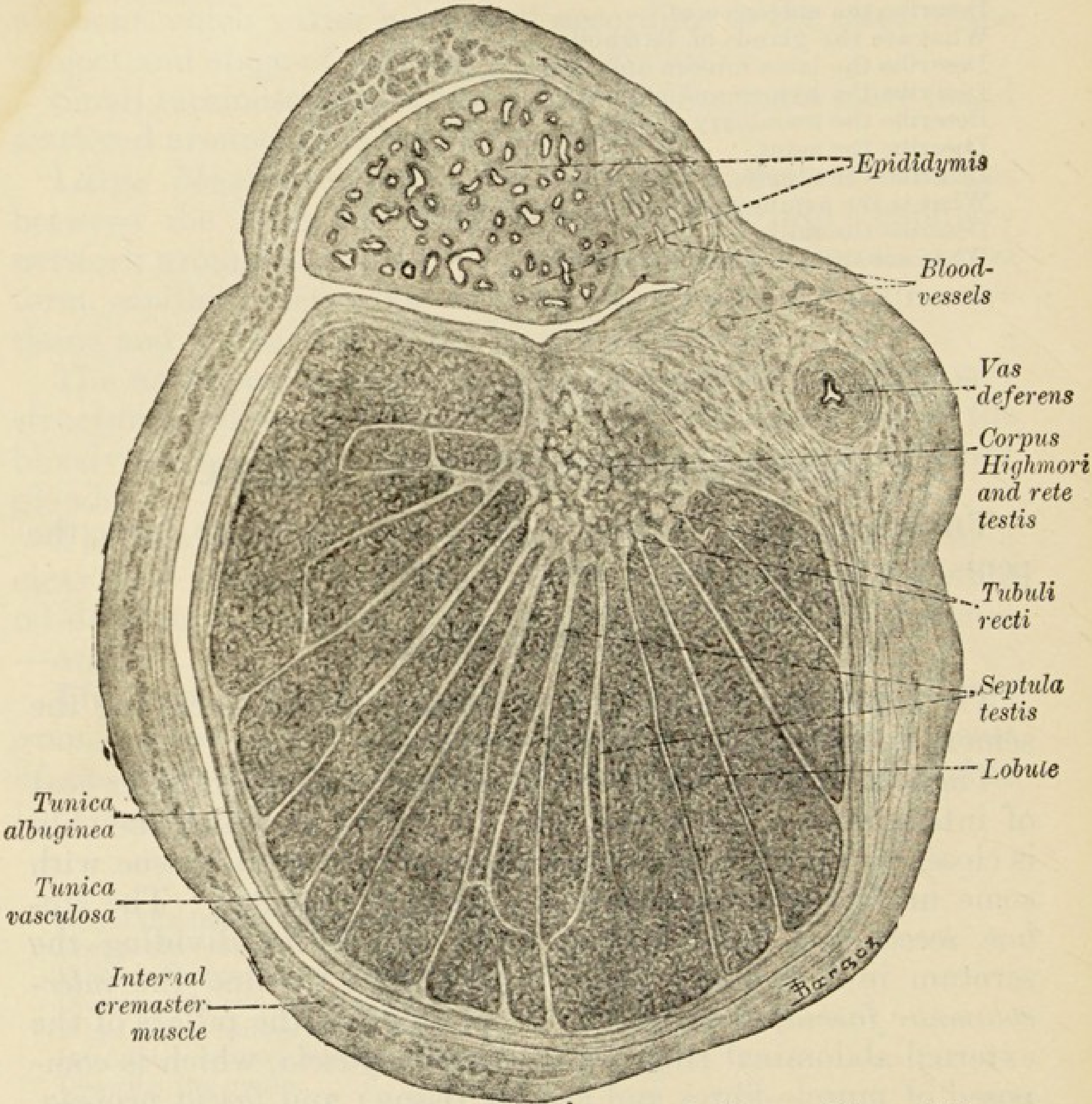
The **testes** are two compound tubular glands secreting the semen, and are situated in the scrotum.

The **scrotum** is a cutaneous pouch made up of an outer coat of integument. Beneath this is the *dartos*, to which the skin is closely connected, and is composed of contractile tissue with some unstriated muscle-fibre, being very vascular. The *septum scroti* is a band derived from the dartos, dividing the scrotum into halves. Beneath the dartos we find the *intercolumnar fascia*, from the fibres constituting the pillars of the external abdominal ring, the *cremasteric fascia*, which is composed of muscle-fibres and areolar tissue; and *fascia propria*, derived from the transversalis fascia. The next layer is the *tunica vaginalis*, or the true covering of the testicle.

The testicle proper is enclosed within a dense capsule of fibrous tissue, the tunica albuginea, and is surrounded by a serous sac, the tunica vaginalis.

The tunica vaginalis is a pouch of serous membrane which invests the testicle, and part of the head and body of the epididymis, extending upward into the spermatic cord for

Fig. 76.

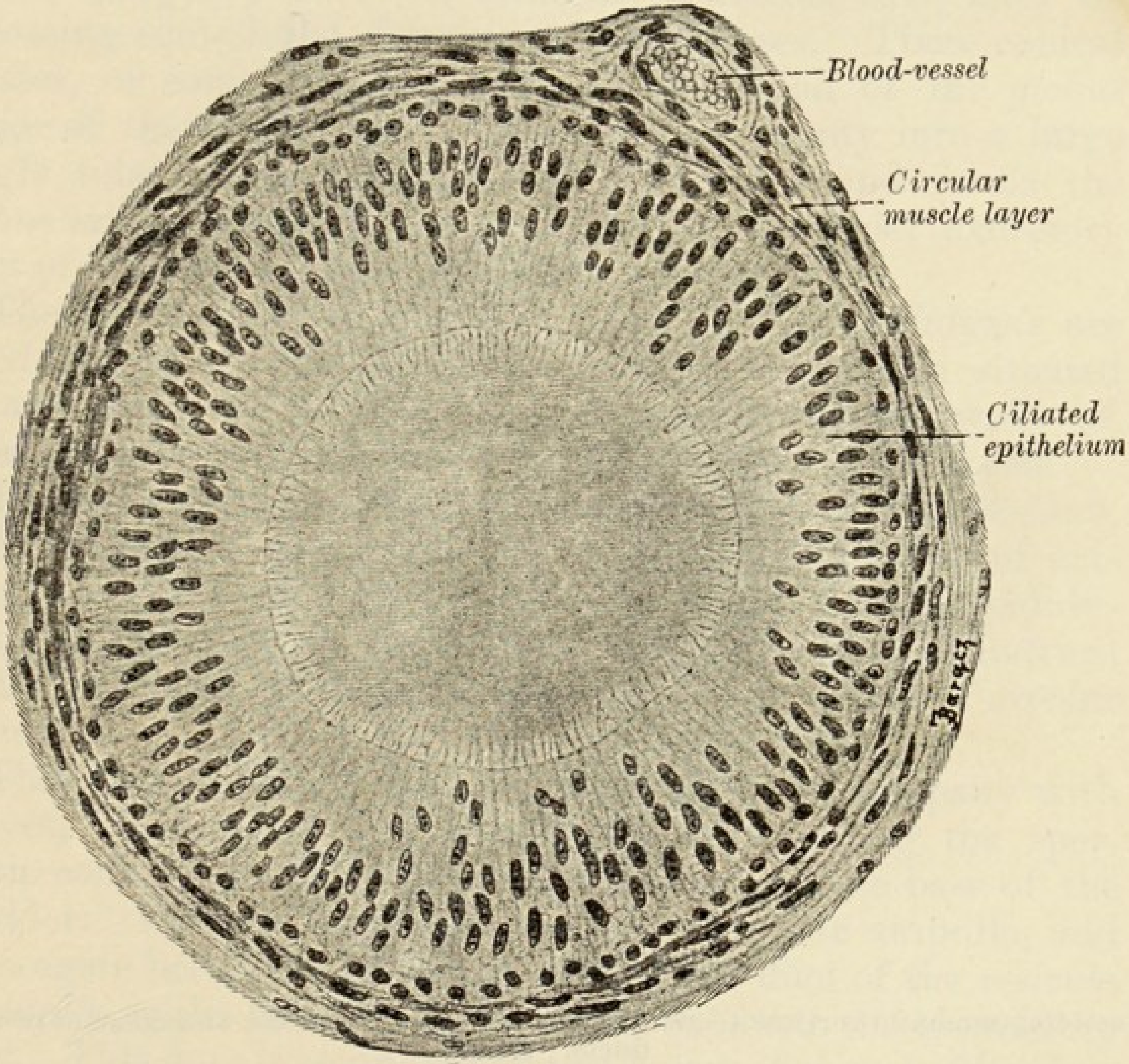


Transverse section of the testis of a two and a half year old boy. × 7. (Szymonowicz.)

about a half inch, derived from the peritoneum during the descent of the testicle in the fœtus. It has a visceral and a parietal layer, both lined with flattened endothelial cells, and acts as a bursa for the protection of the testicle and the head of the epididymis.

The *tunica albuginea* is composed of white fibrous tissue, and its inner side consists of a thin, highly vascular layer of fibroëlastic tissue, called the *tunica vasculosa*. Posteriorly it

FIG. 77.

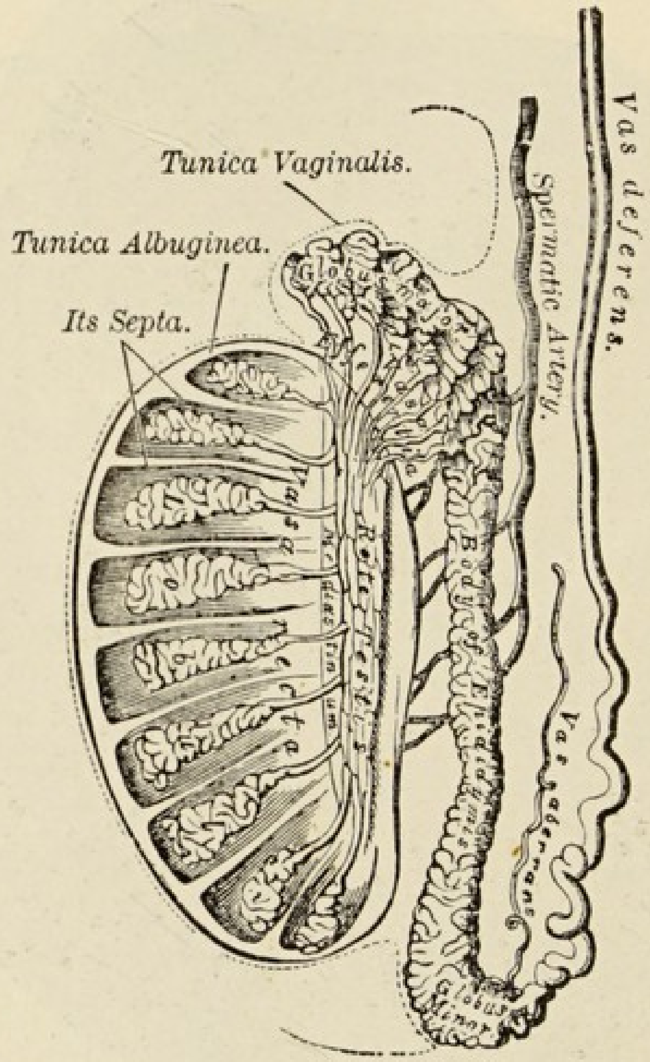


Transverse section of a human epididymis. × 300. (Szymonowicz.)

is thickened to form the *mediastinum* or *corpus Highmori*. The mediastinum gives off fibrous septa or *trabeculæ*, which divide the parenchyma of the testicle into cone-shaped compartments or lobules, each containing a number of seminiferous tubules. The mediastinum carries the bloodvessels to and from the gland.

The *epididymis* is the rounded elongated body with expanded ends which arches over the outer side of the posterior border and the upper end of the testicle. It is made up of a *body*, which is the main portion, the *globus major*, an upper large expanded portion, and the *globus minor* a lower smaller expansion.

FIG. 78.



Semidiagrammatic vertical section of the testicle, to show the arrangement of the ducts. (Gray.)

The *seminiferous tubules* are minute convoluted tubes lined with several layers of seminal cells placed on a hyaline basement-membrane and surrounded by a capillary network, the whole being held together by an intertubular connective tissue. These tubules as they approach the mediastinum from the periphery of the tubule lose their convoluted form and become narrow and straight, called the *vasa recti*, and are lined with a single layer of low columnar epithelium. After entering the fibrous structure of the mediastinum these tubules form a series of communicating channels, lined with a single layer of flattened epithelium, and are known as the *rete testis*. These tubules upon emerging from the mediastinum terminate in from fifteen to twenty ducts, the *vasa efferentia*, and after penetrating the *tunica albuginea* follow a straight course at first, later on becoming convoluted, forming conical masses. These conical masses, or *coni vasculosi*, make up the head of the *globus major* of the epididymis. These tubules empty into a large single tube which becomes very convoluted and forms the *globus minor*, which is the beginning of the chief excretory duct of the gland, namely, the *vas deferens*.

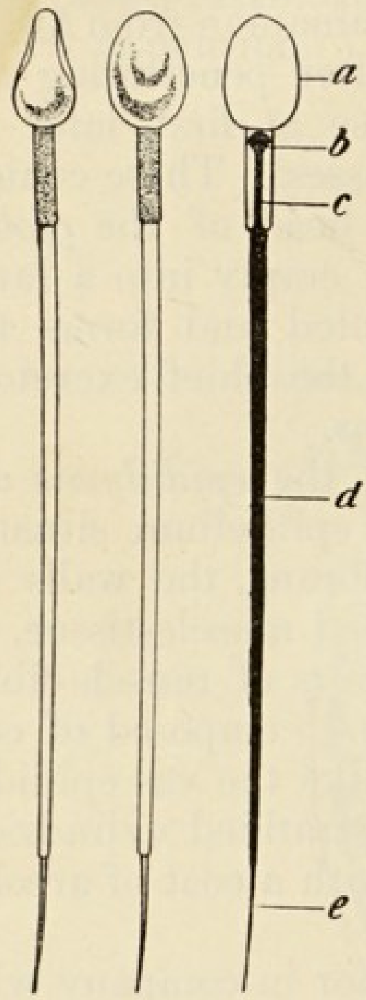
The *vasa efferentia* and the tubes of the *epididymis* are lined with a stratified columnar ciliated epithelium situated on a well-marked fibrous basement-membrane, the walls of tubules containing some circularly arranged muscle-tissue.

The *vas deferens* consists of several layers of muscle-fibre, lined internally with a mucous membrane composed of columnar ciliated cells, in the upper part like the vas epididymis, but lower down passes over into a stratified cylindrical epithelium, and externally it is covered with a coat of areolar tissue.

This duct extends from the globus minor in company with nerves, bloodvessels, and lymphatics, constituting the spermatic cord, up through the inguinal canal to the base of the bladder. Here it becomes wider, forming the ampulla, and then again becomes contracted, joining the duct of the *vesicula seminalis* at the base of the prostate to form the *ejaculatory duct*. This duct is composed of two layers of muscle-fibre surrounding a submucosa, which separates the tunica propria with its layer of columnar epithelial cells from the muscular layer.

The *seminiferous tubules* consist of three portions, the convoluted tubules constituting most of the lobules, the straight tubules formed at the apices of the lobule, and the tubules in the mediastinum forming the *rete testis*. These tubules are composed of epithelial cells, resting upon a basement-membrane, which is surrounded by a loose connective tissue rich in bloodvessels. In this interstitial connective tissue are found numerous large cells, known as *plasma-cells.* They have small nuclei, are rounded, coarsely granular, and contain fat-droplets, pigment, and crystalloids. They are situated in small groups or columns in the spaces between the adjacent seminiferous tubules. They are supposed to be of connective-tissue origin, but some authors claim that they are derived from epithelial cells. Their function is not known. The outer or parietal cells lining the tubules are of low cuboidal epithelium and of two kinds, the *sustentacular cells,* or *Sertoli's columns,* which are not concerned in the formation of the spermatozoa, and the *spermatogenetic cells.* Inside of this outer layer we find, during the activity of the gland, a second zone whose elements are large spheroidal cells undergoing rapid karyokinetic changes. These are the *mother-cells,* and are derived from the outer zone of spermatogenetic cells. These cells, after division, form the daughter-cells, or *spermatoblasts.* The nucleus of these daughter-cells develops into the head of the spermatozoön through a succession of changes, and the completed spermatozoön may be seen in the lumen of the tubule.

FIG. 79.



Human spermatozoa; the left figure represents the side view and the middle figure surface view of a spermatozoön. *a,* head (nucleus); *b,* end-knob (centrosome); *c,* middle piece; *d,* tail of flagellum; *e,* end-piece. The thickness of *d* may be owing to the presence of a sheath surrounding the actual flagellum, which projects from the sheath at *e.* (Böhm and Davidoff, after Retzius and Jensen.)

The *blood-supply* of the testicle is derived from the spermatic artery, which enters at the mediastinum and sends branches through the septa between the lobules to form a fine capillary network around the tubules.

The *veins* collect in the interstitial connective tissue between the lobules and leave the organ by the path of the arteries, through the mediastinum.

The *lymphatics* form a superficial and a deep plexus, the vessels from each anastomosing and forming large vessels, which, after uniting with the lymphatics from the epididymis, become a part of the spermatic cord. The final *ending* of the *nerves* supplying the testes is not known.

The *semen*, the secretion of the testicle, is composed of spermatozoa, epithelial elements, fluid from Cowper's glands, together with a number of granular and hyaline bodies.

The *spermatozoa*, which are the active agents of the semen, are made up of a head, a middle piece, and a tail. In 1 cubic millimeter of semen it has been estimated that there are about 60,000 spermatozoa.

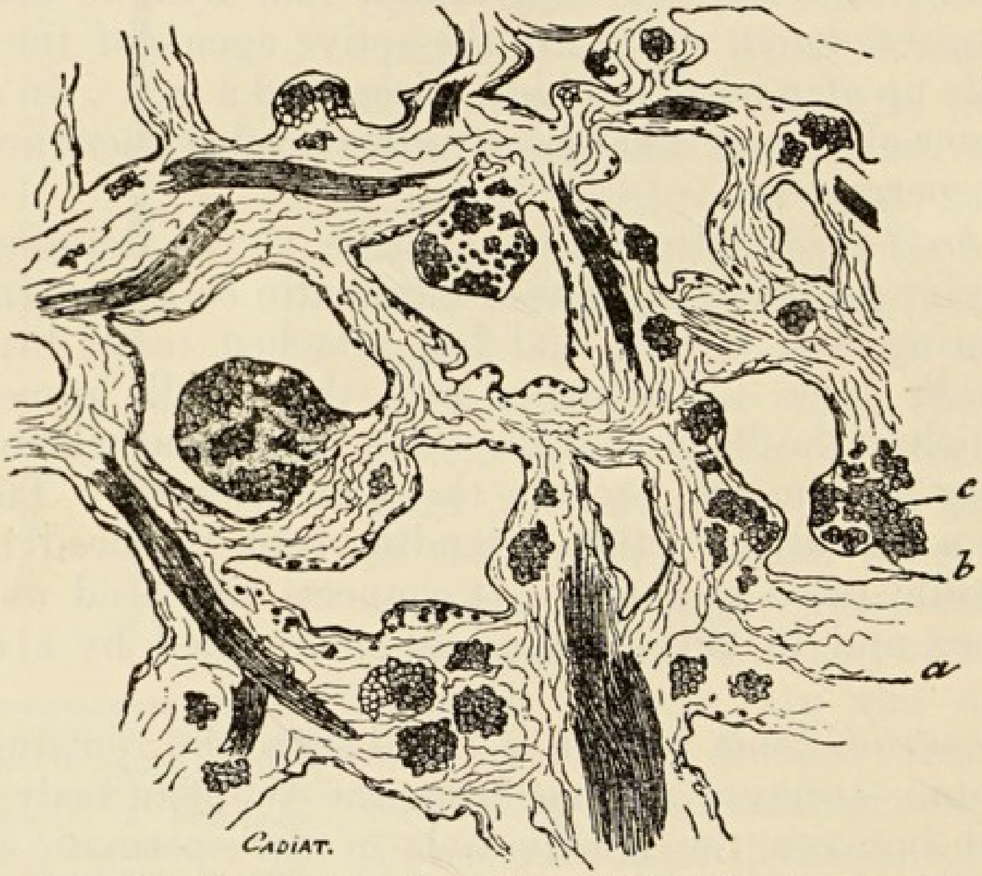
The *head* is of flattened, oval shape, shows depressions in its anterior part, and consists of chromatin substance (nuclein) constituting the nucleus, and has attached to its broad end the *middle piece*. Continuous with the middle piece is the *tail*, which is the longest of the three parts, and which, by its vibratory movements, propels the spermatozoön. The *axial fibre* is a delicate structure extending from the head through the middle piece and tail. It connects the head and middle piece, and in this location is surrounded by a delicate sheath.

The *paradidymis* (organ of Giraldè) is the remains of an embryonic structure arising from the Wolffian body, and is situated between the bloodvessels of the spermatic cord in the neighborhood of the testis. This structure consists of a few blind tubules lined with a layer of ciliated epithelium. Similar embryonic remnants, the *ductali aberrantes*, consisting of tubules with blind ends and lined with ciliated epithelium, are connected with the vas epididymis. The *hydatid of Morgagni* is another similar structure, made up of vascular connective tissue and lined with ciliated epithelium, situated in the upper part of the head of the epididymis, and probably the remains of the embryonic structure known as Müller's duct.

THE PENIS.

The **penis** consists of three cylindrical masses of erectile tissue, the two *corpora cavernosa* and the *corpus spongiosum*, with the glans penis at the apex, all enveloped in a fibrous sheath and covered with skin and subcutaneous tissue, the latter containing no fat. The *corpora cavernosa* are two fibrous cylindrical tubes, surrounded by a dense fibroëlastic sheath, the *tunica albuginea*, composed of white and elastic

Fig. 80.



Cavernous or erectile tissue of penis: *a*, fibrous trabeculæ; *b*, cavernous sinuses; *c*, smooth muscle in cross-section. (Cadiat.)

fibres longitudinally arranged and forming a common covering for both bodies. Each corpus is composed of an envelope of white fibrous and elastic tissue, circularly arranged, and enclosing the erectile tissue. This coat forms the *pectiform septum* which separates the two bodies.

The erectile tissue is composed of fibrous trabeculæ derived from the enveloping coat and containing bundles of involuntary muscle-fibre. They go to make up a system of communicating *venous sinuses* or *cavernous spaces*, lined with flattened endothelial cells. These sinuses are distended with blood during erection, but in the quiet stage are not concerned in the nutrition of the tissue.

The *corpus spongiosum* is similar to the corpus cavernosum, with the exception that the enveloping membrane is thinner and more elastic, the trabeculæ are finer, the sinuses smaller, and through its centre runs the urethra. The anterior part of the outer extremity expands to form the *glans penis*, which is covered with stratified squamous epithelium containing many special sensory nerve-terminals. Sebaceous glands, the *glands of Tyson*, whose secretion mixed with epithelial elements goes to form the smegma, are found at the base of the glans where it joins the prepuce.

The *blood-supply* to the erectile tissue is derived from the dorsal artery of the penis and the arteries of the corpora cavernosa. The bloodvessels penetrate the fibrous capsule and, entering through the trabeculæ, communicate directly with the venous sinuses. Veins gather up this blood and carry it to the dorsal vein by the same route followed by the arteries. The arteries supplying nutrition to the structures consist of a distinct set, being branches of the above-named vessels, but not communicating with the blood to the cavernous sinuses. These nutritive vessels are very tortuous in their course and are known as the *helicine arteries*.

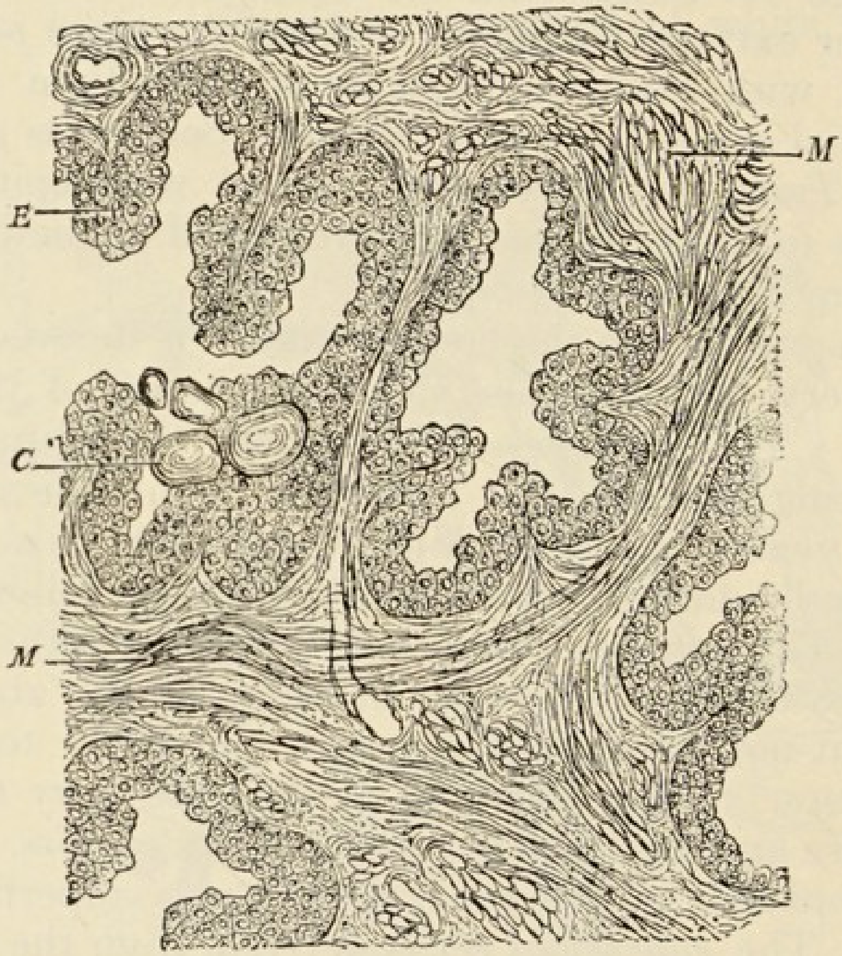
The *lymphatics* of the penis consist of a superficial and a deep set. The *superficial* set is derived from the glans, prepuce, and mucous membrane of the urethra, and terminate in the superficial inguinal glands, while the *deep* set come from the corpus spongiosum and cavernosum and end in the deep pelvic lymphatics.

Sensory and *motor nerves* supply the structures of the penis, while some of the sensory nerves end in the special genital bulbs on the glans.

THE PROSTATE.

The **prostate** is a compound tubular gland covered by a dense capsule composed of fibroëlastic tissue containing some involuntary muscle-fibres. The greater part of the prostate is composed of a firm connective tissue containing many bundles of smooth muscle-fibres. The lesser part is of glandular structure, and contains within its body a portion of the urethra and ejaculatory ducts. From the muscular coat surrounding the prostate and from the muscular layer surrounding

FIG. 81.



Section of the prostate. Sections of one acinus and portions of three others are included in the figure. These are surrounded by fibrous tissue traversed by bundles of smooth muscular fibres. *E*, epithelial lining of the acini; *M*, *M*, smooth muscular tissue; *C*, concretions of amyloid material, showing concentric lamination. (Hutzmann.)

the urethra, septa are given off which pass into the glandular structure of the organ. The interstitial tissue increases with age, while the glandular structures atrophy, thus producing the condition of hypertrophied prostate so often seen in old men. The *glandular* substance is made up of many pouches or alveoli opening into long canals, which empty on the free surface of the urethra. The alveoli are large and irregular, and are lined with a single layer of columnar epithelium, the nuclei of the cells being placed near the base of the cell.

The excretory ducts, near their termination, are lined with transitional epithelium similar to the lining of the prostatic portion of the urethra.

The alveoli often contain small, round, laminated masses of a calcareous nature, called the prostatic concretions.

The *prostatic sinus* is that portion of the prostate where the excretory ducts empty, and is marked by a depression on either side of a urethral crest. This sinus is lined with stratified squamous epithelium, continuous with that of the urethra.

The *uterus masculinus* occupies the anterior portion of the urethral crest, and is the homologue of the uterus and vagina of the female. The prostatic *secretion* is mucoid in character and acid in reaction, and enters into the composition of the semen.

The *bloodvessels,* which are derived from the pudic, vesical, and hemorrhoidal arteries, enter the capsule and send branches through the fibromuscular trabeculæ to form a capillary network around the alveoli.

The *lymphatics* originate in the clefts of the trabeculæ and, accompanying the veins, empty into the deep lymph-glands. *Medullated* and *non-medullated nerve-fibres* are found in the prostate, under the capsule, and in its trabeculæ.

COWPER'S GLANDS.

These are two small branched tubular glands, composed of several lobes, and are situated beneath the membranous urethra. The lobules are made up of acini lined with a single layer of columnar cells, the whole being held together by a fibromuscular connective tissue. The small ducts emptying the acini are lined with a cuboidal epithelium, which gradually becomes taller as the ducts increase in diameter. The two large excretory ducts are lined with a stratified epithelium, and empty into the posterior part of the urethra. The *secretion* is a clear, viscid fluid which enters into the formation of the semen.

The *bloodvessels* pass between the lobules and form networks around the acini.

DEVELOPMENT OF THE REPRODUCTIVE ORGANS.

The beginning formation of the genital organs is the appearance of a ridge due to a thickening of the lining of the body cavity. This *genital ridge*, or *indifferent sexual gland*, is placed near the Wolffian body, and is attached to it until about the seventh week of fœtal life, when the distinction of sex begins, the genital ridge becoming either the testicle or the ovary.

Internal Female Reproductive Organs.—The *ovary* is formed from the genital ridge by a thickening of the germinal epithelium covering it, with an ingrowth, into the substance of the ridge, of cells which go to form the primitive ova. These later become the mature Graafian follicles. The stroma of the ovary is produced by a secondary ingrowth of the surrounding mesoderm among the primitive ova.

The *Fallopian tubes* are from a portion of the *ducts of Müller*, these ducts being at first closed at their outer end, but later a cleft forms, which is developed into the fimbriated extremity of the tubes.

The *Müllerian duct* makes its appearance after the establishment of the Wolffian body, and is situated near and parallel to this latter structure, with its upper end opening into the body-cavity and its lower extremity ending in the cloaca and afterward within the urogenital sinus.

The *uterus* and *vagina* are formed from the two Müllerian ducts which coalesce, the intervening septum being absorbed and the cavity of the uterus and vagina formed. The Wolffian duct and tubules atrophy in the female and form the parovarium, Gärtner's duct, and the paroöphoron, which remain as vestigial structures.

External Organs.—About the sixth week of fœtal life a tubercle forms anterior to the cloaca. This is the *genital tubercle*, and is surrounded by two folds, the *genital folds*. Later a groove appears on this tubercle, forming the genital furrow.

Female.—The *clitoris* is derived from the *genital tubule*, the *labia majora* from the *genital folds*, and the *labia minora* from the lips of the *genital furrow*.

Male.—The *testicle*, except its excretory ducts, is derived from the *genital ridge* by an ingrowth of the epithelial cells

FIG. 82.

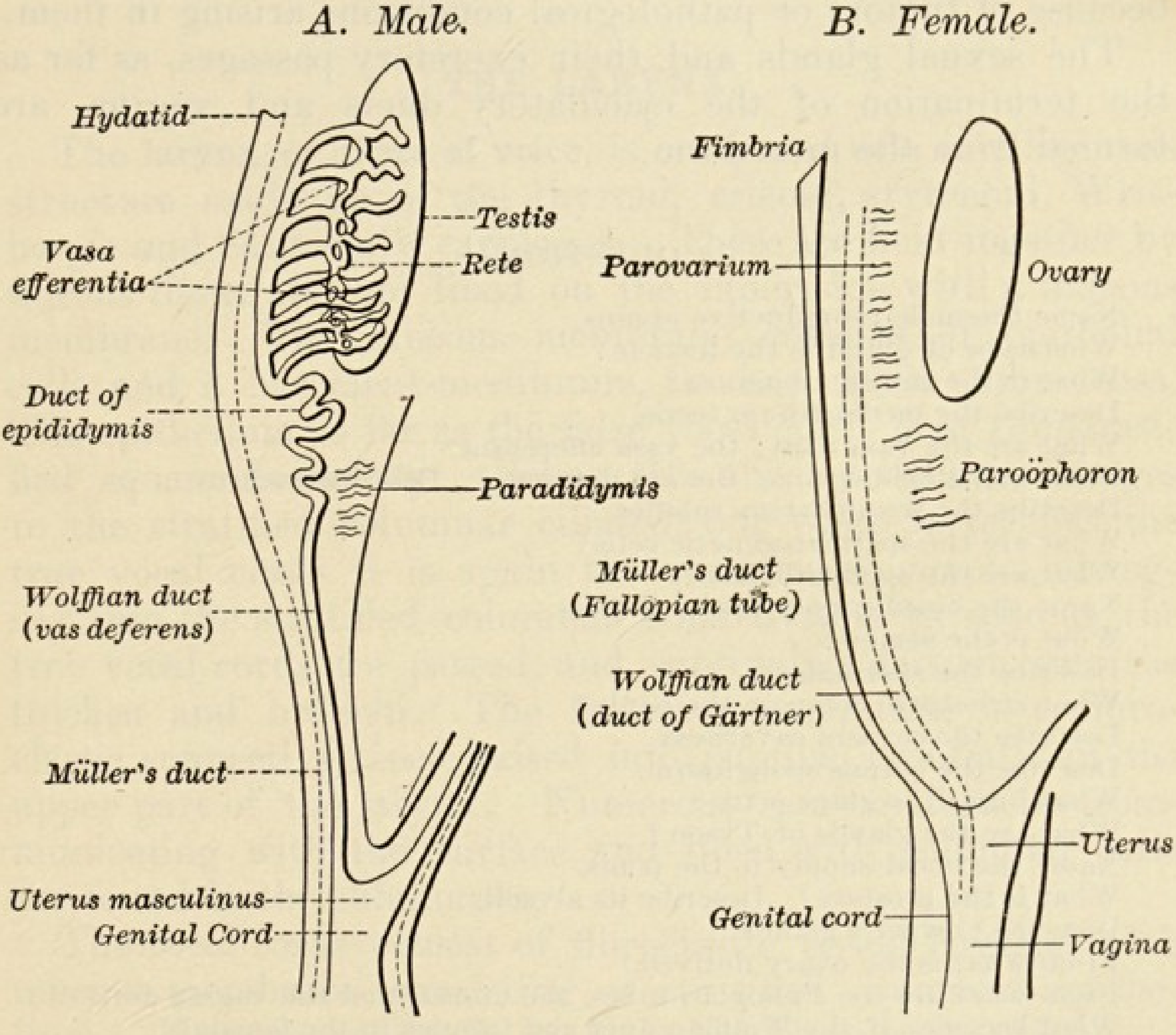


Diagram to illustrate the homologies of the sexual apparatus. (After Minot.)

covering it, forming the lining of the seminal ducts. The tubules composing the *globus major* and *paradidymis* are from the *Wolffian tubules*, while the *epididymis* and *vas deferens* are derived from the *Wolffian duct*.

The *penis* is derived from the *genital tubercle*, the penile portion of the urethra is formed by the closing of the *genital* *furrow,* while the *scrotum* is formed by the union along the median line of the two *genital folds.*

The ducts of Müller atrophy in the male, their upper extremity forming the hydatid of the epididymis, while the lower ends unite and form the uterus masculinus or sinus pocularis. These embryonic structures, which remain rudimentary in either male or female, are of interest largely because of tumors or pathological conditions arising in them.

The sexual glands and their excretory passages, as far as the termination of the ejaculatory ducts and vagina, are formed from the mesoderm.

QUESTIONS.

Name the male reproductive organs.
What type of gland is the testicle?
What is the tunica albuginea?
Describe the mediastinum testis.
What are the vasa recti; the vasa efferentia?
What is the epididymis; the vas deferens? Describe each.
Describe the seminiferous tubules.
What are the spermatogenetic cells?
What are the spermatoblasts?
Name the blood-supply to the testicle.
What is the semen?
Describe the spermatozoa.
What structures compose the penis?
Describe the corpora cavernosa.
Describe the corpus spongiosum.
What forms the glans penis?
What are the glands of Tyson?
Name the blood-supply to the penis.
What is the prostate? Describe its alveoli.
Describe Cowper's glands.
From what is the ovary derived?
From what are the Fallopian tubes, the uterus, and the vagina derived?
What becomes of the Wolffian duct and tubules in the female?
From what is the testicle derived?
What structures do the Wolffian duct and tubules make in the male?
From what is the penis derived?
What becomes of the ducts of Müller in the male?
From what layer of the blastoderm are the sexual glands derived?

CHAPTER XII.

THE RESPIRATORY ORGANS.

THE respiratory organs **consist of** the air-passages, as the nasal fossæ, pharynx, larynx, trachea, and bronchial tubes, with the special organs, the lungs, which act as glands.

THE LARYNX.

The **larynx**, or **organ of voice**, is composed of a cartilaginous structure made up of the thyroid, cricoid, arytenoid, Wrisberg's and Santorini's cartilages. These are held together by fibrous tissue and are lined on the inner side with a mucous membrane. The mucous membrane consists of epithelial cells and a basement-membrane, having also a submucosa. The epithelium as far as the false vocal cords is of the stratified squamous variety. Below this the epithelium changes to the stratified columnar ciliated, but when it reaches the true vocal cords it is again the stratified squamous, changing into the stratified columnar ciliated type as soon as the true vocal cords are passed, and continuing as such into the trachea and bronchi. The basement-membrane is a fibro-elastic connective tissue raised into papillæ, especially in the upper part of the larynx. Numerous mucous follicles communicating with the surface and lined with columnar cells are found in the submucosa.

The *vocal cords* consist of fibroëlastic tissue covered with mucous membrane, consisting of stratified squamous epithelium. No mucous glands are found on the vocal cords.

The *cartilages* of the larynx are of both the hyaline and the yellow elastic variety, the former variety predominating.

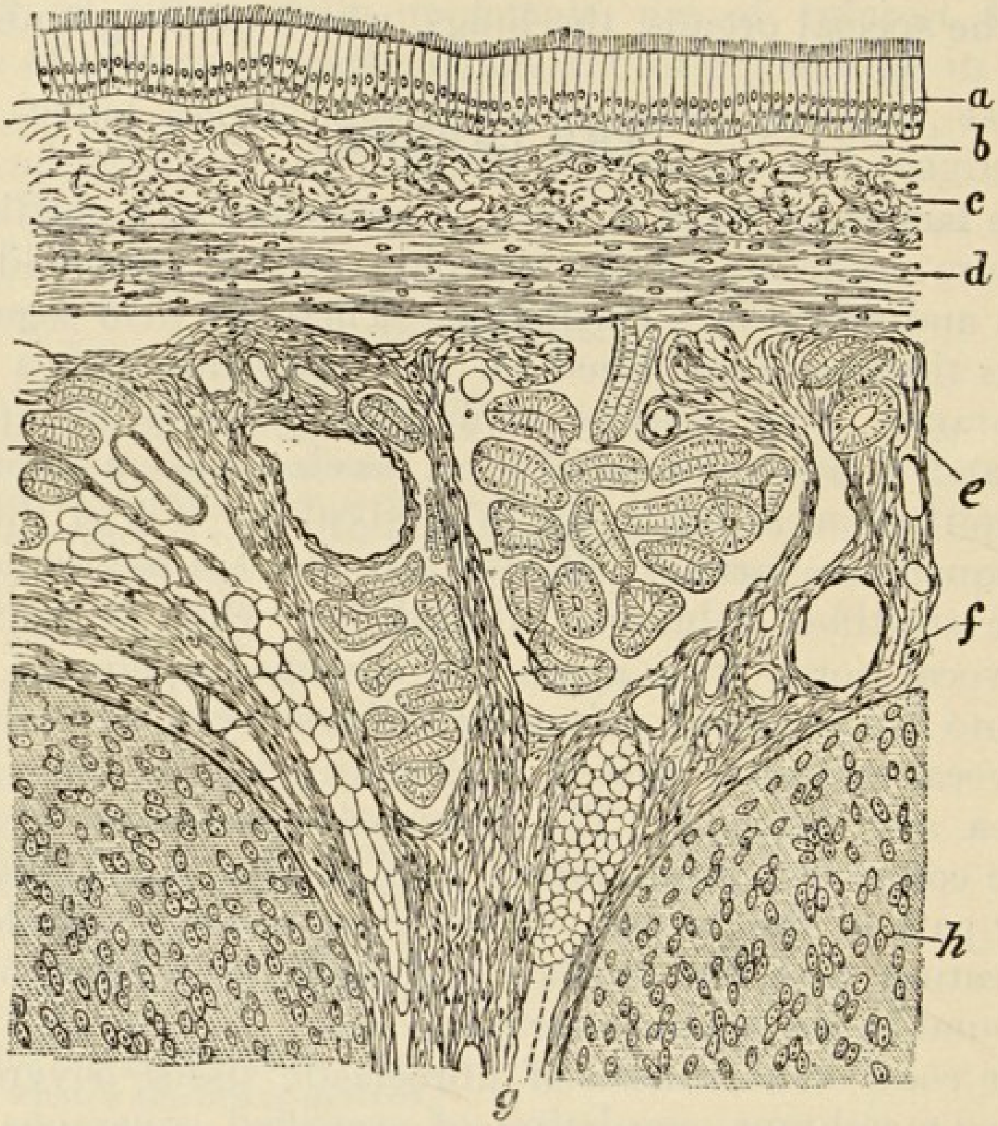
The *bloodvessels* end in capillary networks in the mucosa. A superficial and a deep set of lymphatics, situated in the mucosa and submucosa, are present.

The *nerves*, both medullated and non-medullated, terminate in the mucosa, show small ganglia in their course, and on the lower surface of the epiglottis end in small taste-buds.

THE TRACHEA.

The **trachea** is a cylindrical tube of fibroëlastic tissue, within the layers of which are enclosed a series of incomplete cartilaginous rings, and is lined internally with mucous

FIG. 83.



From a longitudinal section through the trachea of a child: *a*, the stratified columnar ciliated epithelium of the internal free surface; *b*, the basement-membrane; *c*, the mucosa (tunica propria); *d*, the network of longitudinal elastic fibres (the oval nuclei between them indicate connective-tissue corpuscles); *e*, the submucous tissue, containing mucous glands; *f*, large bloodvessels; *g*, fat-cells; *h*, hyaline cartilage of the tracheal rings. (Only a part of the tracheal wall is given in the figure.) (Klein.)

membrane. It extends from the larynx downward for about four inches, where it divides into the two bronchi.

Stratified columnar ciliated epithelium lines the trachea, numerous goblet-cells also being present. The tunica propria is made up of a dense fibroëlastic tissue, the elastic fibres being well marked posteriorly, where they form several longitudinal bundles between the ends of the cartilaginous rings. The submucosa contains many racemose glands, the acini of which are lined with cuboidal cells, while the long ducts which communicate with the surface epithelium are lined with low columnar cells. These glands are especially abundant where the tracheal wall is free from cartilage.

The external *fibrous coat* is made up of fibroëlastic tissue containing some longitudinally and circularly arranged bundles of involuntary muscle-fibre. Posteriorly it is but a single layer, while anteriorly it divides into two layers, thereby forming a complete covering for the cartilaginous rings.

The *cartilaginous rings* are of the hyaline variety, and extend about two-thirds around the trachea. These semilunar cartilages are connected at their free ends by transverse bundles of non-striated muscle-fibres.

Bloodvessels, *nerves*, and *lymphatics* supplying the trachea are in the mucous and submucous coats, the bloodvessels surrounding the acini of the glands in a capillary network. The lymphatics occur also as solitary follicles in the submucosa.

The *larger bronchial tubes* are similar in structure to the trachea, but as they become smaller the cartilaginous rings are gradually reduced in size, until finally they disappear; the muscle-fibres, however, increase in number, while the lining epithelium is reduced to a single layer of columnar ciliated cells. The bronchi become reduced in size by continual subdivision until they form the *terminal bronchi*. These open into the alveolar ducts, whose walls are much thinner and are lined with flat polygonal cells. The alveolar ducts terminate in blind sacs, the *infundibula*, the walls of which are surrounded by the *air-sacs*, the latter communicating freely with the cavities of the infundibula.

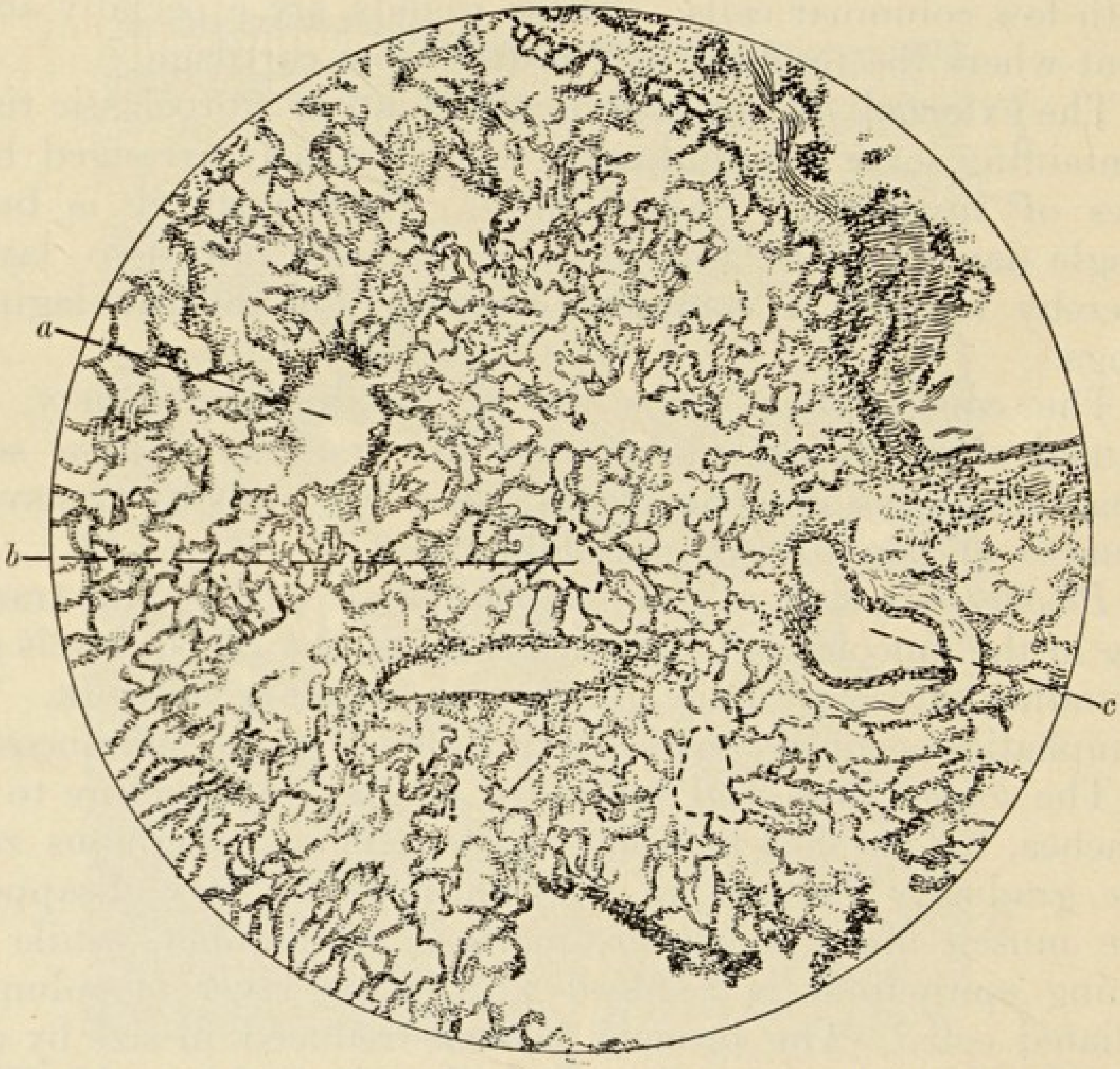
THE LUNGS.

The **lungs** consist of a number of *air-sacs*, or *alveoli*, grouped together and opening into an *infundibulum* or *pouch*.

These are enclosed in connective tissue to form lobules, and the lobules are grouped into lobes.

The lungs resemble in structure and development compound racemose glands. The air-sacs, or alveoli, represent the acini

FIG. 84.



Section of lung of the dog: *a*, alveolar passage opening into an infundibulum and also into a solitary alveolus; *b*, cross-section of an infundibulum. The dotted line indicates the limits of the infundibular space. Opening into it are a number of alveoli. Were the dotted line removed, the infundibular cross-section and the alveoli around it would form a stellate space in the section. *c*, junction of two radicles of the pulmonary vein. At the top of the section, to the right, is an oblique section of a bronchiole. (Dunham.)

of racemose glands, while the infundibulum, into which they open, resembles the duct of the gland. The elastic tissue of the infundibulum is arranged circularly at the outlet of the air-sacs, and gives off fibres which form the framework of same.

The *air-sacs* constitute the bulk of the lung, and their walls are composed of a fibroëlastic tissue framework, an epithelial layer, and a meshwork of fine capillaries. The fibroëlastic tissue derived from the infundibulum forms the framework which supports the lining epithelium as well as the capillary vessels. This interlobular connective tissue usually contains a considerable amount of pigment, as coal-dust breathed into

FIG. 85.

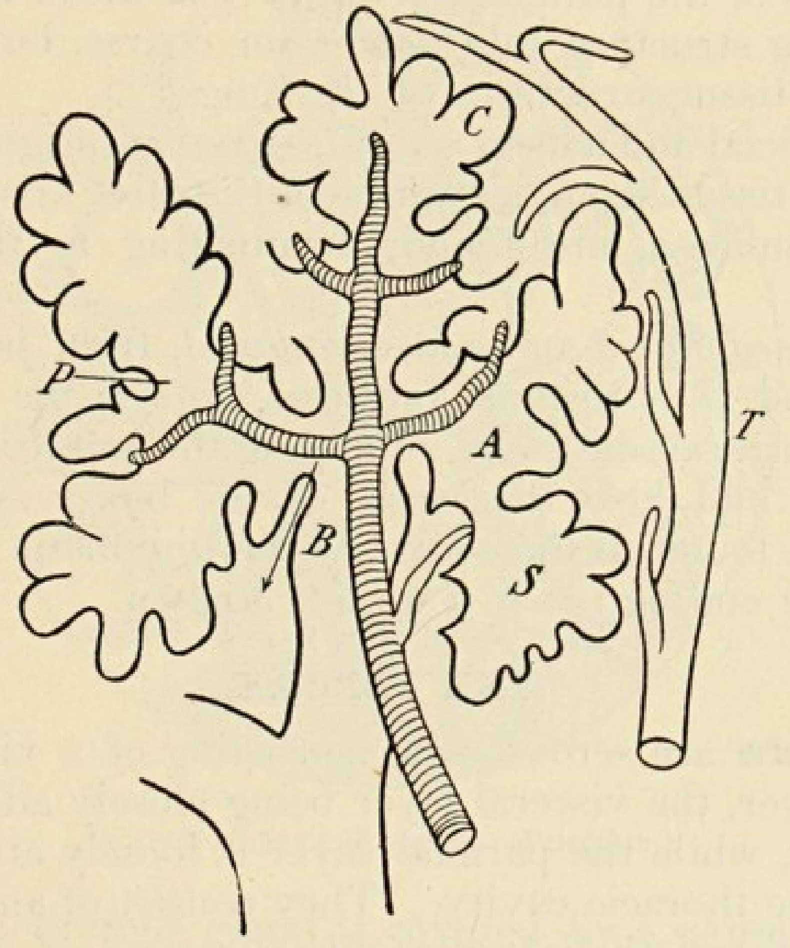


Diagram of air-vesicles and termination of bronchi: *B*, terminal bronchiole (the line leads from a terminal artery); *A*, *P*, alveolar passages; *S*, infundibulum; *C*, air-vesicle; *T*, beginning vein. (Miller.)

the lungs. The lymphatic vessels convey this foreign material to the lymph-glands at the base of the bronchi, and there it is reclaimed.

The epithelium consists of a single layer of flat endothelial cells or plates, some few simple polyhedral cells being also present.

The *bloodvessels* of the lungs, as in the liver, comprise two distinct sets, one supplying the framework of the organ with nutrition, the bronchial arteries, and the other, the pulmonary arteries, carrying blood to the lungs, to undergo a change in composition, thereby fulfilling the respiratory function. The bloodvessels enter at the root of the lung and follow the bronchial tubes to their smallest ramifications. Here the branches of the pulmonary artery surround the base of the air-sacs, and small capillaries are given off which surround each alveolus. This blood is aërated, and is carried away by the radicles of the pulmonary vein. The blood for the nutrition of lung structure takes the same course, but ends in the connective-tissue structures of the lungs.

A superficial and a deep set of *lymphatics*, originating in the connective-tissue septa, as well as a third set arising from the bronchial mucosa, are found, terminating in the bronchial glands.

Nerves, *medullated* and *non-medullated*, from both the sympathetic and cerebrospinal systems, follow the air-tubes to their terminal ramifications, supplying the muscles, the mucous membrane, and also the walls of the bloodvessels. Small ganglia are found in the course of the lymphatic nerve-fibres. Their exact ending is not definitely known.

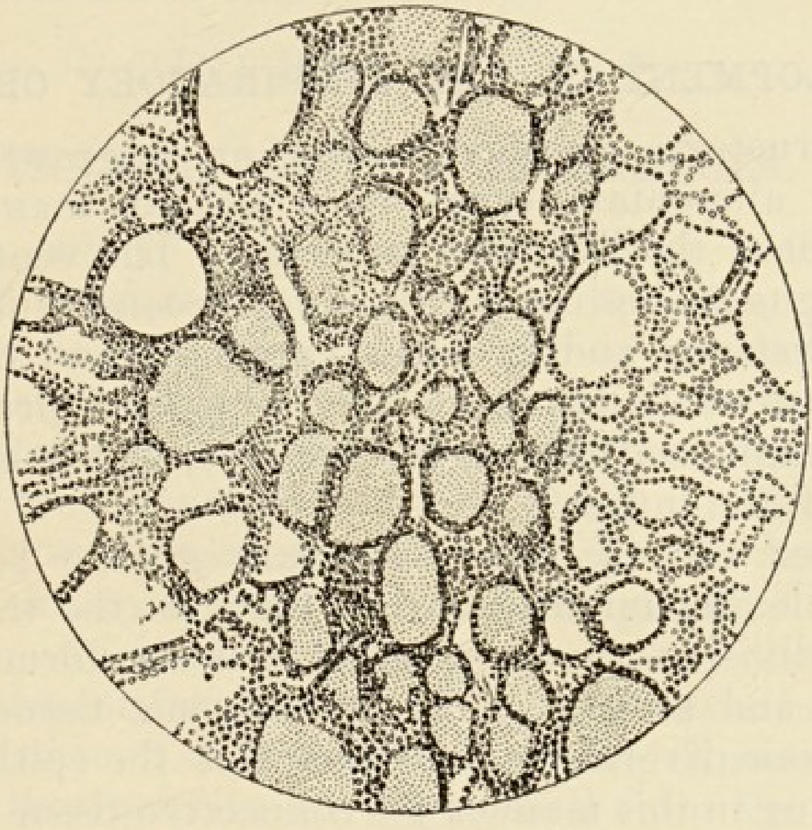
THE PLEURÆ.

The **pleuræ** are serous sacs, consisting of a visceral and a parietal layer, the visceral layer being closely adherent to the lung-tissue, while the parietal layer is loosely attached to the walls of the thoracic cavity. They consist of an inner lining of flattened endothelial cells and an outer coat of fibroëlastic tissue, having at some points a subpleural tissue containing bundles of unstriated muscle-fibres. The endothelium contains numerous small openings or stomata, which communicate with the lymphatic spaces within the adjoining tissue. This subpleural tissue supports the blood- and lymphatic vessels as well as the nerves to the pleura.

THE THYROID GLAND.

The **thyroid gland** is usually considered in connection with the respiratory organs on account of its anatomical relations to these structures. It is a compound tubular gland of the "ductless type," its excretory duct having become obliterated in early embryonic life. The thyroid gland is supposed to have an internal secretion which affects the general metabolism of the system, but it is often seen in an enlarged pathological state called goitre.

FIG. 86.



Alveoli of thyroid gland. (Dunham.)

The adult thyroid gland is covered by a dense *capsule* of fibrous connective tissue, projections from which extend into its substance and divide the gland into lobes, the lobes being composed of lobules and the latter of tubular acini.

The *acini* are spherical sacs with no outlet or duct, and are lined with a single layer of cuboidal epithelium. These cells often contain refractive granules in their protoplasm and have a nucleus near the centre of the cell. These acini are filled with a characteristic homogeneous mass, the *colloid substance*, within which are leucocytes, red blood-cells, and detached epithelium. These acini are separated from each other by very little connective tissue and lie close together.

The *blood-supply* is very abundant, the larger vessels entering between the lobes and lobules to break up into a capillary network around the acini.

The *lymphatics* are numerous, consisting of a deep and a superficial set, the superficial set of vessels being supplied with valves.

The *nerves* are few, and chiefly derived from the sympathetic system, and are distributed to the walls of the bloodvessels.

DEVELOPMENT OF THE RESPIRATORY ORGANS.

These structures are developed as an outgrowth from the entodermic alimentary canal in a similar manner to the development of the liver and pancreas. The ventral wall of the œsophagus pushes out a *pulmonary groove*, which descends for some distance, and becomes expanded and divides into two lateral diverticula, which subdivide into three branches, one on the right and two on the left side, which later become the bulbs of the lungs.

The upper end of this pulmonary groove becomes the larynx, while the middle portion becomes the trachea. By continued division the original diverticula form the small bronchioles and air-sacs. The mesodermic tissue surrounds the entodermic diverticula, and into this the epithelial tubes grow, forming in this manner the connective-tissue framework of the lung. The thyroid is developed as an outgrowth from the entodermic lining of the primitive pharynx. This grows into the surrounding mesoderm in the form of epithelial cords, the latter becoming hollow and appearing as tubular glands. The surrounding mesodermic tissue divides the gland into lobules and acini, forming the framework of the gland.

QUESTIONS.

Name the respiratory organs.
Describe the larynx.
What are the vocal cords composed of?
Describe the trachea.
Where does the cartilage leave off and the muscle take its place?
Describe the air-passages from the trachea to the alveolar ducts.
Of what do the lungs consist?
Describe the air-sacs.

Describe the blood-supply to the lungs.

What are the pleuræ? Describe their structure.

What type of gland is the thyroid? Describe its acini.

From what embryonic structures are the respiratory organs developed? Describe the process.

From what layer of the blastoderm is the epithelium derived?

From what is the connective tissue derived?

Describe the development of the thyroid gland.

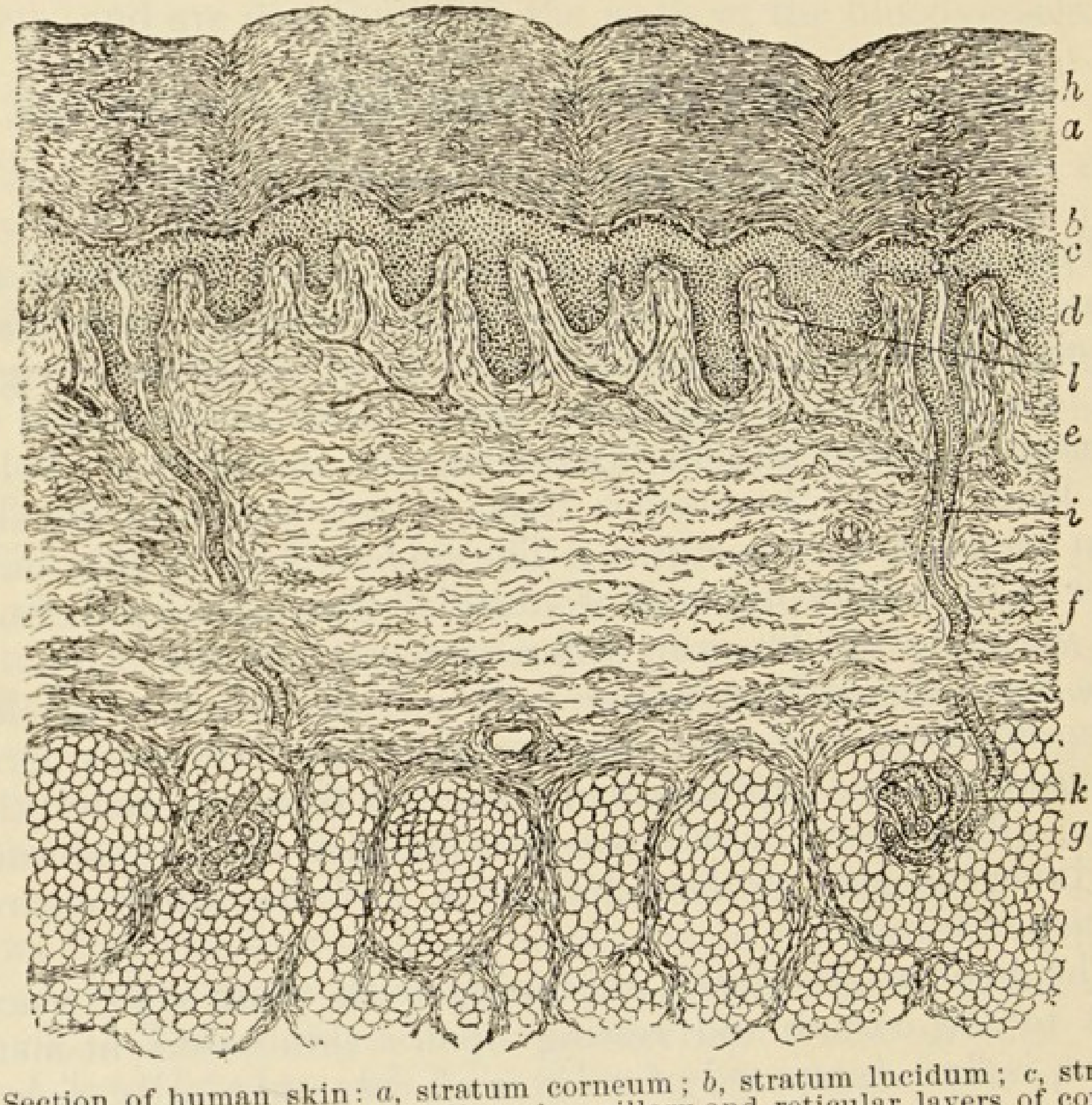
CHAPTER XIII.

THE SKIN AND ITS APPENDAGES.

THE skin, which covers the whole outer surface of the human body, consists of two portions, the outer, *epidermis* or cuticle, which is an epithelial layer and of ectodermic origin, and the inner, *corium* or true skin, which is composed of connective tissue and derived from the mesoderm. Below this layer is the *subcutaneous tissue*, which separates the skin from the adjacent structures. The *epidermis* is the thin outer layer of the skin, composed of stratified squamous epithelium, and varies in thickness in different regions of the body. It rests upon the corium, whose surface is thrown into papillæ, the under surface of the epidermis showing depressions corresponding to these papillæ when separated from the underlying layer. Two layers of cells are distinguished in the epidermis, the inner darker, *stratum Malpighii*, and the outer clearer, *stratum corneum*.

The *stratum Malpighii*, beginning with those cells placed next to the corium and resting upon a thin basement-membrane, is first composed of a layer of columnar cells, rich in nuclear substance and staining deeply. As they ascend, the columnar shape changes more to polyhedral, the cells becoming broader, some of which are surrounded by delicate spines, being known as the *prickle cells*. Next to these cells is a layer of flattened spindle-shaped cells with peculiar, granular contents, consisting of *eleidin*, called the *stratum granulosum*. Above these is found a layer of large, flat, polyhedral cells, whose protoplasm has undergone a change into *keratin*, called the *stratum lucidum.* The stratum corneum is above or external to the last-named layer, and is composed of large, flattened, horny cells or scales, without nuclei, and undergoing desquamation. This continual loss to which the skin is subjected by desquamation is overcome by a continual growth

FIG. 87.



Section of human skin: *a*, stratum corneum; *b*, stratum lucidum; *c*, stratum granulosum; *d*, stratum Malpighii; *e*, *f*, papillary and reticular layers of corium; *g*, stratum of adipose tissue; *h*, *i*, spiral and straight portions of duct of sweat-gland; *k*, coiled portion of sweat-gland; *l*, vascular loops occupying papillæ of corium. (Piersol.)

of new cells, which pass through the different forms from the first layer of the stratum Malpighii up until they appear at the surface of the stratum corneum.

The deeper cells of the stratum Malpighii often contain pigment-granules, giving the characteristic color to the different races. In the white race a brown pigment occurs in various places, as the skin of the scrotum, the nipple, around the anus and the labia majora, while much coloring-matter is found in the skin of the negro. In this latter skin the color is due to fine pigment-granules in the epidermal cells of the deepest layer of the stratum Malpighii and in the upper surface of the corium. A very thin, structureless membrane, the *basal membrane*, separates the epidermis from the corium.

The *corium*, *dermis*, or *true skin*, is composed of an outer layer, the *stratum papillare*, and an inner layer, the *stratum reticulare*.

The *stratum papillare* is composed of dense fibroëlastic tissue, containing some non-striated muscle-fibre, and is raised into conical elevations, the *papillæ*. The papillæ are various sizes, connected to the corium by a thin base, their free extremity often being divided into two or more parts. They contain the nerve-terminals and capillary bloodvessels, being especially well developed in the palms of the hands and soles of the feet.

The *stratum reticulare* is composed of a less dense connective tissue, which gradually merges into the underlying subcutaneous tissue.

The *subcutaneous* tissue is made up of fibroëlastic and muscular tissues, the meshes of which usually contain masses of fatty tissue, varying in amount in different parts of the body.

The muscular tissue in certain regions is very distinct, as in the dartos of the scrotum.

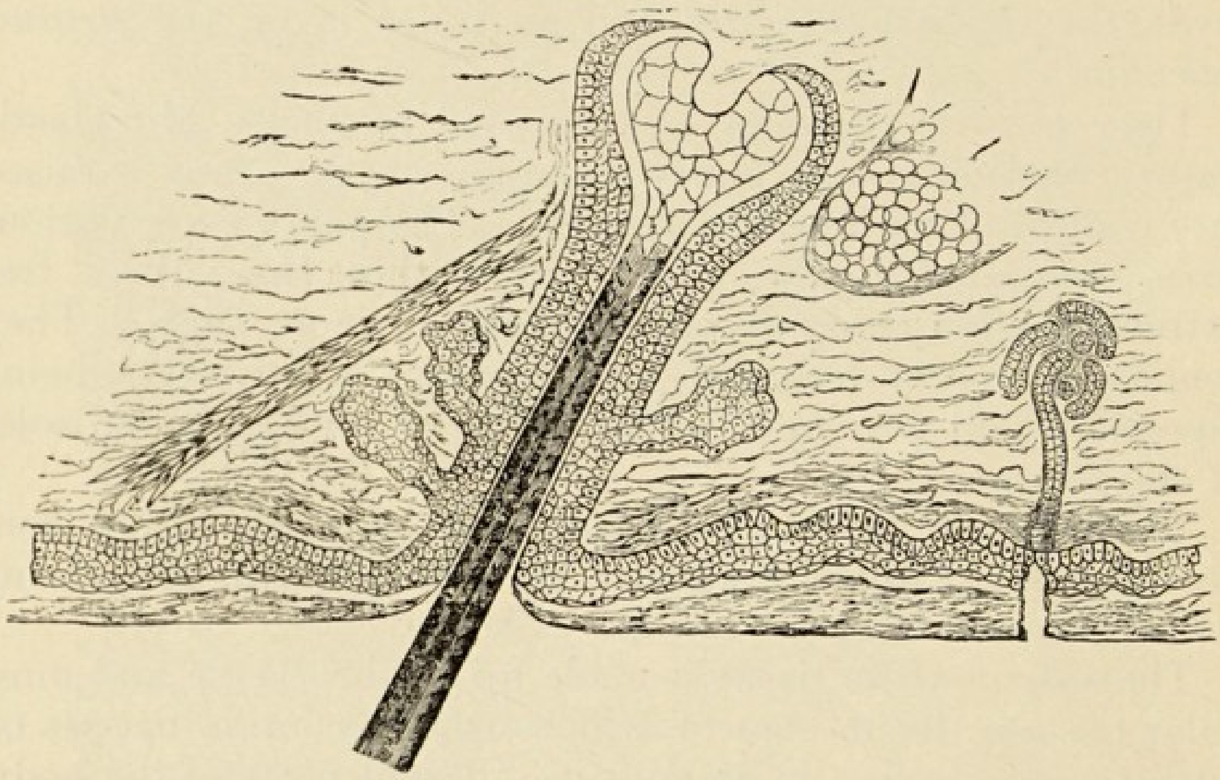
THE HAIR.

The hair is considered as a special differentiation of the skin, and is derived from the epidermis ; therefore it is of ectodermic origin. It occurs over the entire extent of the skin, except the palms of the hands, the soles of the feet, and the red borders of the lips, and is especially abundant in some regions, such as the scalp. The portion of the hair above the skin is called the *shaft*, while that embedded in the skin is the *root*.

The *root* has an enlargement at its lower extremity, lighter in color than the shaft, called the *bulb*, into which a highly vascular papilla of the corium projects, and is surrounded by a sheath, the *hair-follicle*. The hair is composed of three layers, the cuticle, the cortex, and the medulla.

The *cuticle* consists of a single layer of thin, transparent, horny, epithelial cells or scales, overlapping each other and containing no nuclei in the upper part of the root and shaft,

FIG. 88.



Microscopic section of skin, showing the epidermis and derma; a hair in its follicle; the erector pili muscle; sebaceous and sudoriferous glands. (Gray.)

but in the bulb are cells richer in protoplasm and having distinct flattened nuclei. The overlapping edges form irregular transverse markings on the surface of the shaft.

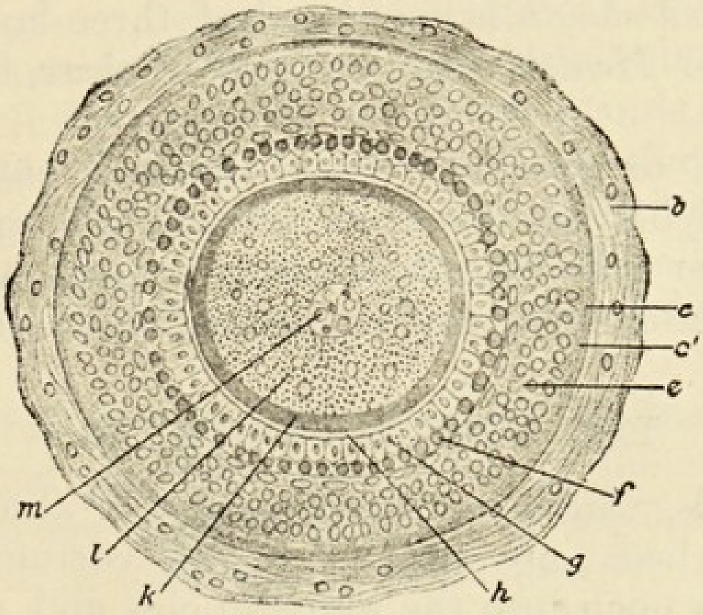
The *cortex* consists of several strata of long flattened cells containing oval nuclei. They are so closely cemented together that at times the individual cell-walls can not be distinguished. These cells lie with their long axes parallel to the hair-shaft and cause the hair to appear longitudinally striated.

A variable amount of pigment is deposited within and between the cells of the cortex, the amount depending on the color of the hair.

The *medulla*, which is usually, not however always, present, is situated in the central part of the shaft, and is composed of a structure of polygonal, nucleated, and pigmented cells. Often these cells contain air-bubbles, which, with the pigment in the cortex and medulla, determine the color of the hair.

The *hair-follicle* is a tubular involution of the epidermis and corium, lying perpendicular or oblique to the surface, and encloses the bulb of the shaft.

FIG. 89.



Hair-follicle from the human scalp; cross-section from middle third of the follicle: *b*, longitudinal and encircling layers of the fibrous coat; *c*, hyaline layer, formed of an outer faintly fibrillated and an inner non-homogeneous lamina, *c'*; *e*, outer root-sheath, continuous with rete mucosum of epidermis; *f*, Henle's sheath; *g*, Huxley's layer; *h*, cuticle of root-sheath; *k*, cuticle of hair; *l*, cortical cells of the hair; *m*, medulla. (Mertsching.)

The ducts of one or more sebaceous glands open into the upper half of the follicle. Small bands of involuntary muscle, attached at one end to the fibrous coat of the hair-follicle below the sebaceous glands, at the other end to the corium, are present. These are the *erectores pilorum*, which when they contract elevate the hair, causing a contraction of the surrounding epidermis with the appearance of the characteristic goose-skin, or *cutis anserina*.

The **hair-follicle** is composed of a fibrous and an epithelial coat. The outer or fibrous coat consists of three layers: an outer, consisting of longitudinal bundles of connective tissue, containing the bloodvessels and nerves; a middle circular, made up of spindle-shaped cells; and an inner, clear, or hyaline membrane, which acts as a basement-membrane for the cells of the preceding coat. The epithelial portion of the follicle is composed of two zones, known as the *inner* and the *outer* root-sheaths.

The *outer root-sheath* is a continuation of the *stratum Malpighii*, consisting of prickle-cells surrounded by columnar cells, the same as in the corresponding part of the adjacent skin.

The *inner root-sheath* is composed of three layers:

The outer, or *Henle's, layer* consists of clear, flattened, nonnucleated cells.

The middle, or *Huxley's, layer* is somewhat thicker and consists of polyhedral nucleated cells containing *eleidin*.

The inner, or *cuticular, layer* is composed of transparent overlapping plates lying against the cuticle of the hair.

THE SEBACEOUS GLANDS.

These glands, which are distributed over almost the entire surface of the body, are situated in the corium of the skin, and their ducts open into the hair-follicles and upon the free surface of the skin where the hairs are absent. These glands are not found in the palms of the hands and the soles of the feet. They are small racemose glands, consisting of short ducts lined with a stratified scaly epithelium, emptying the acini, which are lined with long cuboidal cells, and are surrounded by a connective-tissue capsule derived from the corium or the hair-follicle. These cells secrete the sebum with which the lumen of the acini are usually filled. It is a semisolid, oily substance mixed with degenerated cells and granular débris.

THE SWEAT-GLANDS.

The **sweat- or sudoriparous glands** are a modification of simple tubular glands, and begin as a convoluted mass in the subcutaneous layer of the skin, and pass up toward the surface as a straight excretory duct until the stratum corium is reached, when the duct becomes wavy and terminates in a funnel-shaped orifice opening on the free surface of the skin. They are widely distributed over the surface of the skin, with the exception of the inner surface of the prepuce, the glans penis, and the red border of the lips, and have an important role to perform physiologically.

The *convoluted tubules* in the subcutaneous tissue are lined with a single layer of columnar secreting cells, containing a fatty granular substance and resting upon a distinct basement-membrane. Between the epithelial cells and the basement-membrane is a thin layer of involuntary muscle-fibre, especially well developed in the lower glands.

The *straight portion of the excretory duct* is smaller in diameter than the tubules of the gland proper, and is lined with cuboidal or low columnar epithelial cells, situated on a basement-membrane and surrounded by a delicate connective-tissue coat.

In the *spiral portion of the duct* its distinct walls are lost, and it is lined with the horny cells of the epidermis. The secretion of these glands depends on location of the glands, those situated in the axilla and around the anus secreting a thick, oily substance, while those of other parts of the body secrete a colorless fluid, the sweat proper.

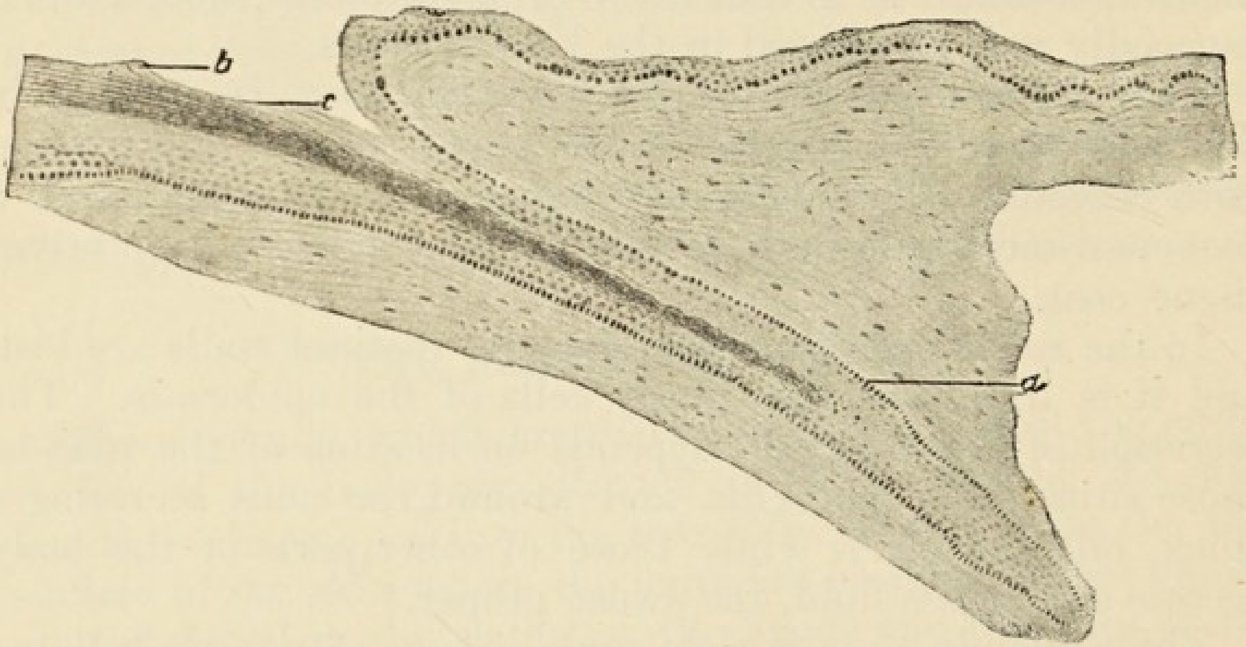
These glands have a rich *nerve-supply* of non-medullated fibres, which form a fine network on the outer surface of the membrana propria. They pass through the basal membrane and end among the gland-cells as fine end-bulbs.

THE NAILS.

The **nails** are made up of the *body*, which is the large exposed area; the *free edge*, which is the anterior projection from the body; and the *root*, that portion extending under the *nail-groove* or *-fold*. The borders of the nail at the side are covered by the *nail-wall*. The nail is a development of the stratum lucidum of the skin, and is composed of layers of horny nucleated epithelial cells. It rests upon the *nail-bed*, the posterior portion of the nail-bed which is covered by the root being the *matrix*. The groove existing between the nail-wall and nail-bed is known as the *sulcus of the matrix*. The *nail-bed* consists of the corium and of the epidermis, the epidermal portion corresponding to the stratum Malpighii of the ordinary epidermis. True papillæ are not present on this part of the corium, longitudinal ridges, however, being formed, which again become continuous with the papillæ of the skin at the point where the nail parts from its bed.

The matrix, made up of corium and epidermis, has papillæ on its surface covered with stratified scaly epithelium. These

FIG. 90.



Section through the root of the nail of a sixth-months fœtus. *a*, matrix of the nail formed by an invagination of the rete mucosum. Near the point indicated by the letter the epithelial cells have begun to change into keratoid material. *b*, loosened scales of the surface of the nail; *c*, remains of the fœtal cuticle which have not become keratoid. The letter *a* and line proceeding from it both lie in the corium. (Ernst.)

epithelial cells multiply and form the horny cells of the nail, and as multiplication takes place the nail is pushed forward. The growth of the nail thus proceeds from behind forward by a transformation of the matrix-cells into true nail-cells taking place at the posterior and the lateral borders as well as at the lower and often upper surface of the nail-root. The anterior extremity of the matrix is marked by the convex border of the *lunula*, an opaque area which can be seen just in front of the *nail-fold*. The *nail-root* is of a light, opaque color, in contrast to the pink of the *nail-body*. The *nail-wall* and *nail-fold* are the same as ordinary skin.

THE BLOOD-, LYMPH-, AND NERVE-SUPPLY OF SKIN.

The *arteries* form a plexus in the subcutaneous tissue, sending branches from here to the hair-follicles, adipose tissue, and sweat-glands. A second plexus, formed by branches from these vessels, is found immediately beneath the corium, small capillary vessels being given off which go to supply the papillæ.

The *veins* form four networks parallel to the surface in the papillæ of the corium.

Lymphatics originate in the cell-spaces of the various tissues, uniting to form a superficial and a deep plexus, which communicate with each other.

The *nerves* enter the subcutaneous tissue, from where they give off numerous branches, some ending in the sebaceous glands and involuntary muscles, others passing up toward the surface and ending in the papillæ of the corium. Some branches have free endings between or beneath the epithelial cells, while others terminate in special end-organs, such as the *tactile corpuscles of Meissner* and the *corpuscles of Vater*.

DEVELOPMENT OF THE SKIN AND ITS APPENDAGES.

The *epidermis* is derived from the *ectoderm* and the *corium* from the *mesoderm*. The nails and hair are outgrowths from the epithelial layer, and the glands are invaginations of the same layer. The *corium*, the connective-tissue part of the skin, is an outgrowth of the *cutis plates* of the primitive *segments*, or *somites*. Papillæ form, and about the fifth month the meshes of the subcutaneous tissue begin to be filled with fat and are differentiated from the overlying corium. The epidermis in the earliest stage of development consists of a single layer of low cuboidal cells; later another layer superficial to this becomes differentiated, known as the *epitrichium*.

These two strata probably correspond to the corneous and

Malpighian layers of the fully developed epidermis. The nails are developed by a specialization of the stratum lucidum. The primitive epidermis becomes thicker over the ends of the fingers and toes, followed by the formation of a furrow and an ingrowth of the Malpighian strata to form the root. This is followed by an increase in the cells of the stratum lucidum and the appearance of eleidin in the superficial cells of the stratum Malpighii with the formation of the nail-body as the result. The superficial layer of the epidermis covering the primitive nail is gradually thrown off, followed by the separation of the end of the nail from its bed, forming a free edge due to a desquamation of the stratum lucidum. The hairs are developed by a plug of epithelial cells growing down toward the underlying corium. These cells form the hair-follicle. Each of these tubular prolongations is met by a papillary outgrowth from the corium, and from these structures are derived the hair and its inner root-sheath, thus making the hair of both ectodermic and mesodermic origin.

The *lanugo*, or *primary*, hair is shed about the time of birth or soon after, and is followed by the more permanent hairs.

The *sebaceous glands* develop as buds from the outer root-sheath. These buds, at first solid, grow out into the surrounding structures, become hollow tubes by a disintegration of the central cells, which have undergone a fatty degeneration and produced a sebaceous secretion, and form the primitive sebaceous glands.

The *sweat-glands* are invaginations or ingrowths of cells from the epidermis into the corium. At first solid, like the beginning sebaceous glands, they later become tubular, the epidermal cells forming their lining, while the connective-tissue sheath and basement-membrane, upon which they rest, are derived from the surrounding mesodermic structures of the corium.

The non-striated muscle-fibres of the sweat-glands, situated between the basement-membrane and the lining epithelium, are derived from the ectoderm, this being the only exception where muscle-tissue is not derived from the mesodermic layer of the blastoderm.

QUESTIONS.

Of what parts does the skin consist?
Name the two layers of the epidermis.
Describe the stratum Malpighii.
Describe the stratum corneum.
What are the prickle-cells?
Describe the layers of the corium.
What is the subcutaneous tissue?
What is the hair?
Name the parts of a hair.
Of what layers is the hair composed? Describe each layer.
Describe the hair-follicle.
Of what does the epithelial portion of the follicle consist?
Where are the sebaceous glands found? What variety of glands are they? Describe their acini.
What are the sweat-glands? Name the parts.
Describe the convoluted tubules.
Describe the straight and the spiral tubules.
Name the parts to the nail.
Describe the nail-bed, the groove, and the matrix.
How does the nail grow?
From what layer is the epidermis derived?
From what layer is the corium derived?
How are the nails and hair formed?
From what primitive structure is the corium derived?
Of what does the epidermis consist in its earliest stage?
Describe the development of sebaceous and sweat-glands.

CHAPTER XIV.

THE CENTRAL NERVOUS SYSTEM.

THE MEMBRANES.

THE spinal cord and brain are enveloped by three membranes: the *dura mater*, or outer; the *arachnoid*, or middle; and the *pia mater*, or inner. These furnish protection and support the bloodvessels.

The *dura mater* is the outer membrane, and is composed of bundles of dense fibroëlastic tissue, containing in its meshes flat connective-tissue cells. Plasma-cells are also found, especially in the superficial layers. The dura covering the cord and brain differ in a few respects. The dura of the brain is composed of two layers. The outer layer is attached to the inner side of the cranial bones, forming their periosteum.

It is separated from the inner layer at certain points, forming venous sinuses and lymph-spaces. The inner layer is of the same structure as the outer, and is lined internally with flattened endothelial cells. It dips down between the fissures of the cerebrum and cerebellum. Between the outer layer and the cranial bones occurs the *epidural space,* filled with lymphatics. Beneath the inner layer of the dura mater is the *subdural space.* The nerve- and blood-supply are abundant. The *nerves* follow the course of the arteries, some of which end in the vessel-walls. The cerebral veins empty directly into the venous sinuses between the two layers of the dura.

The dura mater of the cord is of the same structure, having its fibrous bundles arranged longitudinally. It is separated from the vertebral column by the epidural space, which is filled by a lymphatic and a venous plexus. It does not form the periosteum for the bones of the vertebral column, nor does it divide to form venous sinuses or dip into the fissures of the cord. The dura of the cord is poorly supplied with bloodvessels and nerves.

The *arachnoid*, or *middle membrane,* is composed of several layers of a very delicate and loose connective tissue, covered on its free surfaces with endothelium. It is separated from the dura above by the subdural space, and below it is separated from the pia mater by the *subarachnoidean space.* Numerous bands, or trabeculæ, covered with endothelium, connect the pia mater and arachnoid. At certain points the outer surface is raised into villous projections consisting of a connective-tissue base with an endothelial covering. Along the superior longitudinal sinus these villi form the *Pacchionian bodies,* due to a hypertrophy of their elements, with an increase in size following. Their growth pushes the dural coverings before them until they reach the cranial bones. Here by continual pressure a portion of the bone is absorbed, leaving the characteristic depression on the inner side of the cranial bones. Unlike the dura, the arachnoid contains neither bloodvessels nor nerves.

The *pia mater,* or *inner membrane,* is composed of two layers. The outer layer consists of longitudinally arranged bundles of connective tissue, containing many elastic fibres. This layer is highly vascular, and is covered externally with endothelium where it forms the inner wall of the subarachnoidean space. The inner layer is made up of the same tissue, only finer in structure and covered on both surfaces with endothelium. It is intimately adherent to brain and cord, dipping down into all the sinuses and fissures. The inner layer accompanies the bloodvessels to the interior of the brain, forming the choroid plexus, which is suspended in the form of lobules or villous-like projections within the ventricles. Between the two layers are a number of lymph-spaces and also bloodvessels. The pia mater is supplied by both medullated and non-medullated nerves, usually ending in the walls of the bloodvessels.

The *pia mater of the cord* is divided into two layers: the outer, which somewhat resembles the arachnoid and joins the connective-tissue strands passing across the subarachnoidal space; and the inner (*pia intima*), which is a thin membrane of connective-tissue bundles circularly arranged.

The *pia mater of the brain* is somewhat similar to the *pia intima* of the spinal cord.

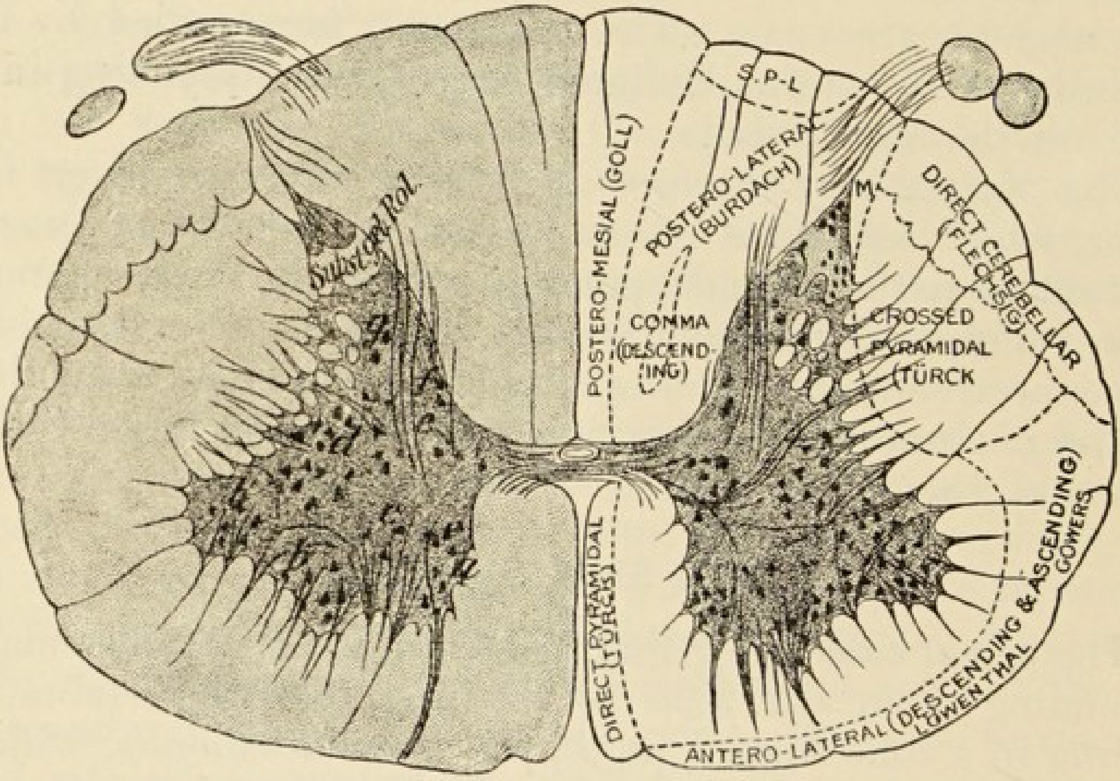
THE SPINAL CORD.

The **spinal cord** is a cylindrical column of nervous matter, extending from the atlas to the first lumbar vertebra, and ending in a cone-shaped point, the *conus terminalis*, which is continued downward for a variable distance as the *filum terminale.* It is composed of gray matter internally, and white matter externally, the whole enveloped by a sheath of connective tissue, the pia mater, which contains the bloodvessels. It has two enlargements, the cervical and lumbar, and is divided into symmetrical lateral halves by a broad and shallow *anterior median fissure,* and posteriorly by an ingrowth or projection of the pia mater, forming a fibrous septum called the *posterior median fissure.*

The arrangement and relations of the gray and white substances are best seen in transverse sections. The gray matter occupies the centre of the cord, and is arranged as a crescent in each hemisphere connected by a horizontal bridge, the *gray commissure*, the whole thus resembling the letter H. The crescents are directed anteroposteriorly, and each have an anterior and a posterior horn.

The distribution of the gray and of the white matter in the cord may even be seen with the naked eye in unstained specimens, where they appear in their respective color; the white matter being on the outer part and surrounding the central gray portion. The relative amounts of the gray and

Fig. 91.

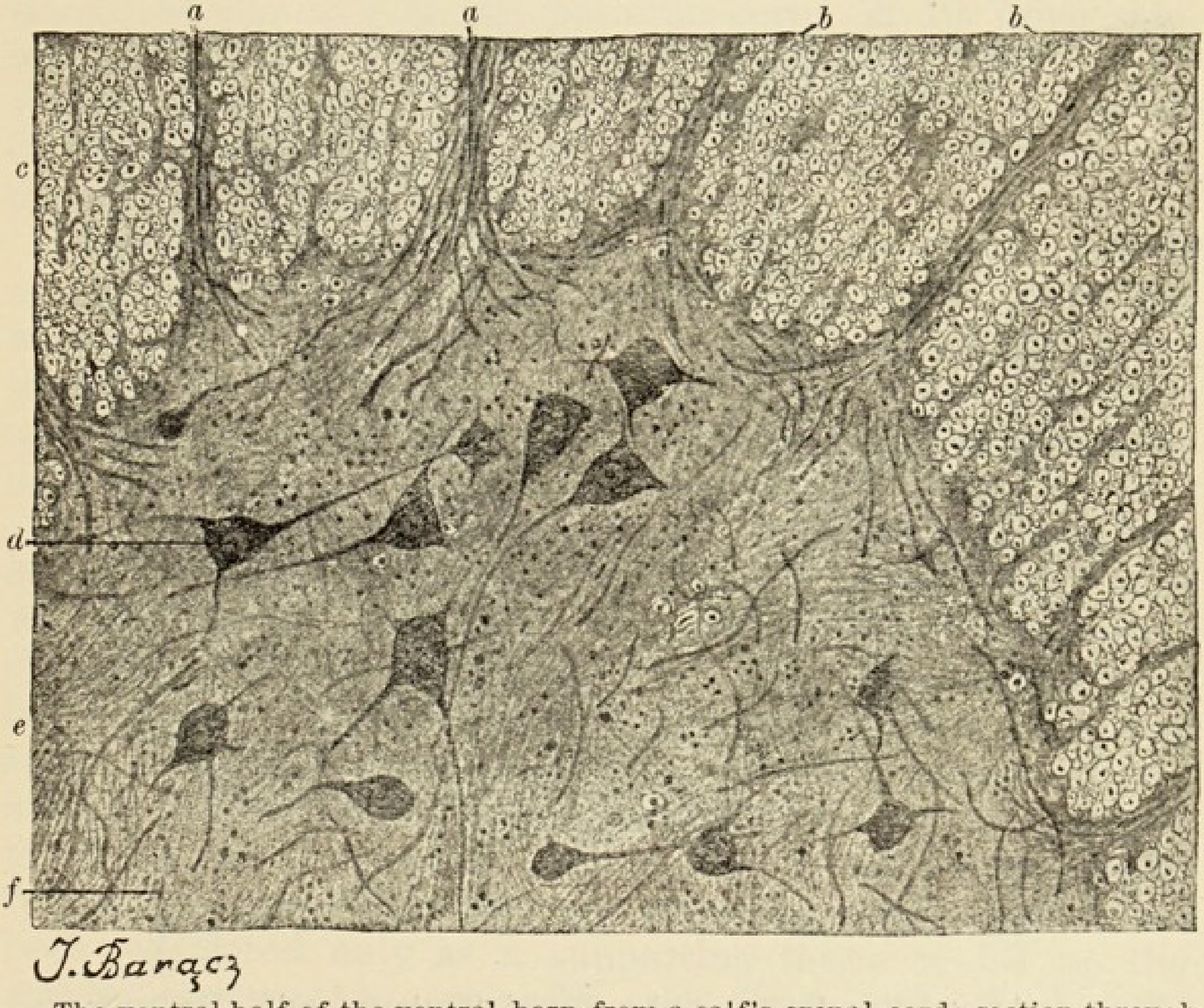


Transverse section of human spinal cord from the lower cervical region. (Schäfer.)

the white matter vary in the different regions of the cord, and in the sacral region the gray matter is present in larger amounts than the white matter, this being accounted for by the fact that the white matter is made up mostly of the distributing fibres, which have been given off higher up.

The *anterior horns* are short and thick, and do not extend to the periphery of the cord. Their margin is stellate and has emerging from it the anterior roots of the spinal nerves. The *posterior horns* are long and narrow, extend to the periphery, and are continuous with the posterior roots of the spinal nerves. The points where the anterior and posterior roots emerge are called the *anterolateral* and *posterolateral fissures.* In the middle of the gray commissure is a minute *central canal*, the remains of the primitive neural tube, varying in size and shape in different parts and extending the full

Fig. 92.

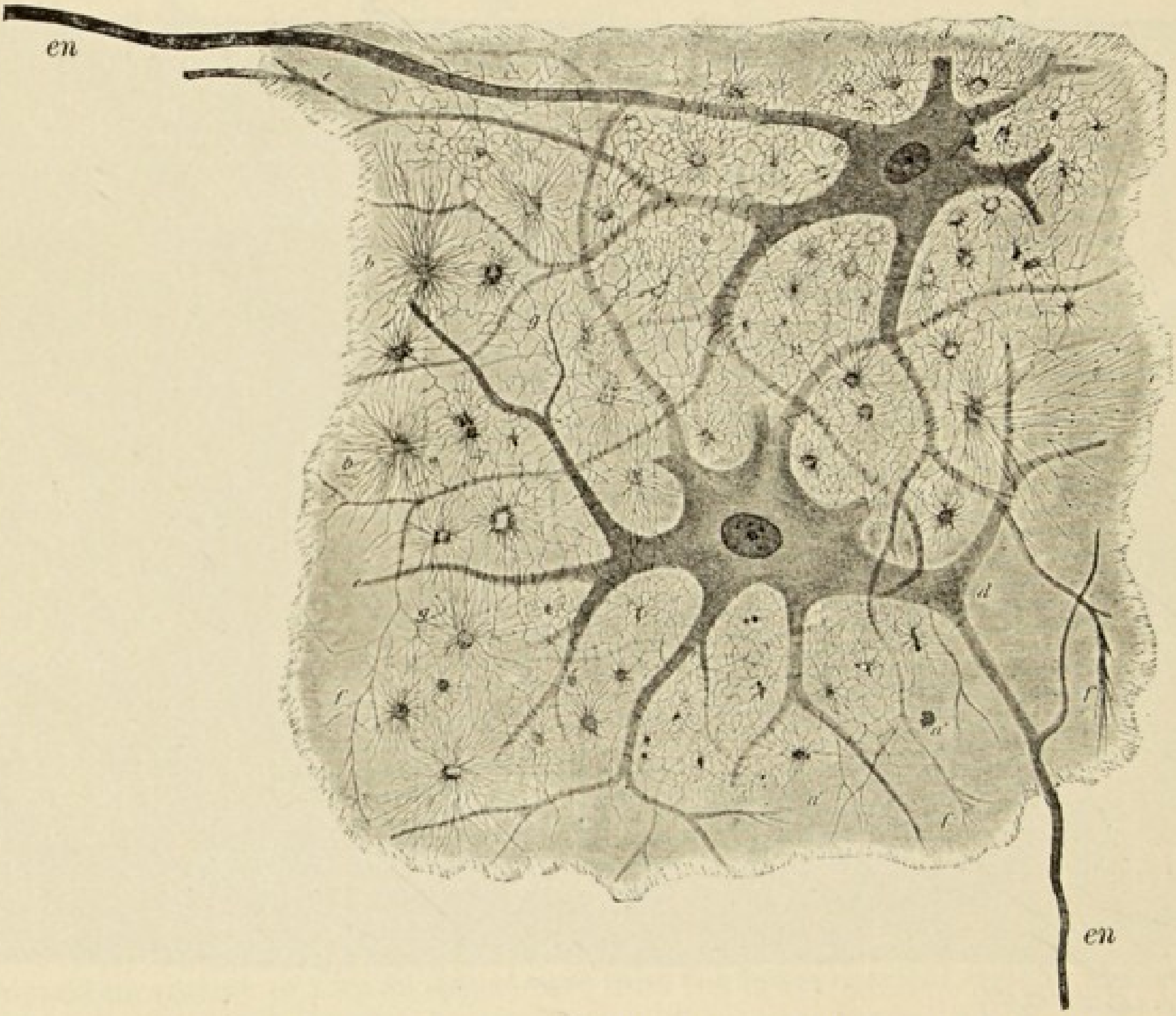


The ventral half of the ventral horn from a calf's spinal cord; section through the cervical enlargement: *a*, longitudinal sections of medullated fibres; *b*, medullated nerve-fibres cut across; *c*, white matter; *d*, nerve-cells; *e*, gray matter; *f*, glia-cell. × 80. (Szymonowicz.)

length of the cord, opening above into the fourth ventricle and ending below in a blind extremity. It is lined with a single layer of columnar cells, these cells being furnished with cilia in the fœtus. This layer of columnar epithelium, with its basement-membrane of neuroglia, constitutes the *ependyma.* That portion of gray matter in front of the canal is called the *anterior gray commissure,* while that behind it is known as the *posterior gray commissure.*

Throughout the whole length of the cord, in the gray matter at the apex of the posterior horn, is found a prominent structure called the *substantia gelatinosa* (Rolandi).

FIG. 93.



Nerve- and neuroglia-cells from gray matter of spinal cord; calf. The figure represents two isolated ganglion-cells, with branching protoplasmic processes, and each with a single axis-cylinder process, *en*. The axis-cylinder process of the lower cell gives off a branch a short distance from the cell. Between the ganglion-cells are those of the neuroglia. The protoplasmic processes of the nerve-cells subdivide into very delicate fibres, which lie among those of the neuroglia-cells. (Lavdowsky.)

This consists of small spindle-shaped cells with less neuroglia than other parts of the gray matter.

The *gray matter* consists of interlacing medullated and non-medullated nerve-fibres, with branching processes derived from the ganglion- and neuroglia- or spider-cells, the whole supported in the peculiar connective tissue known as the *neuroglia.*

The ganglion-cells are large multipolar cells, found especially in the anterior part of the anterior cornu, one of the fibres from which goes to make up the neuraxon of a motor nerve. In the posterior horn these ganglion-cells are much smaller and rather well distributed throughout the whole horn. In the base of the posterior cornu, at its inner side, especially in the dorsal portion of the cord, a collection of smaller ganglion-cells is found, called the *column of Clarke,* the fibres originating from these cells going directly into the direct cerebellar tract of the white matter.

There are found in the gray matter nerve-fibres as well as nerve-cells. These fibres are either processes from the nerve-cells in the gray matter of the cord, or they are separate fibres originating elsewhere than in the gray matter of the cord, as from the axones of the spinal ganglion-cells.

The *neuroglia,* or *supporting tissue,* is slightly modified at certain points, as where it surrounds the central canal and where it caps the posterior cornu. The neuroglia is of ectodermal origin, the same as the rest of the nervous system, but in many ways it resembles a connective tissue. Its significance and function seem to be disputed points. Some authors claim that the neuroglia serves as a sort of nourishment for the nerve-cells; others that it has an insulating function in connection with the neurones, while again it has been considered only as a supporting tissue to fill up the spaces between the nerve-cells and -fibres, and afford paths for the circulation of the lymph. The neuroglia is composed of the neuroglia-cells and neuroglia-fibres (*glia-cells* and *glia-fibres*). The glia-cells are of two kinds, the *ependyma cells* and the *astrocytes* (or *Deiters' cells*); the first are cylindrical cells and border on the central canal, the latter are small nucleated cells with little protoplasm, and stellate in shape. The glia-fibres are not cell-processes as formerly supposed, but are independent fibres.

The *white matter* surrounds the gray matter, and is made up of medullated nerve-fibres, the cross-sections of which are shown in a transverse section of the cord. The greater number of these fibres run longitudinally; some, however, in front of the gray commissure, have an oblique direction, forming at this point the *white commissure*, which separates the gray commissure from the bottom of the anterior median fissure. They have a medullary sheath, but no neurolemma, being held together by the neuroglia-cells and connective tissue from the pia mater.

The white matter of the cord has been divided into the anterior lateral and posterior columns, not from any structural peculiarities, but from their functions.

The *anterior column* is that portion between the anterior median fissure and the anterior roots.

The *posterior column* is that between the posterior median septum and the posterior roots.

The *lateral column* is that area bounded by the anterior roots, the gray matter, and the posterior roots.

The anterior and lateral columns are often associated, due to the fact that the anterior horns do not reach the surface and completely divide this portion of the white matter, and are called the *anterolateral columns.*

These three primary columns are subdivided into secondary tracts with regard to the distribution of the fibres. The anterior column is divided into the *direct pyramidal tract* and the *anterior ground-bundle.*

The *direct pyramidal tract*, or *column of Türck*, is next to the median fissure, and is composed of fibres coming directly from the pyramids of the medulla.

The lateral column is divided into the *direct cerebellar tract*, made up of the fibres from the cells of the columns of Clarke; the *ascending anterolateral*, or *Gowers' tract;* the *crossed pyramidal*, made up of the fibres of the pyramids from the opposite side; the *descending anterolateral*, or *tract of Löwenthal;* and the *mixed lateral tract.*

The posterior column is divided into the *columns of Goll* and *Burdach.* The columns of Goll and Burdach conduct mostly *centripetal impulses*, which impulses having the same upward direction, are also conveyed by the direct cerebellar tract and tract of Gowers in the lateral columns.

The *centrifugal* impulses (*motor stimuli*) are conveyed by the fibres of the direct pyramidal tract of the anterior column and by those of the crossed pyramidal tract in the lateral column. The size, the shape, and the relative amounts of gray and white matter of the cord vary according to the several regions which we examine in transverse sections.

The *cervical sections* are large and have a greater transverse diameter, a large H of gray matter with a broad anterior and a slender posterior cornu.

The *dorsal sections* are smaller, nearly circular, and the gray matter is in crescents, only slightly curved, with slender horns anteriorly and posteriorly.

The *lumbar sections* are broad, have a deep anterior fissure, and a large, thick H of gray matter, which occupies most of the section, leaving but little white matter. The white matter gradually diminishes as we descend the cord.

Blood is supplied to the cord principally from the *anterior* and *posterior spinal arteries*, which are found occupying the anterior median fissure and posterior median septum, respectively. Branches from these enter the white substance and then pass to the gray matter, where they break up into a capillary network to supply the cellular structures.

THE MEDULLA.

The **medulla oblongata** is the first part of the brain proceeding from below upward. The medulla may be considered as the superior continuation of the spinal cord wherein a rearrangement of the structures has occurred. The anterior and posterior horns are first modified, due to the decussation of the fibres of the crossed pyramidal tracts and to the increase in size of the columns of Goll and Burdach, respectively. This increase of the tracts of the posterior column is due to the formation of new gray matter, the *nucleus gracilis* and *cuneatus*, which gradually pushes the posterior cornu forward and to the side. With the gradual approach toward the surface of the substantia gelatinosa, which caps the posterior horns, the *tubercle of Rolando* is formed. The central canal of the cord widens out and forms the *fourth ventricle.* The head of the anterior cornu is completely separated from its base, due to the decussation of the fibres of the crossed pyramidal tracts; these fibres with the fibres of the direct pyramidal tract forming the *anterior pyramids* of the medulla; while the head of the anterior horn takes up a position close to the posterior horn, forming the *lateral nucleus.* Between the pyramids and this lateral nucleus new gray matter appears, forming the *olivary body.* The continuation upward of fibres from some of the tracts of the anterolateral column cut up this lateral nucleus, forming the *formatio reticularis.* Still higher up in the medulla the olivary body is supplied by a new formation of gray matter, the *corpus dentatum.* This nucleus is in the shape of a capsule having an opening on its median side, the *hilum,* through which pass the fibres of the *olivary peduncle,* on their way to the gray matter of the interior and to the cerebellum. Two *accessory olivary nuclei,* composed of gray matter, lie in close relation to the corpus dentatum. The base of the anterior cornu remains as a projection in the floor of the fourth ventricle, having on its free surface numerous cells constituting the nucleus of the hypoglossal nerve. Before the expansion of the central canal occurs there lie below it a number of cells which, after the canal opens out, are placed external or rather to the side of this elevation. These cells form a column which is a nucleus for the ninth, tenth, and eleventh cranial nerves. The *white matter* still covers more or less completely the gray matter, and is divided, like the cord, into several columns by the continuation upward of the anterior and posterior median fissures. The depressions formed by the exit of the anterior and posterior spinal nerve-roots in the cord are distinct sulci in the medulla, and mark the points of exit of the ninth, tenth, and eleventh nerves posteriorly and the eleventh anteriorly.

THE PONS.

The **pons** is made up of a ventral and a dorsal portion. The *ventral* portion consists of transverse fibres which connect the hemispheres of the cerebellum. Through these fibres pass fibres from the cerebrum which go to make up the anterior pyramids of the medulla. These fibres are collected into a number of small bundles separated by several layers of the transverse fibres, while below, the fibres become grouped into two laterally placed bundles. Gray matter containing small multipolar cells is found between the fibres. The *dorsal* portion is a continuation of some of the structures of the medulla, with the addition of masses of gray matter which are connected with the origins of the fifth, sixth, seventh, and eighth cranial nerves. Higher up in the pons the floor of the fourth ventricle is formed of white matter, having beneath it a stratum of pigmented nerve-cells.

THE CRURA CEREBRI.

The **crura** are those portions of the brain connecting the pons and cerebrum, and containing within their structure the *aqueduct of Sylvius*, which connects the third and fourth ventricles. They are divided into two portions by a layer of gray matter, having embedded within it pigmented multipolar cells, the *substantia nigra*, forming the *tegmentum* above and the *crustæ* below. Each *crusta* is a thick rounded bundle composed of white fibres, the majority of which end in the internal capsule of the cerebrum.

The *tegmentum* consists of longitudinal and transverse bundles of white fibres, containing within their meshes gray matter composing a *formatio reticularis*. On each side of the median line the formatio reticularis contains a mass of pigmented cells known as the *red nucleus*. The majority of the fibres of the tegmentum terminate in the optic thalamus.

THE CEREBRUM.

The **cerebrum** consists of two hemispheres, each made up of an outer *cortex* of gray matter and an inner *medulla* of white matter. The white matter of the medulla consists of interlacing medullated nerve-fibres having no neurolemma and supported by a delicate connective tissue similar to the neuroglia-tissue of the cord. These fibres may be divided into three groups: (1) those uniting parts of the same hemisphere, and known as *association-fibres;* (2) those uniting parts of the two hemispheres, known as the *commissural fibres;* and (3) those fibres coming from the *crura cerebri* and *basal nuclei*, the *projection-fibres.*

The *corpus callosum* is the bridge between the two hemispheres, and is composed of commissural fibres derived from the ganglion-cells of the cortex. The medulla also contains numerous masses of gray matter which take part in the formation of such special structures as the *ventricular* and *caudate nuclei.*

The *cortex* is composed of gray matter, which may be divided into five not very sharply defined zones. They are the first, or *molecular* layer; second, or layer of *small pyramidal cells;* third, or layer of *large pyramidal cells;* fourth, or layer of *polymorphous nerve-cells;* and fifth, or layer of *spindle-cells.*

The *molecular layer* consists of neuroglia, terminal branches, from nerve-cells situated in the second and third layers, and a few tangential nerve-fibres.

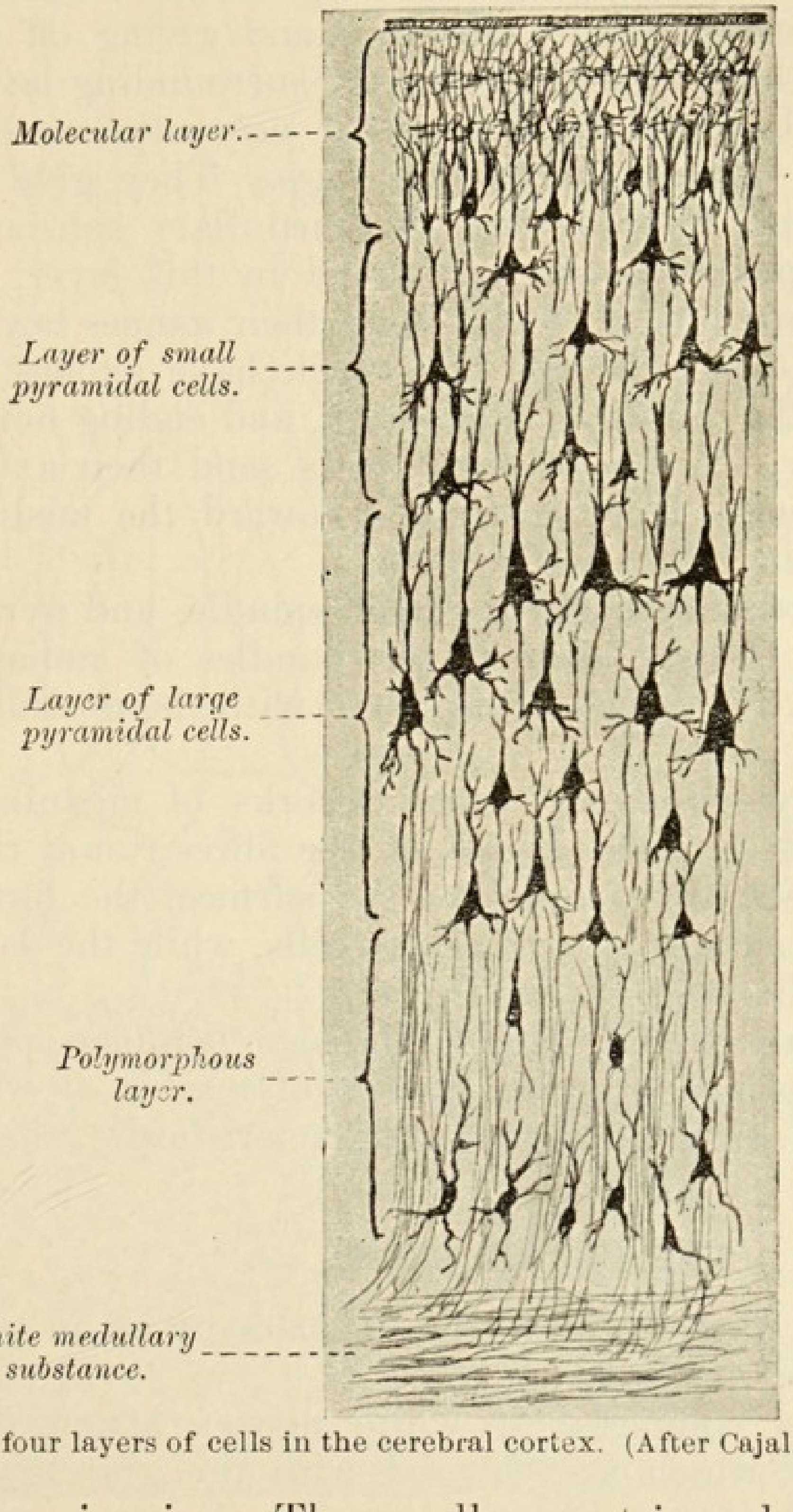
The *cells of Cajol*, found in this layer, are irregular in outline, sending out numerous processes which run parallel to the surface. Fine twigs are given off from these processes which end in arborizations in this layer.

The next layer is made up of *small triangular* or *pyramidal cells*, giving off several processes which terminate near the periphery of the cortex.

The apices of the cells of this layer are directed toward the surface of the cortex, and the bases toward the medulla. The main dendrite proceeds from the apex of the cell toward the surface, passing almost entirely through the thickness of the molecular layer, and in its course gives off many branches and ends in fine arborizations in the outer part of the molecular layer. From the base and sides of the cells other smaller dendrites are given off, while the axone of the cell emerges from the base and proceeds toward the medulla, giving off along its course many collateral branches which run parallel to the surface.

The *layer of large pyramidal cells* is a thick stratum composed of the same cells as the preceding layer, only much

FIG. 94.



The four layers of cells in the cerebral cortex. (After Cajal. Modified from Testut.)

larger in size. These cells are triangular in shape, with their apices directed toward the surface, and are composed of a granular pigmented protoplasm containing a large nucleus and a distinct nucleolus. Numerous *protoplasmic processes* are given off which end in the form of arborizations in the first layers. These processes, however, do not unite with each other. An *axis-cylinder* process is given off from their base, extending into the white substance and giving off collateral branches which turn and enter the surrounding layers.

The fourth, or layer of *small irregular polymorphous cells*, contains cells of various shapes and sizes. They give off dendrites and send axones into the medullary substance. Some spindle-shaped cells are also found in this layer, and are called *Golgi cells type I.*, which send their axones beyond the cortex; and *Golgi cells type II.*, which have axones not reaching outside the limits of the cortex, and ending not far from the cell-body. A few of these cells send their axones toward the molecular layer instead of toward the medulla. These are called the *cells of Martinotti.*

The last layer contains numerous small spindle- and pyramidal-shaped cells, lying between the bundles of radiating nerve-fibres which are directly continuous with the medullary tracts.

The various layers contain fine networks of medullated nerve-fibres as well as cells. Some of the fibres run at right angles, while others are parallel to the surface, the former being mostly the axones of pyramidal cells, while the latter are largely the collaterals of axones.

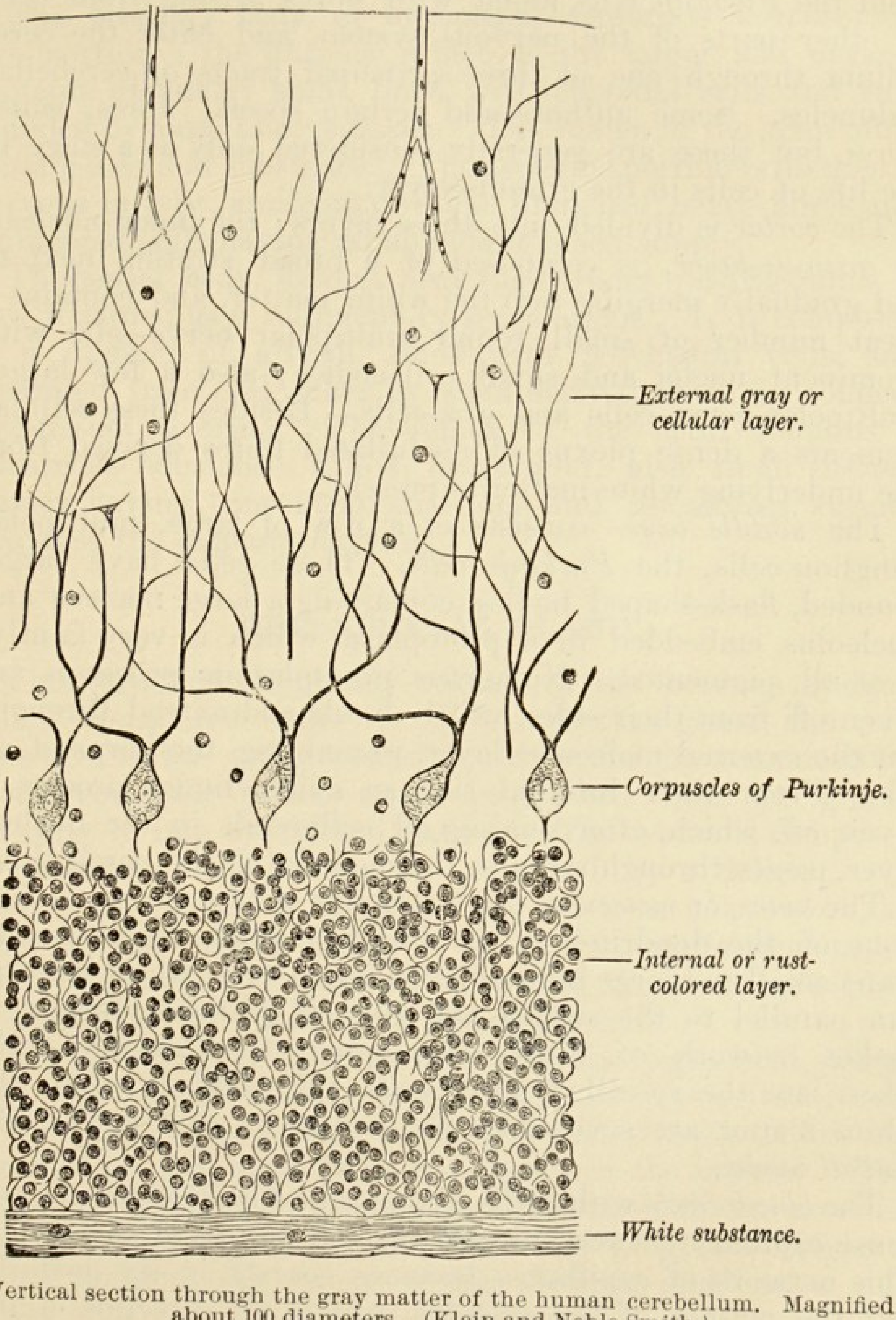
Special ganglionic regions, such as the *optic thalamus, olfactory bulbs*, and *corpus striatum*, consist of masses of white and gray matter, each having its characteristically shaped nerve-cells.

THE CEREBELLUM.

The **cerebellum**, like the cerebrum, is made up of an outer cortex and an inner medulla.

The *medulla* is composed of white matter arranged in branching laminæ, which are covered with the gray matter of the cortex and appear like the branches of a tree, called the *arbor vitæ.* It consists of medullated nerve-fibres devoid of a neurolemma.

FIG. 95.



Vertical section through the gray matter of the human cerebellum. Magnified about 100 diameters. (Klein and Noble Smith.)

The bundles of nerve-fibres are made up of axones derived from the *Purkinje cells*, along with fibres arising from cells in other parts of the nervous system, and enter the cerebellum through one of three principal tracts or cerebellar peduncles. Some authors add certain special fibres, *mossy fibres*, but these are generally considered only as a stage in the life of cells in the granule-layer.

The *cortex* is divided into three layers: the inner nuclear, or *granule-layer*, is composed of a broad stratum next to and gradually merging into the white matter, and contains a great number of small round multipolar nerve-cells with prominent nuclei and small cell-bodies; also a few larger multipolar nerve-cells and glia-cells. Besides these cellular elements a dense plexus of medullated fibres derived from the underlying white matter is present.

The *middle layer* consists of a row of large, multipolar ganglion-cells, the *Purkinje cells*. These cells have large, rounded, flask-shaped bodies, containing a large nucleus and nucleolus embedded in a protoplasm which is very faintly, if at all, pigmented. Numerous protoplasmic processes are given off from their sides, which divide and extend throughout the external molecular layer, resembling the horns of an elk. From their internal side an axis-cylinder process is given off, which, after sending off collaterals in the nuclear layer, passes through same to the medulla of the cerebellum.

The *outer*, or *molecular layer*, consists of extensive ramifications of the dendrites of the Purkinje cells, together with many small and large multipolar ganglion-cells, whose neurites run parallel to the surface and give off branches, forming a basket network of fibrils enveloping the Purkinje cells. These are the so-called *basket-cells*. Embedded within the white matter are several special masses of gray matter, the *central nuclei*.

The *bloodvessels* within the *cerebrum* and *cerebellum* end as a dense capillary network around the cell groups of the cortex. This network of capillaries becomes coarser in the medulla, and the meshes of the network run in the direction of the nerve-fibres.

THE PITUITARY BODY AND THE PINEAL BODY.

The **pituitary body,** or **hypophysis cerebri,** is *composed of* two portions: the *anterior*, which is the larger and darker, contains glandular acini lined with cuboidal cells and surrounded by loose fibrous tissue. The lumen of the acini often contain a colloid substance. The *posterior* portion is distinctly nervous in type, and contains fine branched nerve-fibres and pigmented cells having an abundant blood-supply.

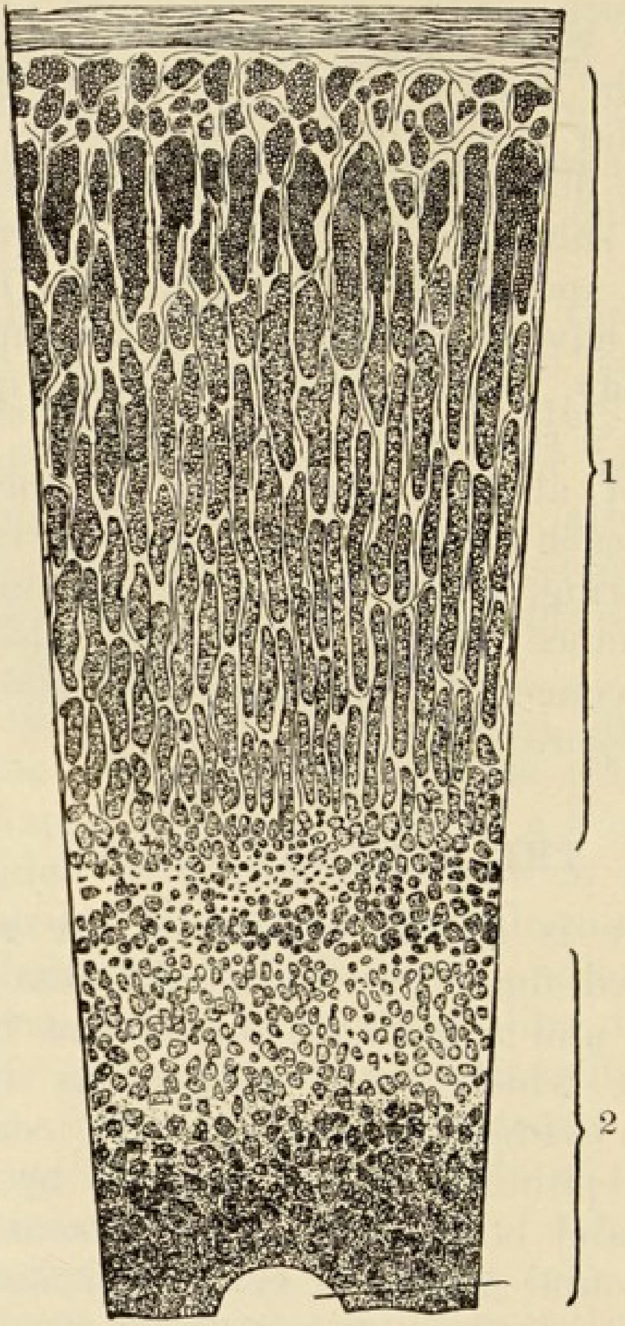
The **pineal body,** located near the corpora quadrigemina, is now regarded as a rudimentary sense-organ. It is composed of a number of alveoli, lined with polyhedral cells, and separated from each other by septa derived from the connective-tissue covering. The lumen of the acini contains a calcareous substance called *brain-sand*, also small discoid masses having concentric striations and resembling starch-granules, the *corpora amylacea.*

THE ADRENAL GLAND.

This structure is closely related to the nervous system, and is considered under it. It is a ductless gland, and consists of a *cortex* and a *medulla*, surrounded by a connective-tissue corpuscle which sends projections into the gland, dividing it into cylindrical masses. The *cortex* is composed of columns of epithelial cells separated by a delicate connective tissue, and is divided into the *zona glomerulosa*, an outer layer of round masses of cells; the *zona fasciculata*, or middle layer of cylinders of cells; and the *zona reticularis*, or inner layer of columns of pigmented cells.

The **medulla** consists of cords of granular pigmented, polygonal cells, ganglion-cells, non-medullated nerve-fibres, connective tissue, and bloodvessels. The *bloodvessels* follow the connective-tissue septa from the capsule to the interior. The *nerves* are numerous, and follow the course of the arteries, ending in plexuses in the medulla. The *lymphatics* originate in the intercellular spaces of the medulla and cortex, and empty into the larger vessels of the capsule.

FIG. 96.



Section of human adrenal gland: 1, cortex; 2, medulla. (Eberth.)

DEVELOPMENT OF THE CENTRAL NERVOUS SYSTEM.

The nerve-cells, the nerve-fibres, and the neuroglia are developed from the *ectoderm* alone. The cells of this layer assume a columnar type and produce a thickened area, the *medullary plate*, and on either side the cells become heaped up to form the *medullary folds*. The medullary plate becomes concave on the surface, or it invaginates and forms the *medullary groove*, which finally closes to form the *primary neural tube*, from the differentiation and specialization of whose walls the essential parts of the nervous system are derived. The wall of this tube is composed of two kinds of cells, the outer of columnar epithelial cells, from which are formed the neuroglia, and are called *spongioblasts*, and the inner of spherical cells with large nuclei, these are called the *neuroblasts*, which form the nerve-cells and the nerve-fibres.

The spongioblasts, which are at first columnar epithelial cells lining the primary neural tube, elongate, their protoplasm undergoing a change, and finally they result in long, slender cells containing large nuclei, and their inner ends

FIG. 97.

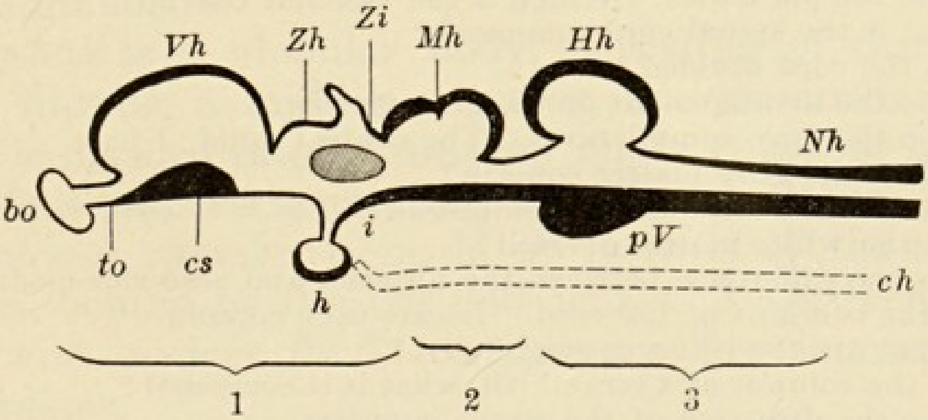


Diagram to illustrate the formation of the primitive brain: *bo*, olfactory bulb; *Vh*, secondary or permanent fore-brain; *Zh*, inter-brain; *Zi*, epiphyses; *i*, infundibulum; *h*, hypophysis; *Mh*, mid-brain; *Hh*, hind brain; *Nh*, medulla or after-brain; *p V*, pons Varolii; *to*, olfactory tract; *cs*, corpus striatum; *ch*, chorda dorsalis. 1, 2, 3, correspond to the three primitive cerebral vesicles. (After Bonnet.)

form a smooth limiting membrane, while the outer form a close reticulum made up of their irregular branches.

The neuroblasts, which at first are the inner layer of the primary neural tube, move toward the outer boundary of the wall and begin to elongate and become pyriform. Thus the nerve-cells at first have but one process, which represents the axis-cylinder, and later develop protoplasmic processes.

The nerve-fibres are developed in two sets: those from the nerve-cells of the medullary tube and those from the cells of the ganglia.

The first nerve-fibres for some time consist only of the axis-cylinder, and the neurolemma and the medullary substance are later additions from the mesoderm. These young nerve-fibres collect into groups and form the nerve-trunks.

About half the neural tube is devoted to the formation of the brain, and is divided into three communicating sacs, called the *fore-brain*, the *mid-brain*, and the *hind-brain* vesicles. These vesicles are developed into the brain, while the remainder of the neural tube forms the spinal cord.

QUESTIONS.

Name the membranes of the central nervous system.
Describe the dura mater.
Where are the subdural spaces?
Describe the arachnoid. The subarachnoidean spaces.
What are the Pacchionian bodies?
Describe the pia mater. Which is the vascular coat?
Of what is the spinal cord composed?
How is the cord divided?
Describe the arrangement of the gray matter.
Describe the gray commissures. The central canal.
What does the gray matter contain?
Of what is the white matter composed?
How is the white matter divided?
What is the difference between the anterior and posterior median fissures?
Name the columns of the cord. Locate each column.
Into what are the columns subdivided?
Locate the column of Clarke. Of what is it composed?
Describe the direction of the nerve-impulses.
Describe sections of the cord in the different regions.
What is the medulla?
What does the central canal of the cord form when reaching the medulla?
Describe the changes occurring in the anterior and posterior horns.
Name the divisions of the pons. Describe each.
What are the crura cerebri?
Describe the substantia nigra.
Describe the crustæ.
Describe the tegmentum.
Of what does the cerebrum consist?
Describe the gray matter of the cerebrum.
Name and describe the layers of the cortex.
Describe the medulla.
What is the arbor vitæ of the cerebellum?
Describe the cortex of the cerebellum.
What are Purkinje's cells?
Describe the pituitary body.
What is the pineal body?
What are the corpora amylacea and brain-sand?
What kind of structure is the adrenal gland?
Name the layers of the cortex of this gland.
Describe the medulla. Describe the bloodvessels, nerves, and lymphatics of this organ.

From what layer is the central nervous system derived?

Describe the formation of the primitive neural tube. Name the two kinds of cells found in this tube, and what parts they form?

From what are the brain-vesicles derived? Name them. Into what are they developed?

From what is the spinal cord developed?

CHAPTER XV.

THE EYE AND ITS APPENDAGES.

THE eye is the organ of sight, and is *composed of* the eyeball and accessory structures—as the eyelids, muscles, and lachrymal glands.

The *eyeball* is a globular body, consisting of three coats, an outer fibrous, a middle vascular, and an inner nervous coat, and is divided into an anterior and a posterior chamber, with the lens and iris separating these two portions.

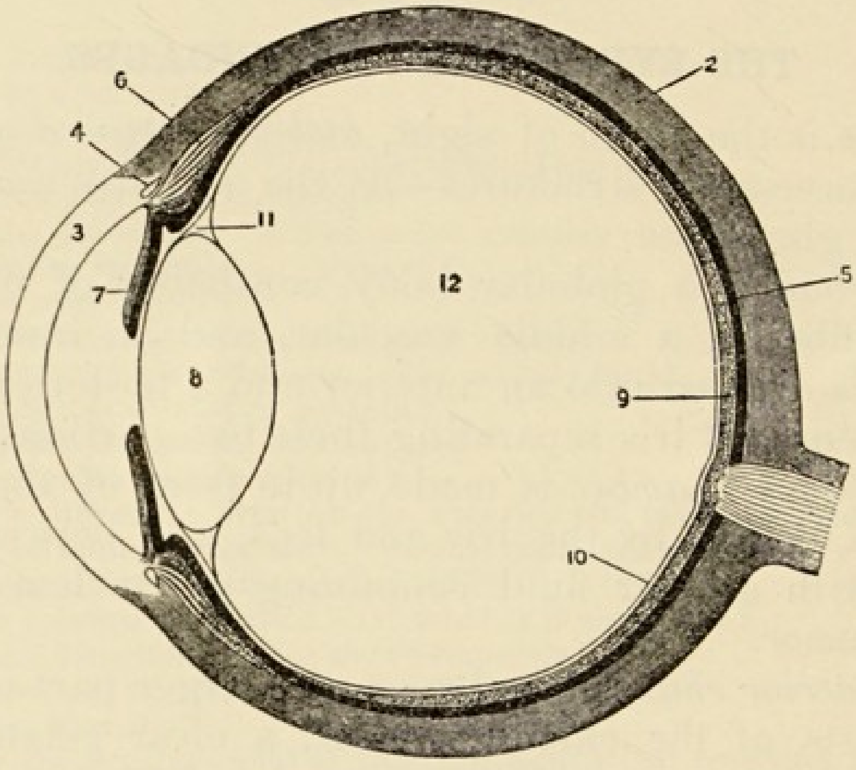
The *anterior chamber* is made up in front of the transparent cornea, behind by the iris and lens, and between these it is filled with a clear fluid containing a few leucocytes, the *aqueous humor*.

The *posterior chamber* embraces the larger part of the eye, and consists of the *vitreous humor*, a clear gelatinous substance containing a delicate network of fibrils, wandering cells, and the remains of minute bloodvessels, surrounded by a delicate membrane, the *hyaloid membrane*. External to this are the three superimposed coats of the eyeball.

The outer, or fibrous coat, consists of two portions, the *sclera* and the *cornea*.

The *sclerotic coat* covers the posterior five-sixths of the eyeball, and is a white, opaque, dense coat. It consists of a fibroëlastic tissue containing within its meshes flattened stellate connective-tissue cells. The inner layer of the sclera is looser in structure, and contains many pigmented cells, being covered with endothelium, and constituting the *lamina fusca*. A loose connective tissue unites the sclerotic and choroid coats, forming the *lamina suprachoroidea*. The spaces between these trabeculæ form the *subscleral* lymph-space, and are lined with flattened endothelial cells. On the outer surface of the sclera is a serous sac composed of a thin translucent fibrous membrane lined with endothelial cells, the *capsule of Ténon.* Posteriorly the sclera is perforated for the entrance of the optic nerve. This is called the *lamina cribrosa,* and has in

Fig. 98.



Horizontal section of right eyeball: 1, optic nerve; 2, sclerotic coat; 3, cornea; 4, canal of Schlemm; 5, choroid coat; 6, ciliary muscle; 7, iris; 8, crystalline lens; 9, retina; 10, hyaloid membrane; 11, canal of Petit; 12, vitreous body; 13, aqueous humor. (Chapman.)

its centre a larger opening, the *porus opticus.* The conjunctiva joins the sclera a little before its junction with the cornea.

The *muscles of the eyeball* are attached to the scleric coat by their tendons passing over into the fibre-bundles of the fibroëlastic tissue constituting the sclera. The muscles are so arranged as to allow the eyeball to move in many directions, and consist of the following muscles: recti superior, inferior, internus, and externus, obliqui oculi superior and inferior, and one for the eyelid, the levator palpebræ superioris.

The *blood-* and *nerve-supply* to the sclera is found in the form of capillary networks and nerve-plexuses between the bundles of fibrous tissue.

The *middle, vascular,* or *choroid, coat* consists of a thin membrane of dark color, surrounding the posterior five-sixths of the eyeball. It is composed of four layers, the *lamina suprachoroidea,* the *vascular layer,* the *choriocapillary layer,* and the *vitreous membrane.* The outer, or *lamina suprachoroidea,* is similar to the lamina fusca of the sclera, and is covered with endothelium. The *vascular layer* is the thickest, and is composed of fibroëlastic connective tissue containing many stellate pigmented cells, and supports the bloodvessels and lymphatics. The principal vessels are the *venæ vorticosæ,* which are formed by numerous capillaries converging to form four or five trunks, which pierce the sclerotic midway between the porus opticus and the cornea.

The *choriocapillary* layer is a thin layer composed of a dense network of capillary bloodvessels.

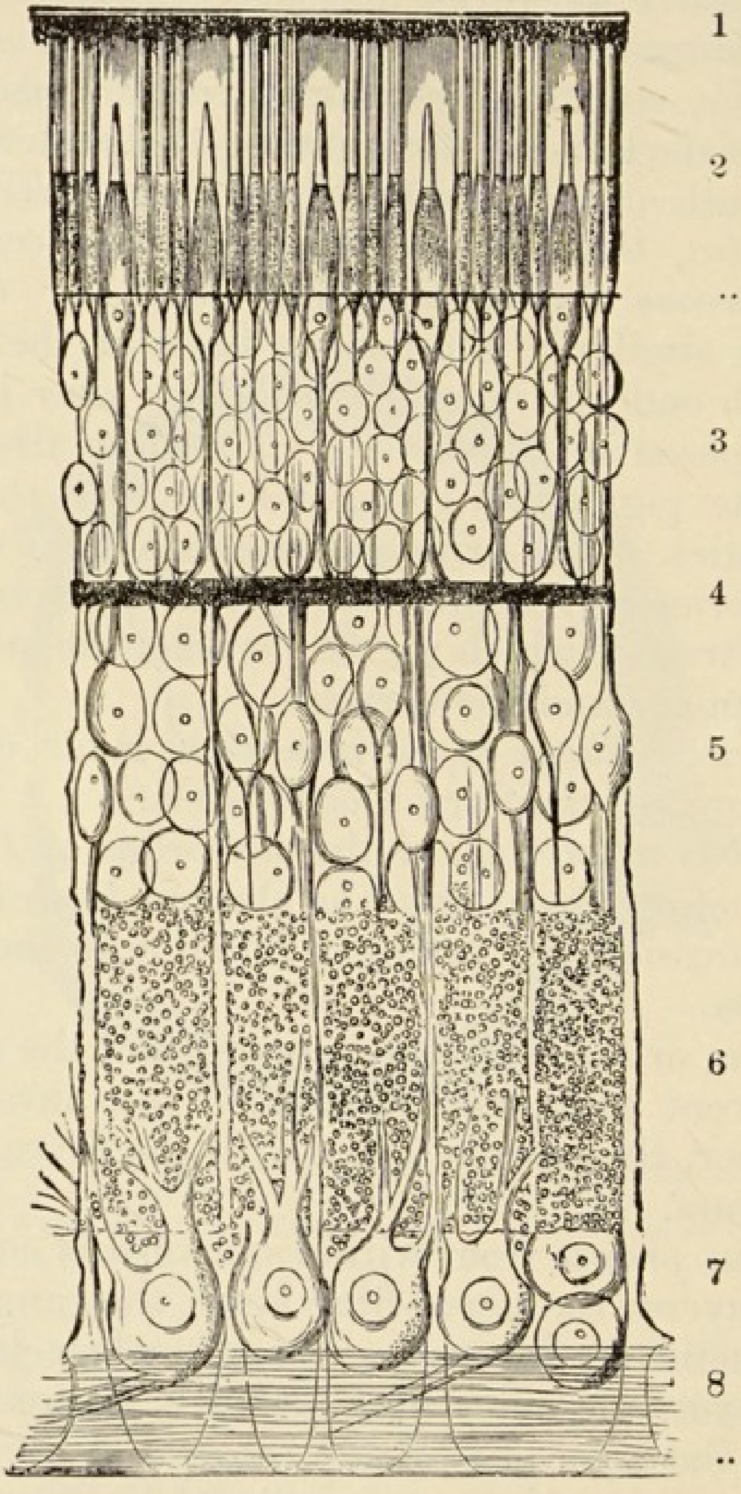
The *vitreous membrane,* or the *membrane of Bruch,* is a thin hyaline structure separating the choroid from the retina, and having impressions on its inner side due to the pigment-cells of the retina.

The *retina,* or *inner nervous coat,* has not the same structure in its different areas, and is divided into three portions, the retina proper, the macula lutea with the fovea centralis, and the ora serrata.

The *retina proper* from within outward is composed of the following layers: the nerve-fibre layer, the ganglion-cell layer, the inner reticular layer, the inner nuclear layer, the outer reticular layer, the outer nuclear layer, the external limiting membrane, the layer of rods and cones, and the pigment-layer. In addition to these layers an internal limiting membrane is sometimes added, and also some elements of a supporting tissue, the *radiating fibres of Müller.* These fibres are elongated cells, the bases of which are expanded and go to form the *internal limiting membrane,* while the remainder of the cell extends in the form of fibres through all the layers to the rods and cones. In their course they give off lateral branches

FIG. 99.

Outer or choroidal surface.



Inner surface.

Diagrammatic section of the human retina: 1, layer of the pigment-cells; 2, layer of rods and cones; . . , membrana limitans externa; 3, outer nuclear layer; 4, outer molecular layer; 5, inner nuclear layer; 6, inner molecular layer; 7, layer of nerve-cells; 8, layer of nerve-fibres; . . , membrana limitans interna. (Schultze.)

which go to make up a network in the different layers, while at their outer extremity they divide into a number of delicate processes which extend between the rods and cones.

The cells of this supporting tissue of Müller are somewhat similar to the ependymal cells of the embryonic spinal cord, and are elements of epithelial nature and of ectodermic origin.

The *nerve-fibre layer* consists of bundles of naked axis-cylinders which are derived from the optic nerve and are united to form a plexus. They radiate from the entrance of the optic nerve to the ora serrata and are continued upward to the layer of ganglion-cells.

The *ganglion-cell layer* consists of large round multipolar nerve-cells having a large nucleus and nucleolus, whose axis-cylinders are continuous with the nerves of the nerve-fibre layer, while the branching processes which they give off from their outer sides extend into the inner reticular layer. Often in the human retina two ganglion-cells are found to be connected by a thick protoplasmic bridge, constituting the *twin cells.* Only one of these cells possesses an axis-cylinder process which connects with the nerve-fibre layer.

The *inner reticular layer* consists of a delicate fibrous reticulum of cells resembling the neuroglia, with branches from the fibres of Müller along with the processes of neighboring nerve-cells. Minute clear granules are found within this reticulum, hence the name *granular layer.*

The *inner nuclear layer* is a zone composed of several varieties of nerve-cells, as well as the nuclei and some branches of the fibres of Müller. These cellular elements are the *amacrines,* which form a layer on the inner side, and whose dendrites enter the inner reticular layer; the oval nucleated bipolar cells whose protoplasmic processes end in the gangli-onic and outer reticular layers; and a layer of multipolar cells striated on the outer side, the axis-cylinders of which end near the cells of the ganglionic layer.

The *outer reticular layer* is a narrow zone made up of a network of fine fibres and few nuclei. The fibrils are from the neuroglia and processes of nerve-cells. These cells are stellate, and are considered by some to be ganglion-cells due to the varicose condition of some of their processes.

The *outer nuclear layer* consists of a delicate network of nerve-fibrils mixed with connective tissue, and containing clear oval bodies, known as the *rod- and cone-granules*, on account of their connection with the rods and cones of the next layer. These granular bodies give off an inner and an outer process, the latter being continuous with a rod and cone, while the former extends to the outer reticular layer.

The *external limiting membrane* is a thin membrane formed from the fibres of Müller, and is perforated by the cells of the rods and cones.

The *layer of rods* and *cones* is composed of rod- and cone-cells, or elongated neuroëpithelial cells, also called *visual* cells. The rod-cells consist of a *rod* and *rod-fibre*, with its nucleus contained in the rod-granule. The *rod*, that portion external to the limiting membrane, is made up of two parts, an outer segment, which is a slender cylinder containing *rhodopsin*, and consisting of a number of thin superimposed disks, and an inner segment, broad and fusiform, striated longitudinally at its outer margin and granular in that portion near the outer limiting membrane.

The rod-fibres extend to the outer reticular layer of the retina, ending in spherical swellings, the *rod-granules*, which contain the oval nuclei.

The *cone-cells* consist of a *cone* and a *cone-fibre* with its nucleus. The *cone*, or the portion of the cone-cell beyond the limiting membrane, is made up of two segments: an outer, which is shorter than the corresponding portion of the rod-cell, is conical, and contains no *rhodopsin;* and an inner broad, fusiform, and striated portion.

The cone-fibre extends to the outer reticular layer, the portion of the same in the outer nuclear zone being expanded, and contains the nucleus.

The *pigment-layer* consists of a single layer of large hexagonal cells, forming a layer over the rods of the preceding layer. The nuclei of the cells are in the outer half, and their inner half contains the pigment-granules. Protoplasmic processes extend from their inner end, passing between the rods and cones.

The *pigment* is in the form of small dark-brown granules and rods, and changes its position under the influence of light, so that it is distributed equally throughout the cell. Thus the rods and cones may become surrounded by pigment-granules in the region of the external limiting membrane. Strong light causes the pigment to move to the outer part of the cells in a thin layer, thus causing the visual cells to become free from pigment.

In the *macula lutea* the ganglion-cells are abundant and are arranged in several layers, the nerve-fibres are incomplete, and the rods are absent. A yellowish pigment is present, giving the characteristic color to the same.

The *fovea centralis* is a trough-like depression in the centre of the macula, and appears as a light spot. This depression is due to a reduction in the number of layers of the retina to such an extent that the cone-cells resting on the pigmented layer alone remain.

In the *ora serrata*, which is the termination of the *retina proper*, a rapid diminution in the layers of the retina occurs. Nerve-fibres and ganglion-cells are wanting, but the cone-cells remain, but are without their outer segment. The radiating fibres of Müller are very prominent. The elements of the inner nuclear layer change into a single row of columnar epithelium, which, with the pigment-layer, continues as the *pars ciliaris* and *pars iridica retinæ*.

These latter structures are covered internally by a new cuticular structure, known as the *internal limiting membrane*, beginning at the ora serrata, which will be described in connection with the iris and ciliary body.

The *blood-supply* to the retina enters with the optic nerve, the *arteria centralis retinæ*, and forms a capillary network in the inner nuclear and nerve-fibre layers.

THE OPTIC NERVE.

The **optic nerve** is surrounded in the orbit by fibrous sheaths similar to the central nervous system. This nerve is composed of medullated nerve-fibres with a neurolemma or sheath of Schwann, the latter being represented by the neuroglia. The sclera and choroid give off connective-tissue fibres which blend with the optic nerve and form the lamina cribrosa. A short distance from the eyeball there enter into the axis of the optic nerve a central artery and vein to supply the retina. They are surrounded by a connective-tissue sheath. The nerve-fibres pass through the lamina cribrosa into the retina, there forming the nerve-fibre layer.

THE CORNEA.

The **cornea** is a circular transparent structure, a modification of the sclera, and is the most anterior portion of the eyeball, comprising about one-sixth of the circumference of the globe. It is in front of the aqueous tumor, being continuous at the sides with the sclera. It consists of five layers, the anterior epithelium, the anterior elastic membrane, the ground-substance, the posterior elastic membrane, and the posterior endothelium.

The *anterior epithelium*, thinner in the centre than at the periphery, consists of stratified squamous cells. The outer cells are flat and contain oval nuclei, while the inner are columnar. Some few prickle-cells are also present in the deeper layers. This layer is a reflection of the conjunctiva.

The *anterior elastic membrane*, or the *limiting membrane of Bowman*, is a homogeneous glossy layer, consisting of a peculiar delicate connective tissue, and forms a basement-membrane for the cells of the preceding layer.

The *ground-substance*, or the *substantia propria*, constitutes the main portion of the cornea, and consists of connective-tissue fibrils grouped into bundles and lamellæ, held together by a clear cement-substance. The bands of white fibres uniting adjacent bundles are known as the *arcuate fibres*. Between the lamellæ are found numerous communicating lymph-spaces, which contain many stellate cells, the *corneal corpuscles*. These corpuscles unite with one another by means of their processes, forming a reticulum. The cornea possesses no bloodvessels, and receives its nutrition through these lymph-spaces.

The *posterior elastic membrane, limiting* or *Descemet's mem-*

brane, is a thin homogeneous band at the inner part of the cornea.

The *posterior endothelium* is a single layer of polygonal endothelial cells, continuous with those lining the anterior surface of the iris.

The cornea is a non-vascular structure, the capillary vessels terminating in loops at its circumference. *Lymphatic vessels* have not as yet been demonstrated in the cornea.

The *nerves* are numerous and are derived from the ciliary nerves. They enter its laminated structure and form a delicate network, and their terminal filaments form a plexus on the surface of the cornea proper beneath the epithelium. They thus form a subepithelial plexus which gives off fibrils passing between the epithelial cells, forming another network, the intraëpithelial plexus.

THE CILIARY BODY.

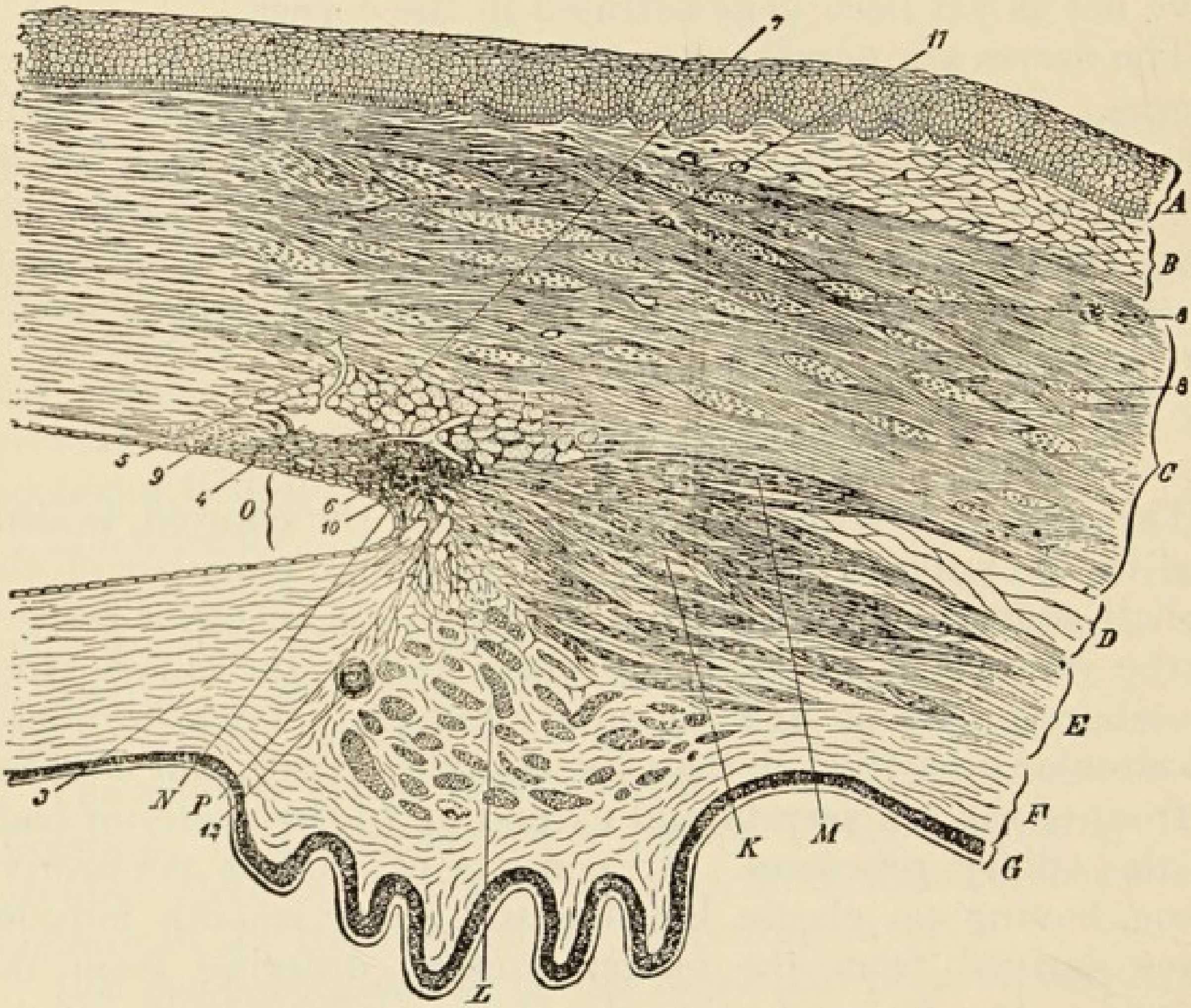
This structure, which is a thickening of the choroid, is situated in the anterior portion of the posterior chamber of the eyeball, extending from the ora serrata to the posterior margin of the iris, and is divided into three parts: the ciliary ring, the ciliary processes, and the ciliary muscle. The *ciliary ring* is a circular area thicker than the choroid proper, and situated in front of the ora serrata and extending to the posterior ends of the ciliary processes. It consists of fibrous connective tissue, having no elastic lamellæ and many smooth muscle-fibres derived from the ciliary muscle, differing from the choroid proper in not having the *choriocapillary layer.*

The *ciliary processes* are about seventy meridionally placed triangular folds, beginning at the ora serrata and gradually increasing in size until they terminate at the edge of the lens. Their extremities form a circle which gives attachment to the suspensory ligament of the lens. They consist of fibrous connective tissue and many bloodvessels, being covered with the vitreous membrane, which is a thin homogeneous structure.

Inside this layer is a double layer of epithelial cells, the outer cuboidal in shape and pigmented, and the inner non-pigmented columnar cells, constituting the anterior continuation of the retina.

The *ciliary muscle* is an annular band of non-striated muscle-fibre lying external to the ciliary processes. Connective tissue is found within the bundles of muscle-fibres, the

Fig. 100.



Section through ciliary body and tunics of eye at corneosclerotic junction: *A*, epithelium of conjunctiva; *B*, tunica propria of conjunctiva; *C*, sclerotic; *D*, laminæ fusca and suprachoroidea; *E*, *F*, choroid; *G*, pars retinæ ciliaris and iridica; *H*, cornea; *I*, iris; *K*, *M*, radial and meridional portions of ciliary muscle; *L*, circular portion of ciliary muscle; *N*, ligamentum pectinatum; *O*, margin of anterior chamber; 1, anterior elastic lamina of cornea; 2, posterior elastic lamina and endothelial layer of cornea; 3, spaces of Fontana; 4, canal of Schlemm; 5, 6, vessels tributary to canal of Schlemm; 7, 8, 9, fibrous bundles of sclerotic cut transversely; 10, origin of meridional ciliary muscle; 11, 12, bloodvessels. (Waldeyer.)

latter being arranged in three groups, namely, the *meridional*, the *radial*, and the *circular fibres*. The circular fibres are the most internal, and form a ring around the attached margin of iris, known as the *ring-muscle of Müller*. The ciliary muscle receives its blood-supply from branches derived from the vessels found in the ciliary body.

THE IRIS.

The **iris** is a connective-tissue membrane, the anterior continuation of the choroid, suspended in the aqueous humor between the lens and cornea. It is contractile, and is perforated at its centre by an opening, the *pupil.* Its margin is attached to the cornea in front by the *pectinate ligament* of the *iris,* and behind it is attached to the ciliary body. It consists of five layers, the anterior endothelium, the anterior boundary layer, the vascular stroma layer, the posterior boundary layer, and the pigment-layer.

The *anterior endothelium* is a single layer of polygonal cells containing a finely granular protoplasm, non-pigmented, and continuous with the endothelium on the posterior surface of the cornea.

The *anterior boundary layer* is a continuation of the choroid, and consists of a loose fibrous tissue containing lymphoid cells within its meshes.

The *vascular stroma layer* constitutes the main portion of the iris, and consists of connective-tissue bundles loosely arranged, in which are numerous bloodvessels and involuntary muscle-fibres. The muscle-fibres are arranged in two sets, one being arranged circularly around the pupil, forming its sphincter, while the other set is arranged radially and dilates the pupil.

The *posterior boundary layer* is a thin, homogeneous membrane corresponding to the vitreous layer of the choroid.

The *pigment-layer* consists of two layers, and is a continuation of that portion of the retina known as the *pars iridica retinæ.* The anterior, or outer, layer is composed of pigmented spindle-shaped cells, while the posterior, or inner, layer consists of polygonal pigment-cells. The posterior surface of this pigment-layer is covered by a delicate cuticular membrane, the *membrana limitans iridis.*

The *blood-supply* to the iris is derived from the long and anterior ciliary arteries, which form a circle around the margin of the iris, from which branches pass toward the pupil, forming a second arterial circle at the margin of the pupil. The *nerves* to the iris form a plexus near its outer margin, branches from this plexus passing into the circular and radiating muscle-fibres. The *pectinate ligament* is formed by the splitting up of the posterior elastic membrane of the cornea into a number of fibres. Some of these fibres, with fibres from the ciliary muscle and sclera, form an annular mass of spongy tissue, which contains the *spaces of Fontana*, which communicate with the *canal of Schlemm*, an annular channel found at the sclerocorneal juncture.

THE LENS.

The **crystalline lens** is a biconcave body suspended by means of its *suspensory ligament*, or *ligament of Zinn*, behind the iris and in front of the vitreous humor. It consists of the *lens-substance* and *lens-capsule*.

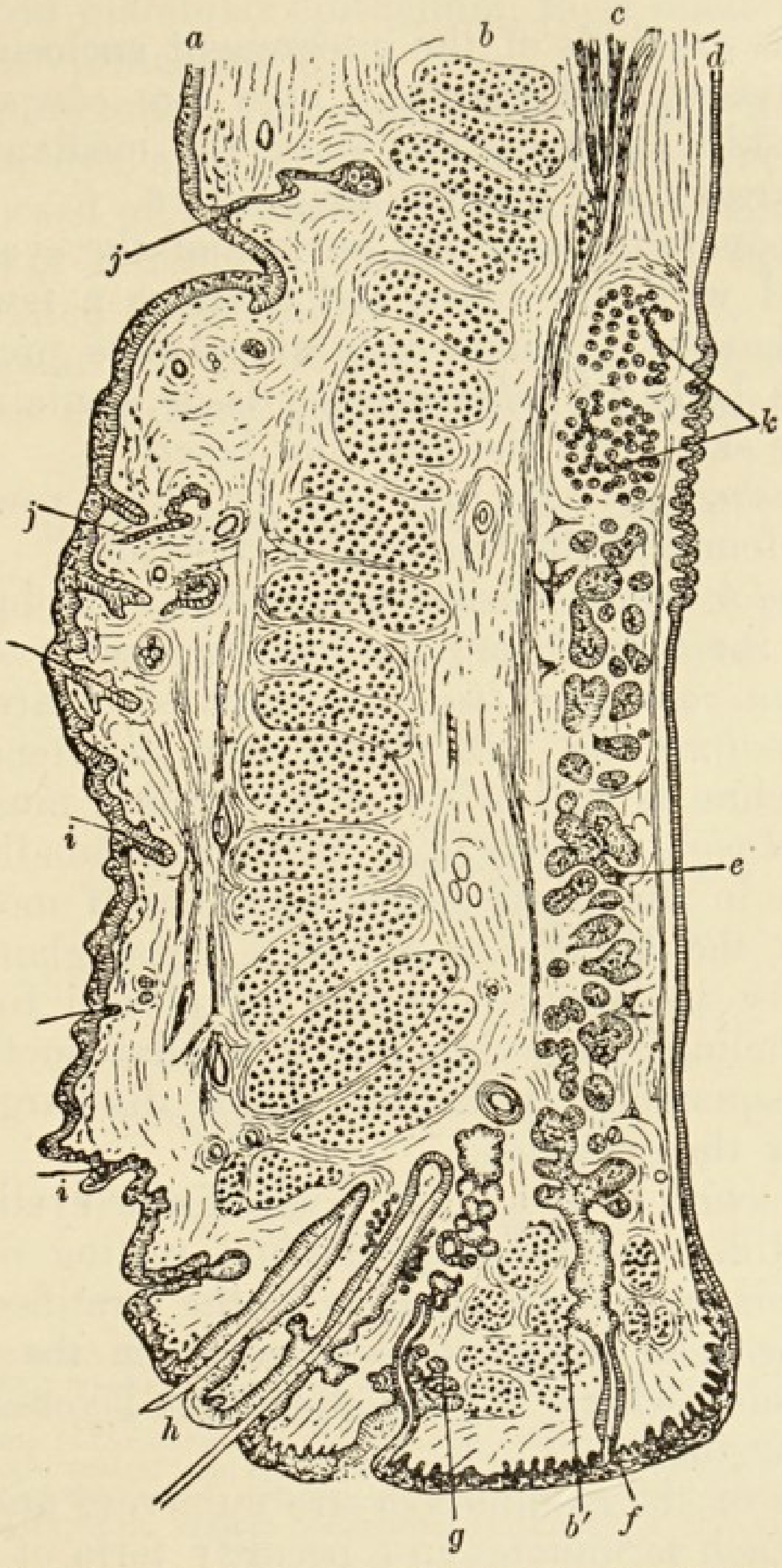
The *lens-substance* is a transparent gelatinous substance composed of *lens-fibres*, and covered on the anterior portion with epithelium. These fibres, which make up the greater part of the lens, are long, transparent, hexagonal epithelial cells cemented together by an albuminous material and arranged concentrically and meridionally. Each fibre has one or more oval nuclei, which are usually placed near the middle of the cells.

The *anterior epithelium* consists of a single layer of low cuboidal cells covering the lens anteriorly, being attached to the capsule by an albuminous material above, while below them a layer of the same material attaches them to the lens-fibres.

The *capsule* is a homogeneous membrane, thicker anteriorly than posteriorly, and composed of elastic tissue, being continuous at the margin with the suspensory ligament.

The *suspensory ligament*, or the *zone of Zinn*, consists of delicate fibres which extend from the surface of the hyaloid membrane near the ora serrata, over the ciliary processes to the capsule of the lens, at which point it divides anteriorly

FIG. 101.



Vertical section through the upper eyelid: *a*, skin; *b*, orbicularis palpebrarum; *b′*, marginal fasciculus of orbicularis (ciliary bundle); *c*, levator palpebræ; *d*, conjunctiva; *e*, tarsal plate; *f*, Meibomian gland; *g*, sebaceous gland; *h*, eyelashes; *i*, small hairs of skin; *j*, sweat-glands; *k*, posterior tarsal glands. (After Waldeyer.)

and posteriorly, leaving a triangular space between, the *canal of Petit.*

THE EYELIDS.

The **eyelids** are folds of the integument enclosing muscles, connective tissue, and glands. They are *composed of* five layers: the skin, the muscular layer, the median connective tissue, the tarsal plate, and the conjunctiva.

The *skin* covers the external surface of the eyelids, and is thin, covered with fine hairs, and contains a few sebaceous and sweat-glands. Pigment-cells are always present in the *true skin.* A layer of *subcutaneous* tissue, containing no fat, separates the skin from the muscular layer.

The *eyelashes*, or *cilia*, are two or three rows of thick curved hair found at the free edge of the lids.

The *muscular layer* consists of bundles of voluntary muscle-fibres of the *orbicularis palpebrarum muscle.*

The *median connective tissue* is composed of areolar tissue, the *fascia palpebralis*, with fibres from the tendon of the levator palpebræ as well as a few involuntary muscle-fibres.

The *tarsal plate* consists of a number of bundles of dense fibrous tissue in which are found a number of modified sebaceous glands, the *Meibomian glands.* These glands, twenty-five to thirty in number, consist of alveoli lined with a cubical epithelium, emptying into a tubular duct lined with a stratified squamous epithelium, which discharges its fatty contents near the eyelashes.

The *conjunctiva* is the inner layer of the eyelid, and consists of stratified columnar epithelium resting on a tunica propria. This epithelium changes to the stratified squamous variety at the point where it is reflected on the cornea, and also at the point where it joins the upper layers of the skin at the lid margins.

The *nerves* of the conjunctiva are numerous and form rich plexuses. Each terminates in a peculiar form of tactile corpuscle, the *terminal bulb of Krause.*

THE LACHRYMAL GLANDS.

The **lachrymal glands** are compound tubular glands having several excretory ducts which empty their secretion on the surface of the conjunctiva. They are serous glands, are lined with polyhedral glandular epithelium, their ducts being lined with columnar epithelium.

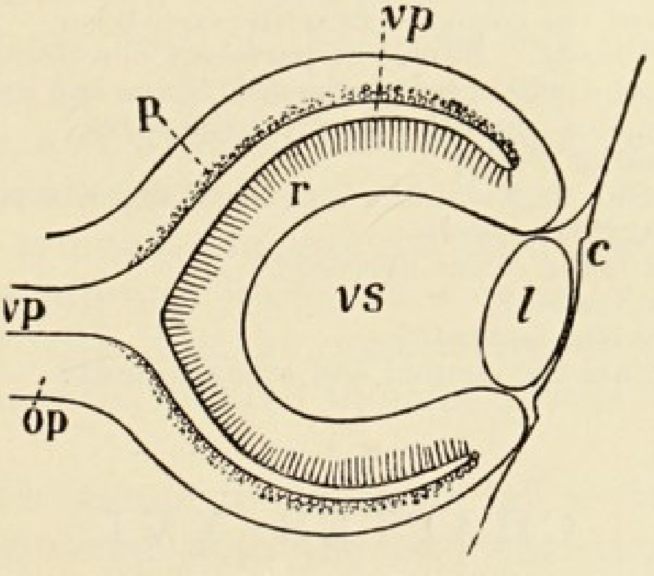
The *lachrymal canals*, or *canaliculi*, beginning at the inner canthus of the eye, and carrying the tears to the *lachrymal sac*, are composed of a stratified squamous epithelium resting upon a tunica of fibroëlastic tissue, surrounded externally by a layer of striated muscle-fibre.

The *lachrymal sac*, as well as the *nasal duct*, is composed of a fibroëlastic coat lined with stratified columnar epithelium.

DEVELOPMENT OF THE EYE.

The retina and optic nerve are the essential parts of the eye, and are *ectodermic*, being an outgrowth from the brain.

FIG. 102.



Diagrammatic sketch of a vertical longitudinal section through the eyeball of a human fœtus of four weeks. Magnified 100 diameters. The section is a little to the side, so as to avoid passing through the ocular cleft. *c*, the cuticle where it becomes later the epithelium of the cornea; *l*, the lens; *op*, optic nerve formed by the pedicle of the primary optic vesicle; *vp*, primary medullary cavity of the optic vesicle; *p*, the pigment-layer of the retina; *r*, the inner wall forming the nervous layers of the retina; *vs*, secondary optic vesicle containing rudiment of the vitreous humor. (After Kölliker.)

A diverticulum, the *optic vesicle*, from the side of the primary *forebrain vesicle*, is formed as the first step in the development of the eye. This optic vesicle grows toward the surface, and the ectoderm at the point of contact becomes thickened and depressed to form the *lens-vesicle*, from which the crystalline lens is developed.

The fibrous structures of the eye, as the capsule of the lens, the sclera, cornea, the choroid, and the iris, as well as the vitreous humor, are derived from the *mesoderm.* The epithelium of the lids and conjunctiva is from the *ectoderm*, as are also the hairs and the glands associated.

QUESTIONS.

Name the parts composing the eye.
Into what two parts is the eyeball divided?
Of what does the anterior chamber consist?
What does the posterior chamber embrace?
Name the layers of tissue enveloping the eyeball.
Describe the sclerotic coat.
Describe the choroid coat.
Name the areas of the retina.
Name the layers of the retina proper. Describe each layer.
Describe the macula lutea; the fovea centralis; the ora serrata.
Describe the blood-supply to the retina.
Name the layers of the cornea. Describe each layer.
Locate the ciliary body. Name the parts and describe each.
What is the iris, and where is it located? Name and describe the layers.
Of what does the lens consist? Describe the parts.
Where is the canal of Petit?
What are the eyelids? Name the layers and describe each.
Describe the lachrymal glands.
From what layer is the retina derived?
What is the optic vesicle?
From what is the lens formed?
From what layer are the choroid and sclera formed?

CHAPTER XVI.

THE ORGAN OF HEARING.

The ear is the organ of hearing, and *is divided into* three parts: the external ear, including the pinna, or auricle, and the external auditory canal; the middle ear, tympanum, or tympanic cavity, which contains the ossicles and communicates with the pharynx by the Eustachian tube; and the inner ear, or labyrinth, which consists of a bony and a membranous portion, the latter being lined with the neuroëpithelium in which terminate the auditory nerves.

The **external ear** consists of the auricle, made up of elastic cartilage covered with subcutaneous tissue and skin, and the auditory canal, composed of cartilage, like the auricle, except the inner bony portion, and covered with a thick skin which is raised into papillæ in the cartilaginous portion of the canal and contains hairs and tubular glands, the *ceruminous glands*, similar to sweat-glands, except secreting a waxy substance. These glands often become confluent, and then have only a single excretory duct, which empties into a hair-follicle near the surface of the skin. The corium of this portion of the canal is loosely attached to the under structures, but in the bony portion of the canal is closely attached to the periosteum. The skin in this latter part contains neither hairs nor glands, and is raised into slender papillæ.

The **middle ear, or tympanum,** is a small, irregular cavity, filled with air, and situated in the petrous portion of the temporal bone between the tympanic membrane on the outer side and the bony wall of the inner ear on the inner side, and communicating with the pharynx through the Eustachian tube anteriorly, and with the mastoid sinuses posteriorly.

The *tympanum* contains the small ear bones, the *ossicles*, connecting the tympanic membrane with the fenestra ovalis. The mucous membrane lining this cavity and the passages communicating with it is thin and composed of a single layer of low cuboidal cells, ciliated in some places and non-ciliated in others.

The *tympanic membrane* consists of a lamina of white fibrous tissue covered with the two varieties of epithelium which line the auditory canal and the tympanic cavity, namely, the outer, of stratified squamous epithelium similar to the skin, and the inner, of simple squamous epithelium.

The *bloodvessels* of the tympanic membrane are derived partly from the vessels of the tympanic cavity, and partly from those of the external meatus. There are two vascular networks—the inner, which lies under the mucous membrane, and the outer, situated between the stratified squamous epithelium and the lamina of white fibrous tissue. These networks surround the handle of the malleus and form ridges around the border of the tympanic membrane. The tympanic membrane receives its *nerve-supply* from the auriculotemporal branch of the inferior maxillary, the auricular branch of the vagus, and the tympanic branch of the glossopharyngeal nerves.

The *secondary tympanic membrane* at the fenestra rotunda is covered externally with mucous membrane continuous with the mucosa of the tympanic cavity, and internally with endothelium continuous with that lining the internal ear.

The *Eustachian tube*, which connects the tympanic cavity with the pharynx, is formed of bone and cartilage, covered with fibrous tissue, and a mucous membrane of stratified ciliated epithelium, thin in the upper portion of the canal and thicker as it approaches the pharynx. The epithelium of the osseous portion contains no glands, but in the cartilaginous portion lymphoid tissue and mucous glands are found, especially near the pharyngeal opening of the tube.

In the mastoid cells the epithelium is closely attached to the periosteum, and is of the simple non-ciliated squamous variety.

The *auditory ossicles*, which are the *stapes*, the *malleus*, and the *incus*, are true bones, having Haversian canals and lamellæ, and covered at their articular ends with cartilage.

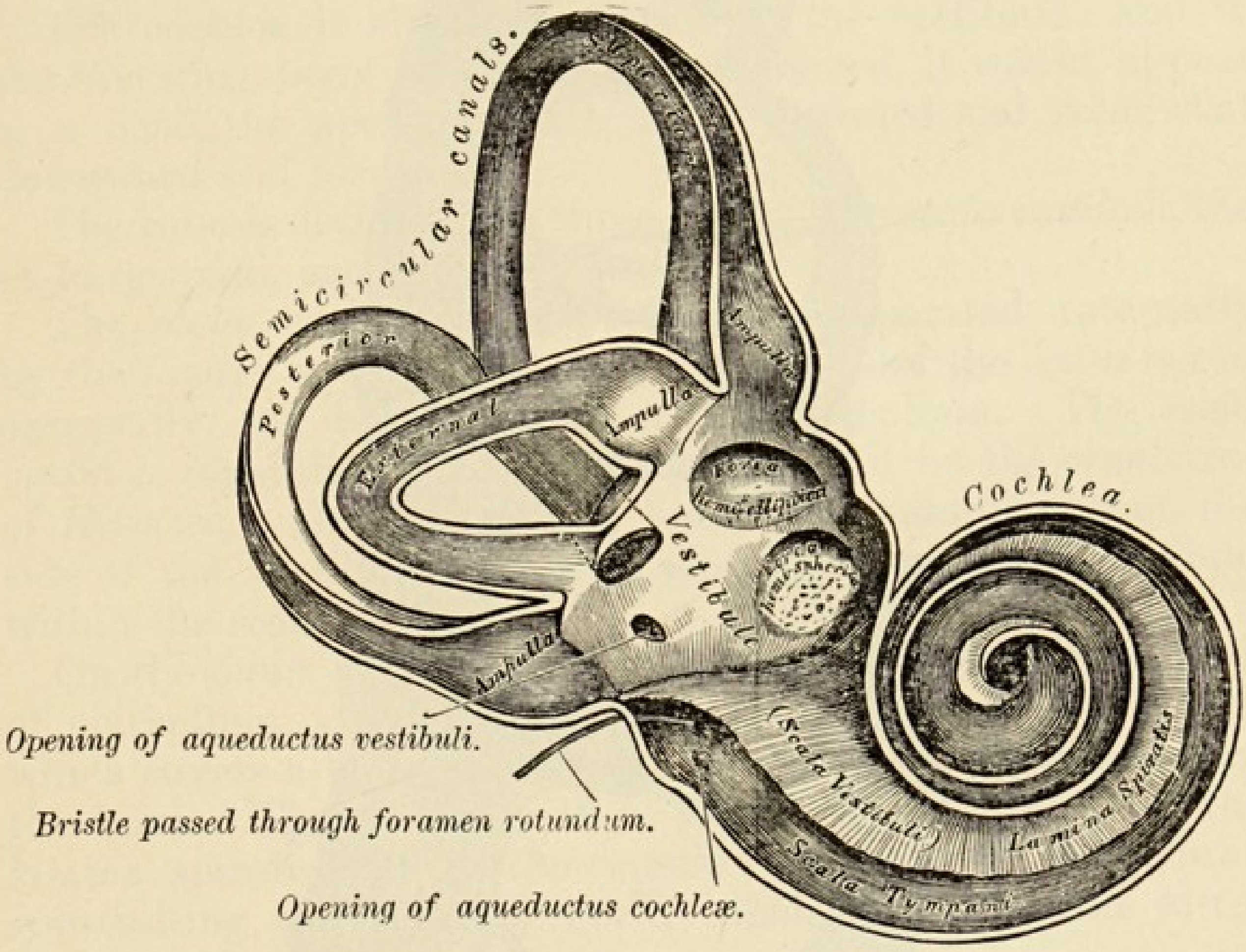
The **internal ear, or labyrinth,** is the most important portion of the organ of hearing, and consists of a series of complex cavities, the *bony* labyrinth, within which is the *membranous* labyrinth.

The *bony labyrinth* is made up of three intercommunicating cavities, the *vestibule*, the *cochlea*, and the *semicircular canals*, which are lined with a delicate periosteum. The *membranous labyrinth* is a cast of the bony labyrinth, and between the two is a lymph-space, lined with endothelium, and containing a fluid, the *perilymph*.

The *vestibule* has bony walls lined with periosteum and a thin serous membrane, secreting the perilymph. It is situated between the cochlea and semicircular canals, is an ovoid bony cavity, and on the outer or lateral wall is the oval window in communication with the tympanum, and at the anterior portion of the inner or median wall is a round depression, the *fovea hemispherica*, through which enters the vestibular branch of the auditory nerve.

In the posterior portion of the inner wall is the small opening of the *aquæductus vestibuli*, and at the lower and anterior portion of the vestibule is a larger opening leading to

FIG. 103.



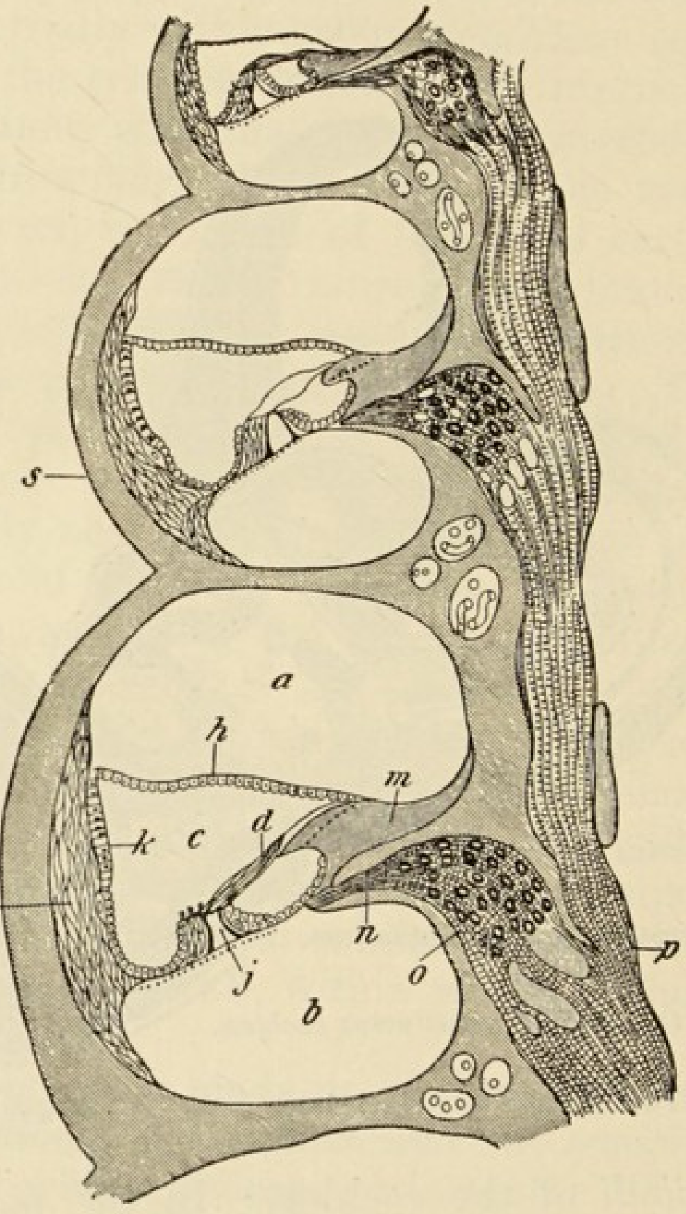
The osseous labyrinth laid open. (Enlarged.)

the *scala vestibuli* of the cochlea. In the posterior portion are five round openings of the semicircular canals.

The *membranous labyrinth* consists of the utricle and saccule, contained in the vestibule, a part of the semicircular canals, and the scala media of the cochlea.

These structures consist of an outer layer of connective tissue, rich in elastic fibres, a middle layer of delicate basement-membrane, and an inner layer of simple squamous epithelium. Where the filaments of the auditory nerve are distributed, the epithelium becomes thicker and the cells approach the columnar shape, until the neuroëpithelium is reached; these latter places being called the *maculæ acusticæ* in the utricle and the *cristæ acusticæ* in the semicircular canals.

FIG. 104.



Radial section of portion of cochlea of guinea-pig: *a*, scala vestibuli; *b*, scala tympani; *c*, scala media: *d*, membrana tectoria; *h*, membrane of Reissner; *j*, organ of Corti, resting on basilar membrane; *k*, stria vascularis; *l*, ligamentum spirale; *m*, limbus; *n*, nerve-fibres in lamina spiralis; *o*, spiral ganglion; *p*, nerve-fibres in modiolus; *s*, bony wall. (Klein.)

The *neuroëpithelium* contains two sorts of cells, the *fibre-cells*, which are long cells with broad extremities, and an oval nucleus; and the *hair-cells*, which are cylindrical ciliated cells.

The cilia on these latter cells are the supposed terminals of the auditory nerve, and are called *auditory hairs*.

THE COCHLEA.

The cochlea *consists of* a tube surrounded by bone and coiled two and a half turns around a column, the *modiolus*, which contains branches of the auditory nerve and is a nearly horizontal central axis.

The cochlea is situated anterior to the vestibule, and if the investing bony substance were removed, it would appear as a cone, the apex of which looks outward and somewhat downward and forward.

The tube is divided into three parts—the *scala vestibuli*, the *scala tympani*, and the *scala media*.

The *scala vestibuli* and *tympani* are separated internally by the *lamina spiralis* of bony substance, and the *scala media* externally, and both are lined with endothelium. The *scala media* is separated from the scala vestibuli by the *membrane of Reissner*, a fibrous structure lined with endothelium on the side of the vestibule and with simple squamous epithelium within the scala media.

On the outer wall of the scala media there is a single layer of epithelium, varying from the squamous to the columnar, which covers a layer of vascular fibrous tissue resting against the bone. The lower wall is composed of a part of the lamina spiralis, the basilar membrane, and the epithelium, constituting the *organ of Corti*, which lies upon this latter membrane.

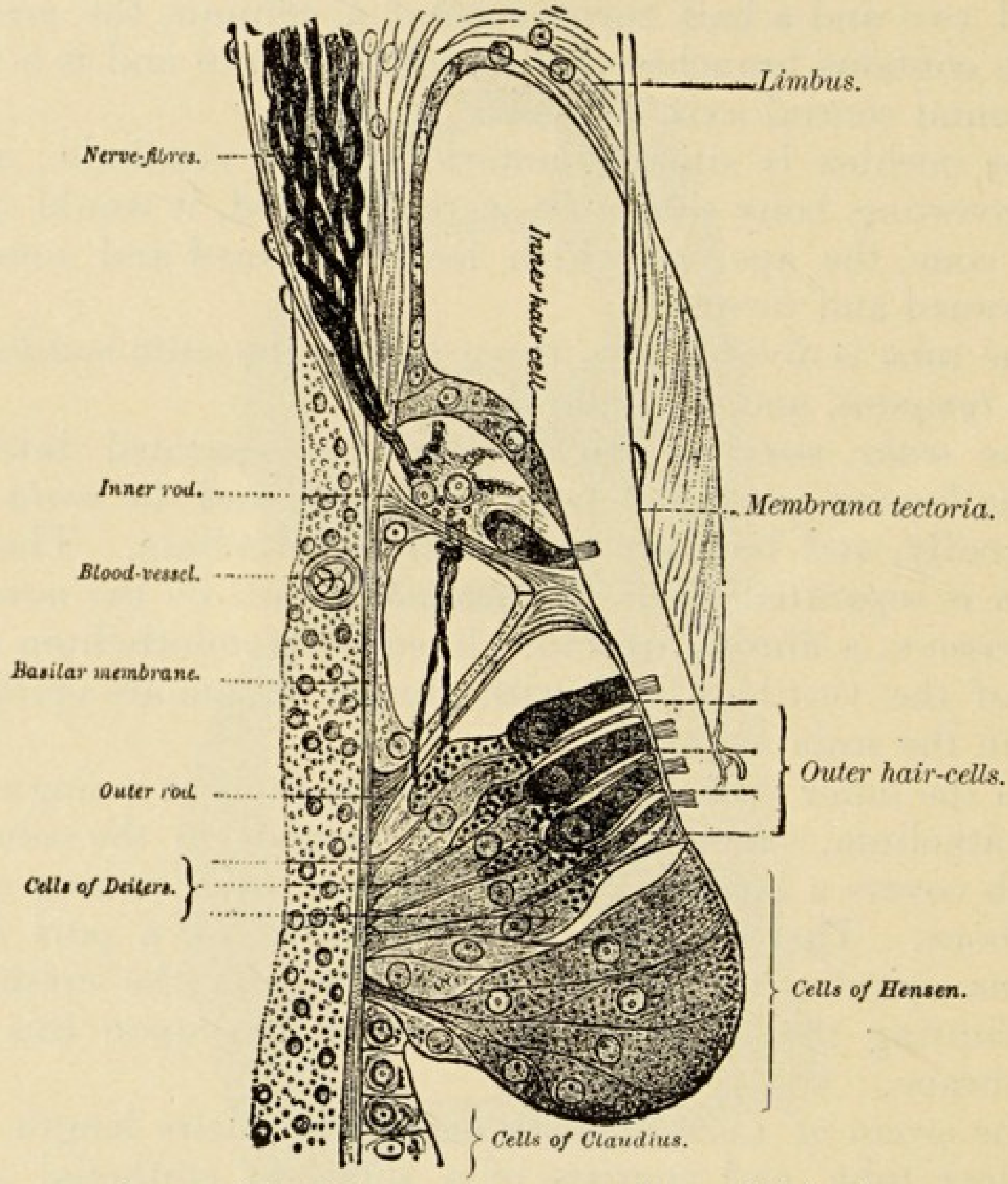
The *organ of Corti* extends nearly the entire length of the cochlear tube, and consists of a series of epithelial arches, the *pillars of Corti*, between which is the *tunnel of Corti*. To these cells the final ramifications of the cochlear branch of the auditory nerve are distributed.

The *pillar-cells* have slender bodies, large extremities, and the nuclei are at the lower end of the cell.

Next to the pillar-cells are the *inner hair-cells*, a single row of columnar epithelial cells, which have cilia on their upper extremity, and the attached ends not extending to the basilar membrane, and the *outer hair-cells*, consisting of several rows of cells similar to the inner cells.

Surrounding and nearly inclosing the outer hair-cells are the *cells of Deiters*, which are fusiform and extend from the

FIG. 105.



Organ of Corti, human, in cross-section. (Retzius.)

surface to the basilar membrane, their bases separated by the *spaces of Nuel.*

External to the outer hair-cells are the *cells of Hensen*, of long columnar epithelium which merges into a lower columnar, the *cells of Claudius*, on the extreme outer part.

The *blood-supply* of the internal ear is the auditory artery, a branch of the basilar, which enters the internal auditory meatus with the auditory nerve and divides for the cochlea and the vestibule.

The *arteria auditiva* divides into three branches: the *arteria vestibularis,* which supplies the upper and lateral parts of the sacculus and utriculus, and the ampullæ of the upper and lateral semicircular canals; the *arteria vestibulo-cochlearis,* which supplies the lower median half of the sacculus and utriculus, the lower end of the cochlea, the posterior ampulla, and the first third of the first coil of the cochlea; the *arteria cochlearis,* which supplies all the rest of the cochlea.

The *lymphatics* of the internal ear terminate in the tympanic and intracranial lymphatic vessels.

The auditory nerve is the nerve of the special sense of hearing, and in the internal auditory meatus it divides into two branches, the cochlear and the vestibular; the former is distributed to the cochlea, and the latter to the walls of the membranous vestibule and ampullæ of the semicircular canals.

The *cochlear branch of the auditory nerve,* after giving off branches to the saccule and ampulla of the posterior semicircular canal, 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 pass through the canalis centralis, and the nerves bend outward to pass between the lamellæ of the osseous spiral lamina. The spiral canal of the modiolus contains the ganglion spirale, consisting of bipolar nerve-cells, which constitute the cells of origin of this nerve, one pole being prolonged centrally to the brain, and the other peripherally to the hair-cells of Corti's organ. On reaching the outer edge of the osseous spiral lamina they pass through the foramina in the labium tympanicum and end, some in the inner hair-cells and some in the outer hair-cells.

DEVELOPMENT OF THE EAR.

The internal ear, with its membranous labyrinth, containing the specialized neuroëpithelium, is the part first formed.

The *ectodermic* cells on the surface of the skin become invaginated to form a pit, which later closes to make the primary *otic vesicle*, from which the membranous tube is developed, while the enveloping fibrous and osseous structures are formed from the surrounding *mesoderm*.

The *otic vesicle* is gradually receded from the ectoderm of the surface by the growth of the intervening mesoderm. Then it changes its spheroidal form and becomes pear-shaped, with the pointed end directed backward to form the *recessus vestibuli*, which is a part of the embryonal labyrinth. The semicircular canals are formed as tubular projections from the *otic vesicle*. At the same time a diverticulum, the cochlear canal, is formed at the lower extremity of the vesicle. The middle ear is developed from the back part or dorsal end of the first *inner visceral furrow*.

The external ear is developed from the first *outer visceral furrow*. The tympanic membrane consists of a *mesodermic* middle layer, and is covered on the outer side by ectodermic, and on the inner side by entodermic, layers.

QUESTOINS.

How do we divide the ear into anatomical parts?

Of what does the external ear consist? Describe each part.

What is the middle ear?

Describe the tympanic membranes.

Describe the Eustachian tube.

What does the internal ear comprise?

Describe the vestibule.

Of what does the membranous labyrinth consist? Describe these structures.

Of what does the cochlea consist? Into what parts is it divided?

Locate the scala media. Describe its upper wall; outer wall.

Of what is the lower wall composed?

Locate the organ of Corti.

Describe the pillar-cells.

Describe the hair-cells.

What are the cells of Deiters?

Describe the cells of Hensen and Claudius.

Describe the formation of the primary otic vesicle.

From what is the middle ear formed? The external ear?

CHAPTER XVII.

THE NASAL MUCOUS MEMBRANE.

THE **nasal mucosa** *consists of* the membrane lining the vestibule, the respiratory region, and the olfactory region, and is continuous with the mucous membrane of the pharynx, sphenoid and ethmoid cells, frontal sinuses, antra of Highmore, or maxillary sinuses, lachrymonasal ducts, and lachrymal sacs.

The *olfactory mucous membrane* proper (Schneiderian or pituitary membrane) is confined to the middle of the superior

FIG. 106.

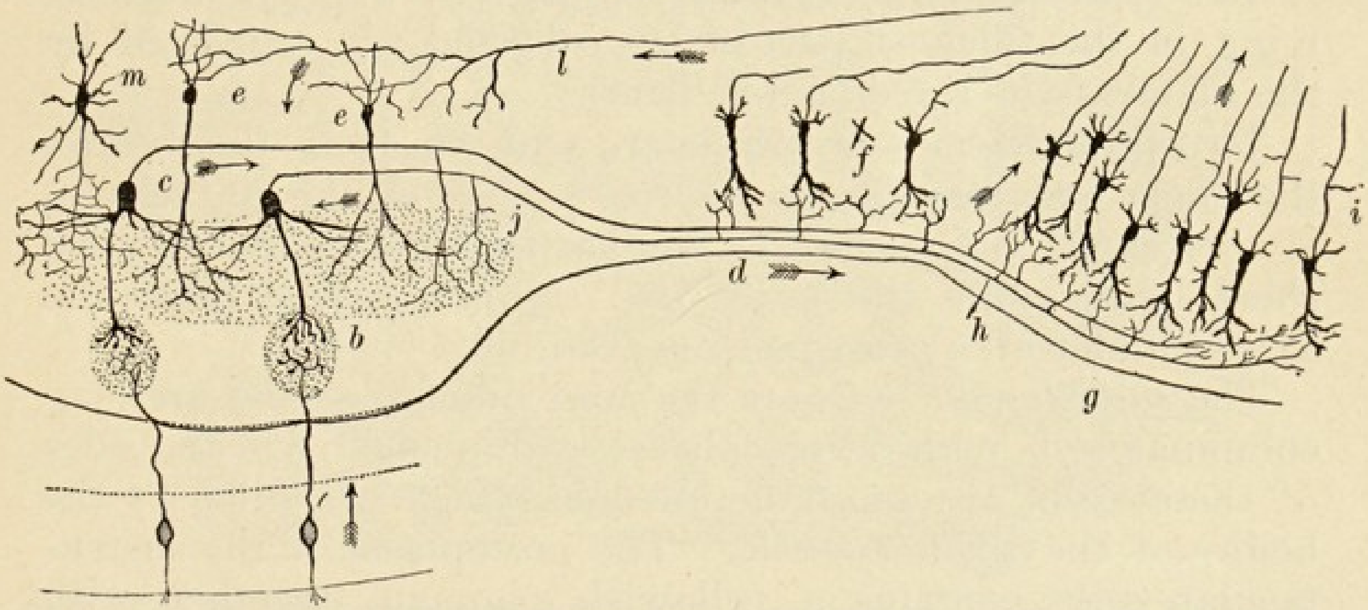


Diagram of the nervous mechanism of the olfactory apparatus: *a*, olfactory portion of the nasal mucous membrane; *b*, second or glomerular layer of the olfactory bulb *j*, at the right edge of the molecular layer, which is dotted. The cells of this layer are omitted. *c*, fourth layer of the bulb, the layer of the mitral cells, two of which are represented; *e*, *m*, cells of the fifth or granular layer; *d*, olfactory tract; *g*, cerebral cortex; *h*, neurite from a mitral cell, giving off a collateral to the dendrites of a pyramidal cell in the gray matter of the brain; *f*, pyramidal cells of the olfactory tract; *j*, collateral from a mitral neurite passing, recurrently, into the molecular layer; *l*, centrifugal neurite from the cerebrum. (R. y Cajal.)

turbinate bone and to the corresponding portions of the nasal septum, while the remaining portions of the nasal fossæ and accessory spaces are lined with the respiratory mucous membrane.

The *vestibule* is lined with stratified squamous epithelium, which is a continuation of the skin, and contains hairs, sebaceous and sweat glands. The hairs and glands disappear a short distance from the outside, and the epithelium becomes similar to a mucous membrane, containing mucous glands.

The *respiratory region* is lined with simple stratified ciliated epithelium, in which are goblet-cells and many bloodvessels. The transition to the respiratory region is usually marked by the appearance of a layer of ciliated epithelial cells and a connective-tissue tunica propria containing many leucocytes and branched tubular glands.

The *olfactory region*, located as above stated, is lined with a mucous membrane not so red in color, more brownish yellow, and consisting of the stratified columnar type, in which three kinds of cells are distinguished—the olfactory cells, the sustentacular cells, and the basal cells.

The *olfactory cells* are spindle-shaped, with a spheric nucleus, lying in the thickest part of the cell, and are connected by the filaments of the olfactory nerve.

Two protoplasmic processes are sent out from these cells: the upper one, reaching to the free surface of the epithelium, is very short, and on its free end are found a number of firm short hairs, while the lower and thinner process forms the axis-cylinder of a centripetal nerve-fibre.

The *sustentacular cells* are the most numerous, and are long columnar cells with deeply placed oval nuclei. On the sides of these cells are small depressions which are filled by the bodies of the olfactory cells. The protoplasm of the sustentacular cells contains a yellowish pigment, together with numerous granules arranged in longitudinal rows, thus giving to this part of the mucous membrane a characteristic color.

The *basal cells* are a row of cells between the surface epithelium and the connective-tissue basement-membrane.

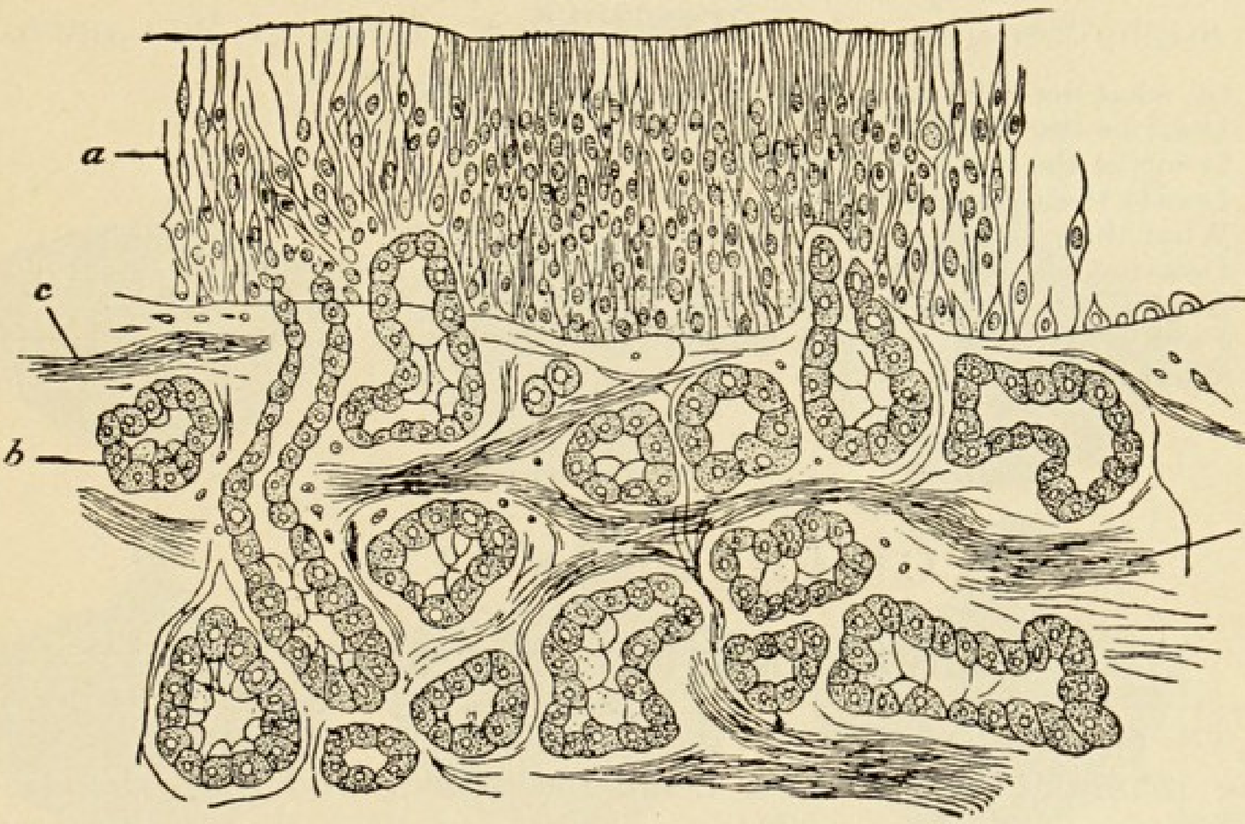
The epithelium of the olfactory region is covered on the surface with an extremely delicate, homogeneous membrane, the *membrana limitans olfactoria*, through which the ciliated extremities of the olfactory cells project. This membrane is covered with a peculiar substance resembling mucus.

The *tunica propria* is made up a loose network of fibro-elastic fibres, in which are embedded numerous *olfactory* *glands* (Bowman's) containing pigmented cells and having a mucous secretion.

The tunica propria also carries numerous branches of the **olfactory nerve** in both the olfactory and respiratory regions. These nerve-ramifications repeatedly subdivide and lose their medullary sheath, and most of them end in *terminal nodules.*

The complete *nerve-supply* to the nasal mucous membrane consists of the olfactory, nasal, and nasopalatine nerves,

FIG. 107.



Section of the olfactory mucous membrane: *a*, epithelium; *b*, glands of Bowman; *c*, nerve bundles. (Cadiat.)

branches from Meckel's ganglion and the Vidian nerve, branches from the anterosuperior dental nerve, and branches from the anterior palatine nerve.

Bloodvessels are very abundant in the submucosa immediately beneath the basement-membrane of the epithelium, and often a well-developed vascular plexus is found, especially at the posterior portion of the inferior turbinate bone, forming here a tissue resembling erectile tissue. The blood-supply of the nasal cavities is derived from the sphenopalatine, anterior and posterior ethmoid arteries, and the artery of the septum.

The *lymph-vessels* are arranged in a network in the tunica propria.

Development of the Nasal Mucous Membrane.—The olfactory epithelium is an ingrowth of the primitive *olfactory plates*, which are two areas of thickened *ectoderm*.

The outgrowth of the surrounding parts converts these areas into the *nasal pits*.

QUESTIONS.

Of what does the nasal mucous membrane consist?
Describe the vestibule.
Describe the respiratory region.
Locate the olfactory region.
What three kinds of cells are found in this region?
Describe the olfactory cell; the sustentacular cell; the basal cell.
How do the nerves terminate?
From what is the olfactory epithelium derived?
What makes the nasal pits?

CHAPTER XVIII.

DEVELOPMENT OF THE OVUM.

In preceding chapters the structure of a typical cell and the primary ovum have been described, and also the development of the special organs from the three primary layers and the early embryonic formations, but there remain to be described the processes of the maturation, the fertilization, and the segmentation of the ovum, and the formation of the blastodermic vesicle with the primary germ-layers.

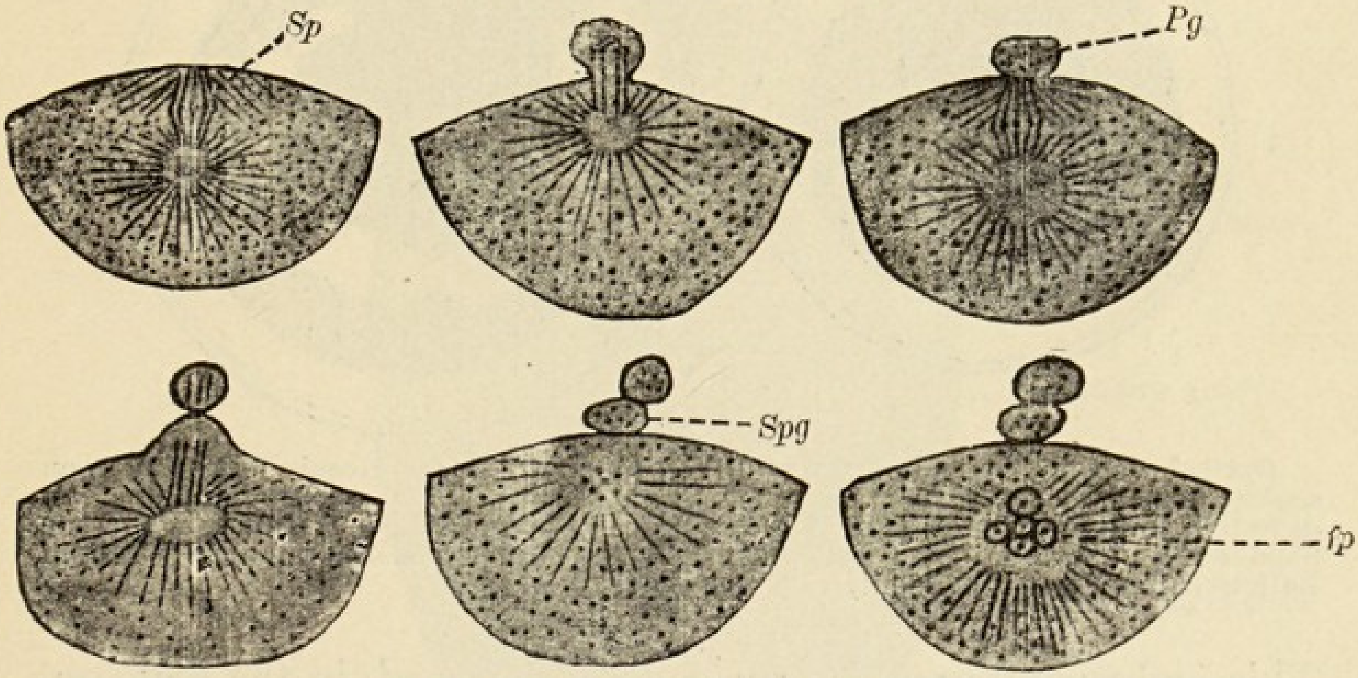
Maturation, or *ripening*, is a process by which the ovum is prepared for fertilization, and without which the latter process would be impossible. It consists in the extrusion from the ovum of a part of its nucleus and a small part of its protoplasm, called the *polar bodies*.

First, the *germinal vesicle*, or *nucleus* of the ovum, moves toward the periphery of the cell; second, there is formed a *nuclear spindle* from the nucleus; third, extrusion of a small portion of the ovum as the *first polar body* occurs; fourth, another division, and the *second polar body* is given off; and fifth, appearance of a new and smaller nucleus, the *female pronucleus*, occurs. The cell is now ready for the next stage.

Fertilization is the union of the male element, a single spermatozoön, with the mature female element, the ovum, and the two resulting in the formation of a new cell to produce another complex organism.

The spermatozoön penetrates the zona pellucida of the ovum, and is met by a projection of the cell-protoplasm in

FIG. 108.



Formation of polar globules in arteria gracialis: *Sp*, nuclear spindle: *Pg*, first polar globule; *Spg*, second polar globule; *fp*, female pronucleus. (After O. Hertwig.)

which the head of the male element becomes blended. The spermatozoön loses its tail and then appears as a small round body within the protoplasm of the cell, called the *male pronucleus*.

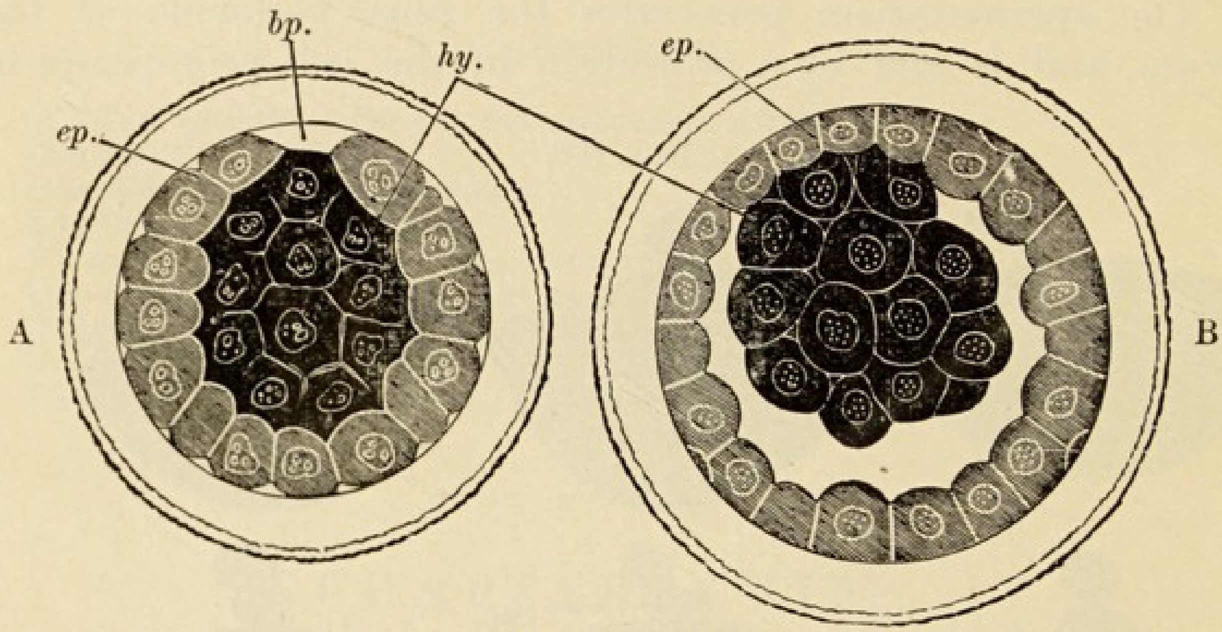
The male and female pronuclei now unite to form the new nucleus of the fertilized ovum, the *segmentation nucleus*.

Segmentation is the process by which the original cell multiplies, the phenomenon of indirect cell-division or karyokinesis.

Some of the cells divide faster than others, and a hollow mass, the *blastodermic vesicle,* is thus formed, having an inner row, the *primitive entoderm,* and an outer row of cells, the *primitive ectoderm.*

At this stage there appears on the blastodermic vesicle an oval dense area of cells, the *embryonal area,* at whose posterior pole a linear opacity occurs, called the *primitive streak.*

FIG. 109.



Optical section of an oösperm of a rabbit, at two stages closely following upon segmentation: *ep.*, ectoderm; *hy.*, primary entoderm; *bp*, the opening in the ectodermic layer at one point, named blastopore by E. van Beneden: this is not a true blastopore. The shading of the ectoderm and entoderm is diagrammatic. (From Balfour, after Ed. v. Beneden.)

This embryonal area is especially concerned in the development of the embryo.

A third layer, the *primitive mesoderm,* is now formed from a splitting off from the entodermic and the ectodermic layers along the primitive streak.

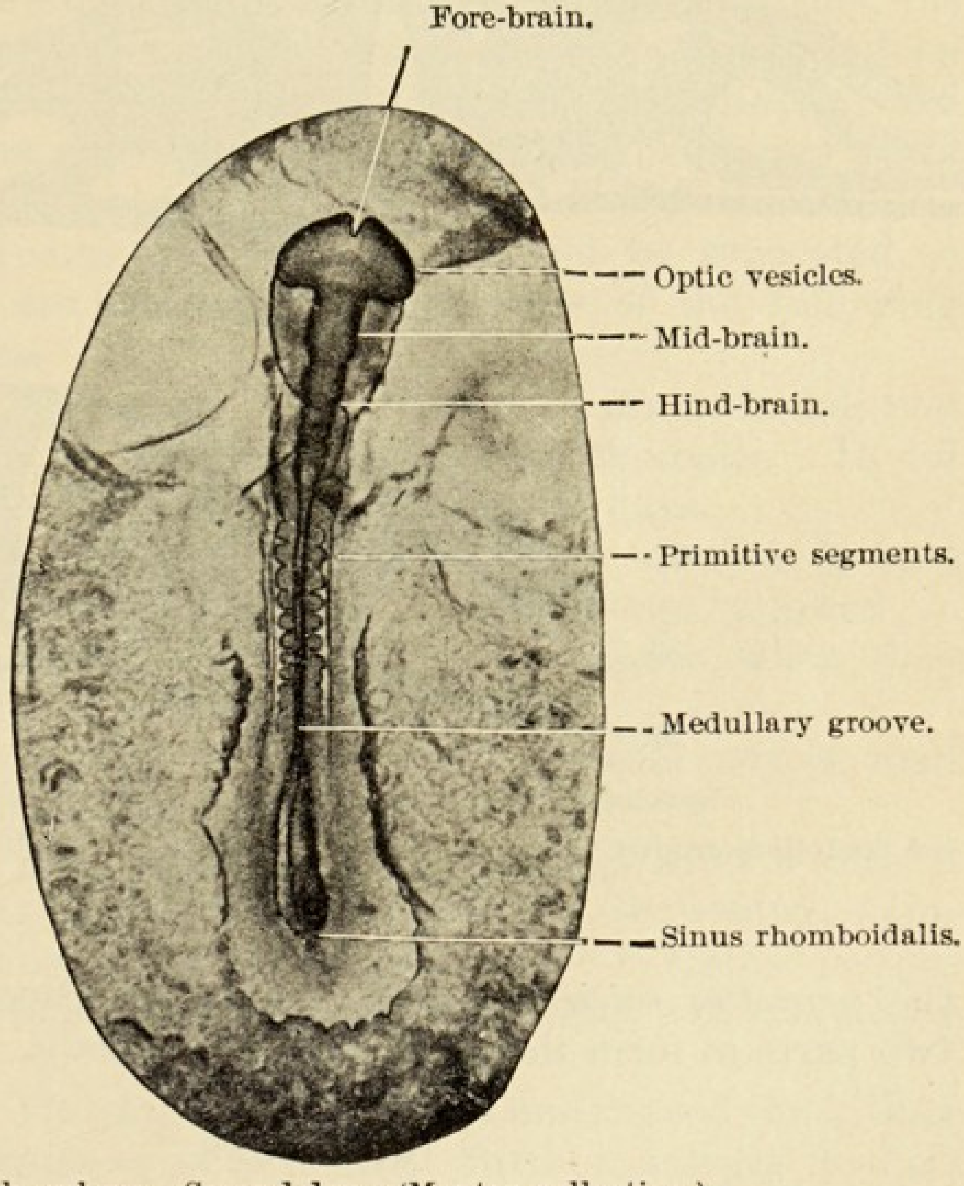
The mesoderm is unlike the other two layers in that it does not extend around the ovum, but is limited to the embryonal area.

The ectoderm, just in front of the primitive streak, thickens into a band of cells on either side of the median axial line; these are called the *medullary plates,* and between them is the medullary groove, or *neural canal,* the antecedent of the cerebrospinal system.

The mesoderm becomes thickened on either side of the neural canal, making two longitudinal bands, the *muscle-plates.*

That portion of the muscle-plate nearest the groove is

FIG. 110.



Chick embryo. Second day. (Manton collection.)

thickest, and is called the *segmental zone*, and the external, the *parietal zone.*

The segmental zone, after undergoing a transverse cleavage, forms the *myotomes,* from which arise the voluntary muscles of the body.

Externally to the parietal zone the mesoderm splits, and an external part unites with the ectoderm to form the *primitive body-wall*, and an external part with the entoderm to form

FIG. 111.

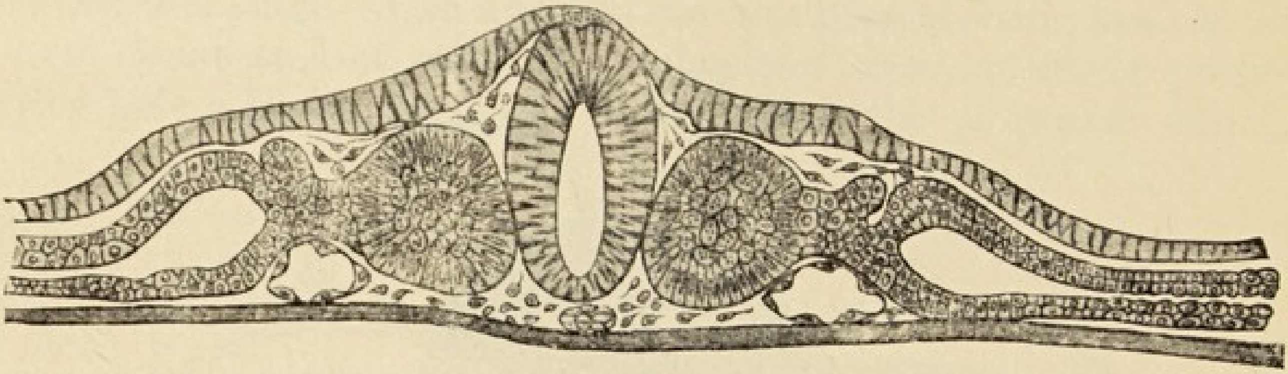
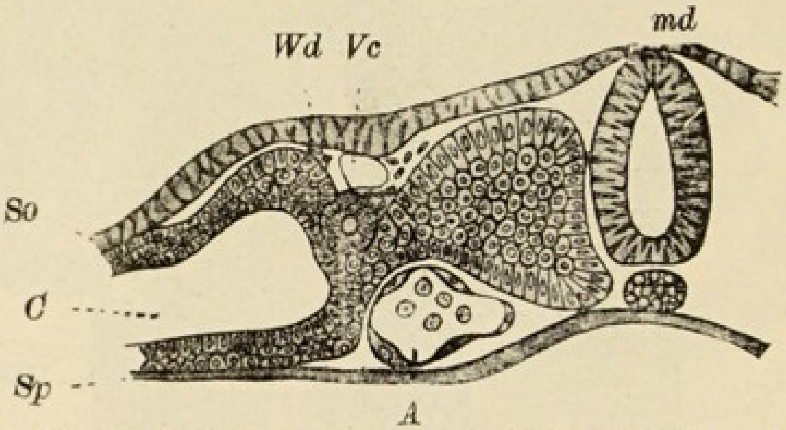


FIG. 112.



Development of the neural canal. (After Waldeyer.)

md, medullary groove; *A*, aorta; *Wd*, Wolffian duct; *Vc*, cardinal vein; *So*, somatopleure; *Sp*, splanchnopleure; *C*, cœlom.

the *primitive intestinal wall*, leaving a space between these two parts to form the *pleuroperitoneal cavity*.

QUESTIONS.

What is maturation? Describe the process.
What is fertilization? Describe the process.
What is segmentation?
Describe the blastodermic vesicle.
What is the primitive streak?
How is the mesoderm formed? What is the peculiarity of this layer?
How is the neural canal formed? What does it later become?
What are the muscle-plates, and what do they form?
How is the primitive body-wall formed? The intestinal wall?
What is the pleuroperitoneal cavity?

CHAPTER XIX.

HISTOLOGICAL TECHNIQUE.

MANY objects may be examined in the fresh state, as blood, detached epithelial cells, etc., between the slide and the cover-slip without further preparation. Some fresh tissues, as muscular and connective-tissue fibres, are often *teased* or torn into minute pieces by needles in a normal salt solution (0.75 per cent. solution of sodium chloride in distilled water), and thus prepared for examination.

With some tissues the elements can not be separated so easily, and we are compelled to use some of the following *macerating fluids:*

a. Potassium or *sodium hydrate* in a 33 per cent. solution for the isolation of muscle-elements and the nails. In 4.6 per cent. solution for hairs, used for several days.

b. Ranver's dilute alcohol in 33 per cent. solution is used for isolating epithelial cells. The tissues are allowed to remain in this solution for about twelve hours, when they may be easily teased out.

c. Hydrochloric acid in 10 per cent. solution may be used to isolate the tubules of the kidney.

Most tissues and organs are best studied after a careful preparation of fixing, hardening, embedding, sectioning, staining, and mounting. The section thus made is almost permanent, and if not exposed too much to the light, will last a long time.

Fixation and Hardening.—By this is understood the killing or fixing the tissues so as to prevent further changes in their cellular structure, and also to harden them to allow sections to be cut when embedded in some substance like celloidin or paraffin.

The fluids most used are the following:

Alcohol.—This is the oldest and most common. It withdraws the water of the tissues and coagulates the albumin, and is used in two ways: first, the gradually increasing strengths, as 50 per cent., 70 per cent., and, lastly, 95 per cent.; or, second, the absolute or 98 per cent. alcohol. The first method requires several days, the latter from a few hours to twenty-four hours. The piece of tissue should never be more than one cubic centimeter in size.

Formalin.—This solution is made by diluting commercial formalin, which is a saturated watery solution (40 per cent.) of formaldehyde gas, with water to make a 2 per cent. or 4 per cent. fixing solution. It is one of the best, cheapest, and most rapid methods used. The tissues should remain in this solution from two to twenty-four hours according to the character of the tissue.

Muller's Fluid.—

Potassium dichromate	2.5 parts;
Sodium sulphate	1.0 part;
Water	100.0 parts.

This solution is one of the oldest and best, but requires several weeks for proper fixation, and should be conducted in the dark, often changing the tissue to fresh fluid. Then wash in water and preserve in 80 per cent. alcohol.

Orth's Solution.—This is made by mixing 10 parts of commercial formalin with 90 parts of Müller's fluid. It has all the advantages of both the formalin and dichromate fixatives, and requires only a short time—from twelve to twenty-four hours. The tissues should afterward be washed in water and placed in 80 per cent. alcohol.

Flemming's Solution.—This is principally employed to demonstrate nuclear structures in cell-division:

Glacial acetic acid	1 part;
Osmic acid (2 per cent. aqueous solution) .	4 parts;
Chromic acid (1 per cent. aqueous solution)	15 "

This solution does not keep well, and should be mixed only as used and kept in a dark place. Small pieces of tissue are placed in this solution immediately after removal from living organs, and allowed to remain for from twenty-four hours to several weeks. The tissue should then be washed and placed in alcohol.

Zenker's Fluid.—

Potassium bichromate	2.5 gms.;
Sodium sulphate	1.0 gm.;
Corrosive sublimate	5.0 gms.;
Glacial acetic acid	5.0 c.c.;
Distilled water	100.0 c.c.

Add the acetic acid to the stock solution of the other ingredients in the proportion of the formula, as the complete solution does not keep well. Place the tissues in this fluid for from six to twenty-four hours, then in water for several hours, and transfer to alcoholic solutions of gradually increasing strengths and finally in absolute alcohol. The crystals of the sublimate present are removed with iodized alcohol. This fixing fluid penetrates easily and fixes the nuclear and protoplasmic structures without interfering with their staining qualities.

Corrosive Sublimate.—This is an excellent fluid, and is made by saturating normal salt solution with corrosive sublimate, heating the mixture to aid solution. From three to twenty-four hours are sufficient time for proper fixing of the tissue. The specimens are next placed in 70 per cent. alcohol, to which has been added tincture of iodine until colored a dark brown. This removes the crystals of sublimate, and the tissue is then preserved in 70 per cent. alcohol.

Decalcification.—Calcareous tissues, such as bone, etc., require that the lime salts be removed before sections may be made. The following are some of the fluids used to decalcify:

Hydrochloric Acid.—1 per cent. aqueous solution in the proportion of fifty times the volume of the specimen.

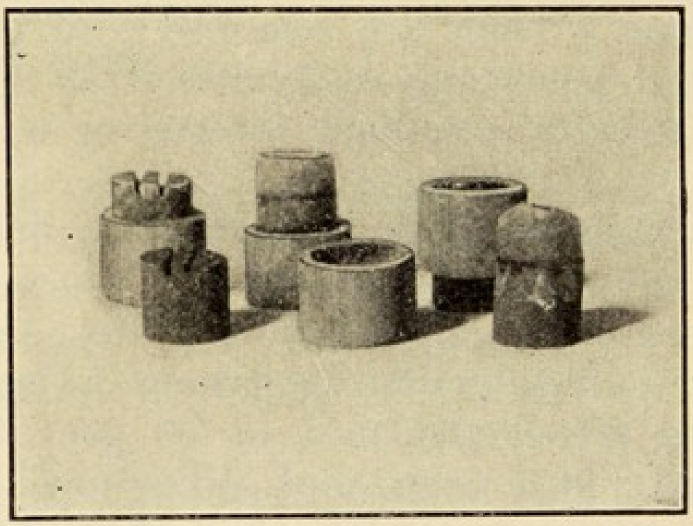
Nitric Acid.—A 3 per cent. to 10 per cent. solution is used as the hydrochloric acid.

Picric Acid.—A saturated aqueous solution requires weeks to decalcify, but is a very satisfactory method. The specimens are **tested** to determine if the lime salts are removed, by sticking the tissue with a sharp needle.

Infiltration and Embedding.—The tissues, after the fixation and hardening in alcohol, are placed in an embedding mass, which penetrates the tissues, and upon cooling or on evaporation of the solvent, hardens into a solid mass, ready to cut. The two methods most used are the following:

Celloidin Method.—Dissolve sufficient of Schering's celloidin in equal parts of absolute alcohol and ether to make a perfect solution, which should be thin enough to pour readily. Make the second solution about the consistency of thick molasses. The tissue, after leaving absolute alcohol, is placed in a mixture of absolute alcohol and ether, equal parts, for twenty-four hours, and then transferred to the thin celloidin solution for several days, from this to the thick celloidin

Fig. 113.



Author's method of embedding tissues in celloidin, mounted on round hard-rubber blocks, surrounded with soft-rubber tubing.

solution for twenty-four hours, and then mounted on round gutta-percha blocks, with grooves cut in the top to allow the celloidin to stick, and having a narrow piece of rubber tube or paper around the block to hold the celloidin.

If many tissues are embedded at the same time, the celloidin may be poured into a small flat dish and allowed to evaporate. When the surface becomes hard the embedded mass should be placed in 80 per cent. alcohol for several days to harden before being cut into sections on the microtome.

Paraffin.—From absolute alcohol the tissues are placed in a mixture of alcohol and xylol and then in xylol from two to twelve hours until cleared. They are then placed in melted paraffin (whose melting-point is 50° C.) at 52° C., from two to ten hours. The tissues are then removed by pouring the mixture of tissues and paraffin into a glass box, with removable sides, and allowed to cool, when it may be cut into blocks ready to make the sections.

This method is probably the best for large laboratories where many sections are needed and very thin sections are desired, but for individual work and diagnosis the celloidin method is far quicker and easier.

Section-cutting.—This is accomplished by two methods, the free cutting with an ordinary razor and by the microtome, an instrument which raises the tissue for the knife. As fast as one section is cut, it allows the razor, which is clamped to the frame, to make another section of the same thickness.

There are many different types of these machines, and they cut either the paraffin, celloidin, or frozen blocks of tissues accordingly as they have been constructed.

Stains.—The following solutions are the ones most in use to stain the tissues.

Borax-carmin Solution.—This is made of the following:

Carmin	2.5 parts;
Borax	4.0 " ;
Water	100.0 " ;
Alcohol (70 per cent.)	100.0 " .

The carmin and borax are dissolved in the water, which has been heated, and the alcohol then added. The solution is set aside for at least two weeks and then carefully decanted.

Delafield's Hæmatoxylin.—

Hæmatoxylin crystals	4 parts;
Absolute alcohol	25 " ;
Ammonia alum (saturated aqueous solution)	400 " ;
Alcohol	100 " ;
Glycerin	100 " .

Dissolve the hæmatoxylin crystals in absolute alcohol, and add the alum solution, after which let the resulting mixture stand in an open vessel for one week, filter, and add the alcohol and glycerin.

Böhmer's Hæmatoxylin.—

Hæmatoxylin crystals	1 part ;
Absolute alcohol	10 parts ;
Potassium alum	10 " ;
Distilled water	200 " .

Dissolve the hæmatoxylin in alcohol and the alum in water. Add the first solution *gradually* to the second, let stand one week, and filter. The author considers this solution the best for routine work, as it is the easiest to prepare and keeps better than any other.

The preceding stains are *nuclear stains,* and but faintly stain the protoplasm. Eosin in alcohol is often used as a contrast-stain, and stains the protoplasm and muscle a deep-red color.

One of the best double or contrast-stains is the following :

Van Gieson's Stain :

Picric acid (concentrated aqueous solution)	100 parts ;
Acid fuchsin (concentrated aqueous solution)	2 " .

The sections are stained in hæmatoxylin, washed in water, and placed in this stain from three to five minutes, then washed in water, dehydrated in alcohol, cleared in xylol, and mounted in balsam.

The nuclei should stain a reddish brown or violet ; connective tissue a brilliant red ; the non-striated muscle-fibres a yellow ; hyaline and amyloid a dark red ; and colloid an orange or yellowish red.

Staining of Tissues.—There are two methods, the staining in *bulk* and the staining of *sections.*

I. **Staining in Bulk.**—Each method has somewhat different details, but the borax-carmin stain will illustrate the process. The tissue is placed in the stain for twenty-four hours, decolorized in acid alcohol (1 per cent. hydrochloric acid in 70 per cent. alcohol), washed in 70 per cent. alcohol, and finally placed in 90 per cent. alcohol ready to embed.

II. **Staining of Sections.—**

A. Celloidin sections.

a. Stain section in hæmatoxylin from three to ten minutes.

b. Wash in water ten minutes.

c. Dehydrate in eosin-alcohol five minutes.

d. Place on slide and blot off alcohol.

e. Add oil of cloves to clear section.

f. Blot off the oil of cloves.

g. Add balsam and cover-slip.

B. Paraffin sections.

These are treated the same as the celloidin, except that we stick the sections to the slide with gum-water and stain on the slide. Also dissolve off the paraffin with xylol.

Special Stains.—

Mallory's Iron Hæmatoxylin for Nuclear Structures.—

1. Place section a few minutes in the mordanting and differentiating fluid (ferric ammonium sulphate, 3 grams, and water, 100 grams).

2. Wash in water.

3. Place one or two minutes in staining solution ($\frac{1}{2}$ per cent. aqueous hæmatoxylin).

4. Differentiate in a dilute solution of ferric ammonium sulphate.

5. Rinse in water, alcohol, and xylol, and mount in balsam.

Altmann's Granula Stain for Protoplasmic Structures.—

1. Harden tissues in solution (potassium dichromate, 5 per cent. aqueous solution; osmic acid, 2 per cent. aqueous solution, equal parts) for twenty-four hours.

2. Wash in water, treat with increasing alcohols, embed in paraffin, fasten to slide, and remove paraffin.

3. Add to object on slide a few drops of solution (anilin water, 100 c.c.; acid fuchsin, 20 grams) and heat gently.

4. Cool and wash in solution (concentrated alcoholic picric acid solution, 50 c.c.; water, 100 c.c.).

5. Heat section with above solution on slide for a few seconds.

6. Treat with absolute alcohol, xylol, and mount in balsam.

The granulæ of the protoplasm are stained red, the nuclei are colorless.

Golgi's Stain for Ganglion- and Neuroglia-Cells.

1. Harden in 10 per cent. formalin or Müller formalin solution for twenty-four hours.

2. Place thin sections of the tissue into 1 per cent. silver nitrate solution and keep them in a dark place for twenty-four hours.

3. Wash in water.

4. Place in 10 per cent. formalin solution for several hours and cut with freezing microtome.

5. Dehydrate in absolute alcohol.

6. Clear with xylol and mount in balsam.

The ganglion-cells and neuroglia-cells are stained an intense black. *These sections are not permanent.*

Pal-Weigert Stain for Medullated Fibres.—

1. Fix tissue in Müller's fluid.

2. Transfer direct to alcohol and harden in a dark place.

3. Embed in celloidin and cut sections.

4. Place sections for twenty-four hours in the following stain:

Hæmatoxylin	1 part;
Absolute alcohol	10 parts;
Distilled water	90 " ;
Lithium carbonate (saturated aqueous solution)	1 part.

5. Transfer sections to $\frac{1}{3}$ of 1 per cent. solution of lithium carbonate.

6. When decolorized (after about a half-hour), place for one minute in a fresh 0.25 per cent. solution of potassium permanganate.

7. Wash with water and place for one hour in the following differentiating solution:

Potassium sulphate } equal parts of a 1 per cent.
Oxalic acid } solution.

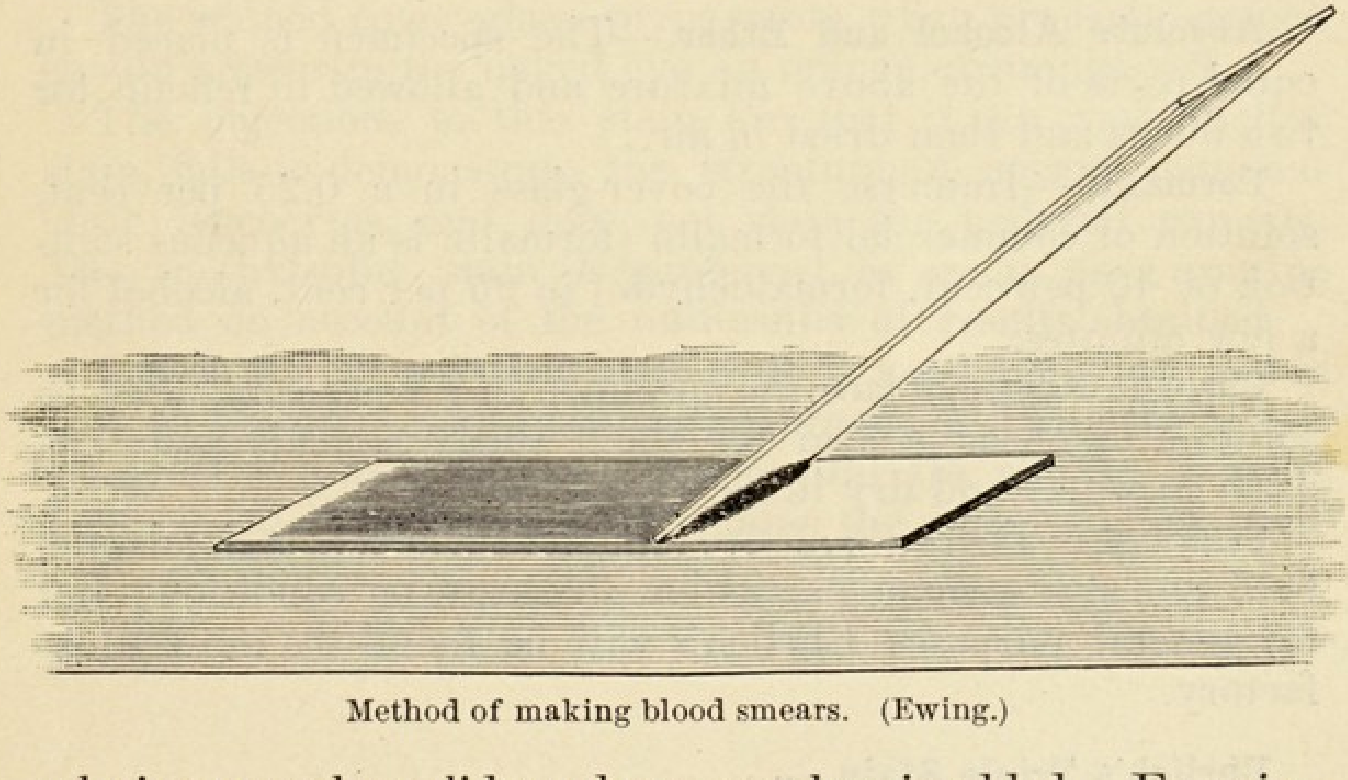
8. Wash in water, dehydrate in alcohol and mount in balsam. They may be counterstained in eosin.

This method stains the medullary sheaths a dark blue, while the gray substance is colorless.

EXAMINATION OF THE BLOOD.

The blood is best obtained by pricking the end of the thumb, after having placed a constriction around the part. This drop is then mixed with a few drops of normal salt

FIG. 114.



Method of making blood smears. (Ewing.)

solution on a clean slide and a cover-glass is added. Examine with a $\frac{1}{6}$- or $\frac{1}{12}$-oil-immersion objective; the latter if greater magnification is wanted to bring out certain details in the white cells.

A little vaselin around the edge of the cover-glass will prevent evaporation and permit a longer inspection of specimen.

Dried and Stained Blood-Mounts.—Place a small drop upon a clean cover-glass and cover with another cover-glass, allowing the blood to spread in a thin, even film between the two glasses, and before drying draw apart by sliding the glasses over each other, and then allow them to dry in the air.

Ewing's method, easier and better, is to place the drop of blood upon a glass slide near one end and with another slide held slanting, spread the blood evenly over about two-thirds of the slide. This avoids breaking the small cover-glasses and is a rapid process.

Fixing.—The blood is subjected to one of the following methods:

Heat.—Place the film in a small oven heated to 125° C. for about twenty minutes and then allow to cool gradually; or a simpler method is to pass the cover-glass preparation through a Bunsen flame about twenty times in rapid succession.

Absolute Alcohol and Ether.—The specimen is placed in equal parts of the above mixture and allowed to remain for two hours and then dried in air.

Formalin.—Immerse the cover-glass in a 0.25 per cent. solution of commercial formalin (formalin is an aqueous solution of 40 per cent. formaldehyde) in 95 per cent. alcohol for a few minutes.

Chromic Acid.—Place the specimen in a 2 per cent. aqueous solution of chromic acid for about thirty seconds and then wash in water and dry in air.

Staining.—There are many stains for the blood, each adapted to demonstrate some particular structure or condition; but for general purposes Ehrlich's will be found the most satisfactory.

Ehrlich's Triple Stain.—

Orange-G (saturated aqueous solution),	6.0	parts;
Acid fuchsin (saturated aqueous solution),	4.0	" .

Add to these, stirring, drop by drop:

Methyl-green (saturated aqueous solution), 6.6 parts.

To this mixture add:

Glycerin (neutral)	5.0	parts;
Absolute alcohol	10.0	" ;
Distilled water	15.0	" .

Shake the mixture well and let stand for several days before using. Stain in this solution for two to three minutes, without heating, and then wash in water, dry, and examine.

The red corpuscles are colored orange, the nuclei of the leucocytes greenish blue, the nuclei of erythroblasts almost black, the acidophilic granulations of the polymorphonuclear eosinophiles and eosinophilic myelocytes bright red, the neutrophilic granulation of the polymorphonuclear neutrophiles and neutrophilic myelocytes violet, while the basophilic granulation of the mast-cells remains unchanged and stands out clearly as characteristic, small, empty spots surrounding the pale-green nucleus.

The stained cover-glass preparation when properly stained should appear to the naked eye an orange or orange red.

The objections to this stain are that it is a poor nuclear stain, fails to demonstrate the structure of normal mononuclear leucocytes, and does not stain the malarial parasite. The methyl-blue stain is preferred by many as a routine method on account of the uniformity of results obtained.

Goldhorn's one solution blood-stain is a new method, and is now on the market and has the advantage of fixing the blood-smear as well as staining. The results are similar to Ehrlich's stain, except that it also stains the parasite of malaria.

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