MANUAL

OF

NORMAL HISTOLOGY

ADAPTED FOR THE USE OF STUDENTS IN THE CLASS ROOM
AND IN THE LABORATORY

BY

TILGHMAN B. MARDEN,

A.B., JOHNS HOPKINS UNIVERSITY; M.D., UNIVERSITY OF MARYLAND

Professor of Histology and Embryology at the University of Maryland, and College of Physicians and Surgeons of Baltimore

Formerly Professor of Histology, Bacteriology, and Biology at the Baltimore Medical College

1916
PRESS OF A. HOEN & CO.
BALTIMORE, MD.

PREFACE

In the preparation of the present Manual, the author has endeavored to supply a want which he considers has been experienced by many of our Medical Students: a text-book upon Histology which, although concise in description shall still be sufficiently minute to furnish a clear and comprehensive idea of the subject.

The following pages represent an effort to condense the description of the structure of the various portions of the human body in such a manner that they may be readily grasped and permanently retained by the student, and to furnish him with the means, in the form of experiments, by the aid of which he may be able to verify such description and impress upon his memory mental photographs of the microscopical appearance of the various tissues and organs, so permanent and distinct that time and future occupations shall fail to erase them.

Although the Manual is not intended by the author to be regarded as a complete and exhaustive treatise on Histology, he feels confident that it will give to the student such a thorough knowledge of the essential facts of the science that he will be able with ease to study and comprehend such matters of histological interest as may, from the elementary character of the work, have been necessarily omitted, or those subjects connected therewith which he may be called upon to study later in his advanced college course or professional career.

As Embryology has now been added as a separate department to the college curriculum, the consideration of the development of the tissues and organs of the body has been omitted, except in a single instance, that of the development of bone.

Except in the occasional instance where he has taken advantage of the excellent illustrations of other duly acknowledged authors, and in those instances where he has attempted to represent by means of diagrams, all the illustrations are faithful representations of specimens examined by the author, and from which drawings were prepared by him expressly for the Manual.

In presenting this work to the public, the author takes advantage of the opportunity to express his appreciation of the cordial reception extended to his Lecture Notes by the members of his former classes as it is largely due to that reception that he was encouraged to prepare the present Manual. He also extends his thanks to the Bausch and Lomb Opt. Co., of Rochester, New York, for their courtesy extended in the contribution of the cut used in Fig. 5.*

T. B. M.

Baltimore, September 10th, 1916.

* NOTE. Fig. 5, has been made Fig. 6, in the 3rd edition.

Preface to the Third Edition.

Twenty years' experience teaching Histology with the aid of the "Manual" has convinced the author that the best results in teaching a laboratory subject are to be obtained by the use of a text-book which describes the subject briefly but explicitly, profusely illustrated with sketches or photographs of the objects which the student is expected to see. Such a book may readily be used in the laboratory as a guide, as well as in the classroom.

Having found the "Manual" to have met his expectations during the years of teaching students of this and many of the other nationalities at the three medical colleges of Baltimore, namely, the Baltimore Medical College, University of Maryland, and College of Physicians and Surgeons, which recently have merged to form one school, the author has endeavored to alter the text as little as possible, only altering and adding merely to bring the book up to the present times, but has added illustrations, mostly microphotographs, taken of specimens actually used by him for his classes in the laboratory, and for the projection upon screens as illustrations of his lectures. Microphotographs Numbers 1 and 19, and Numbers 30, 70 and 71, are specimens stained and mounted respectively by Messrs. Wetherbee Fort and Wm. H. Ingram, members of the author's class in Histology during the Session of 1915-16, to whom due credit and appreciation are extended.

T. B. M.

Baltimore, July 1st, 1916.

CONTENTS.

CHAPTER I.

INTRODUCTORY.

Histology (Gr. ἱστὸς, a tissue; λόγος, a discourse) is the branch of morphology which treats of the minute structure of tissues. As the minute structure of tissues is studied with the aid of the microscope (Gr. μικρὸς, small; σκοπέω, to view), this branch of science is commonly known as *"microscopical anatomy."*

The study of the structure of normal tissues is *"normal histology,"* to distinguish it from the study of diseased tissues, or "pathological histology." As tissues may be animal or vegetable, there are two kinds of histology, termed respectively, "animal" and "vegetal." Animal histology may be divided into human, and comparative; the former being the study of the structure of the tissues which occur in the human body. As the structure of the human tissues and organs in many instances is shown as well, and often better, by the corresponding tissues and organs of lower forms of animal life, the structure of the human tissues and organs, in such instances, may be demonstrated from corresponding tissues and organs of lower animals.

Although the tissues and organs of the body are numerous, there are four groups of tissues which singly, or collectively, comprise all the structures of the body; hence the four groups of tissues are known at *the elementary tissues.*

The elementary groups of tissues are:

Epithelial tissue.

Supporting, more commonly known as connective, tissue.

Muscular tissue.

Nervous tissue.

A tissue consists of two essential portions, a cellular and an intercellular. The intercellular portion may present variations which depend upon the location of, and the function to be performed by, the tissue. In some tissues the intercellular substance is a liquid (blood and lymph); in others it is solid, tough, and elastic (elastic connective tissue); or solid and hard (bone), etc. The proportion between the cellular and the intercellular substances varies; in some instances there is a preponderance of the former; in other instances of the latter. In the embryo the former is the more important and more abundant, while in the adult, usually the reverse is true. Although the intercellular substance varies between wide limits, the cellular elements of one tissue are very similar to those of another, the main difference being one in shape.

A CELL is a mass of *protoplasm* containing a *nucleus,* and enclosed by a *limiting membrane,* or cell wall.

PROTOPLASM, sometimes termed cytoplasm, consists of two portions, spongioplasm and hyaloplasm. The *spongioplasm* exists as a fine fibrillar network; the *hyaloplasm,* sometimes spoken of as paraplasm, as a clear semi-fluid substance in the meshes of the network. In the protosplasm of some cells the network of the spongioplasm can readily be seen (liver-cells), while in other cells the spongioplasm exists as small granular particles disseminated throughout the protoplasm (colorless corpuscles of the blood), the hyaloplasm being between the neighboring particles. Protoplasm may contain fat, pigment, glycogen, etc. In some portion, usually the central, of the mass of protoplasm there is an oval or round dense area of karyoplasm known as the *nucleus,* which is also composed of a fibrillar network, and a semi-fluid substance contained in the meshes of the network. The fibrillar network of the nucleus is termed the *intranuclear network,* and consists of two portions of which one exists as very small granules, which, on account of readily staining with certain aniline dyes are said to be *chromatic* (Gr. κρῶμα, color), the substance of which they are composed being termed *chromatin.* The other portion of the network exists as a delicate less stainable network of fine fibrils, termed *linin.* The semi-fluid substance in the meshes of the network is termed the *nuclear matrix,* or nucleoplasm, which, owing to the fact that it does not stain with certain aniline dyes, is said to be *achromatic,* the substance of which it is composed being known as *achromatin.* At the junctions of the fibres of the intranuclear network are collections of the chromatin, termed *karyosomes,* or false *nucleoli.* In the nuclear matrix there may be one or more small bodies termed *nucleoli,* which are collections of modified karyoplasm termed *paranuclein* or *pyrenin.* The nucleus is separated from the surrounding protoplasm by a membrane known as the *nuclear membrane,* which, owing to the facts that it stains similar to the intranuclear network, and is attached to or continuous with it, may be considered as being composed of the same kind of chromatic substance as that which composes the fibrillae of the network. In some cells there may be more than one nucleus, in which cases the cells are known as *polynuclear cells.* At the periphery of the protoplasm, the protoplasm appears more dense, or, which is more probable, the spongioplasm, besides forming the network of the protoplasm, extends around the periphery of the mass of protoplasm, thus forming a *limiting membrane* or cell wall. Any peripheral condensation of protoplasm, no matter how slight, should be regarded as a cell wall. In some cells the limiting membrane is pliable, elastic, and thin, so thin that it can only be seen after much difficulty. Due to the limiting mem-

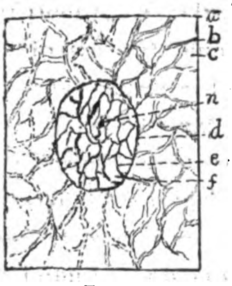
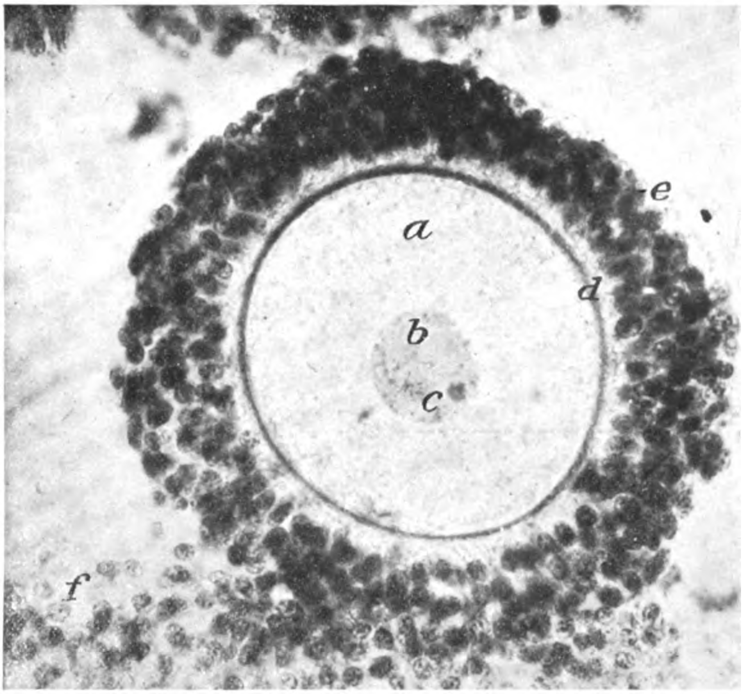
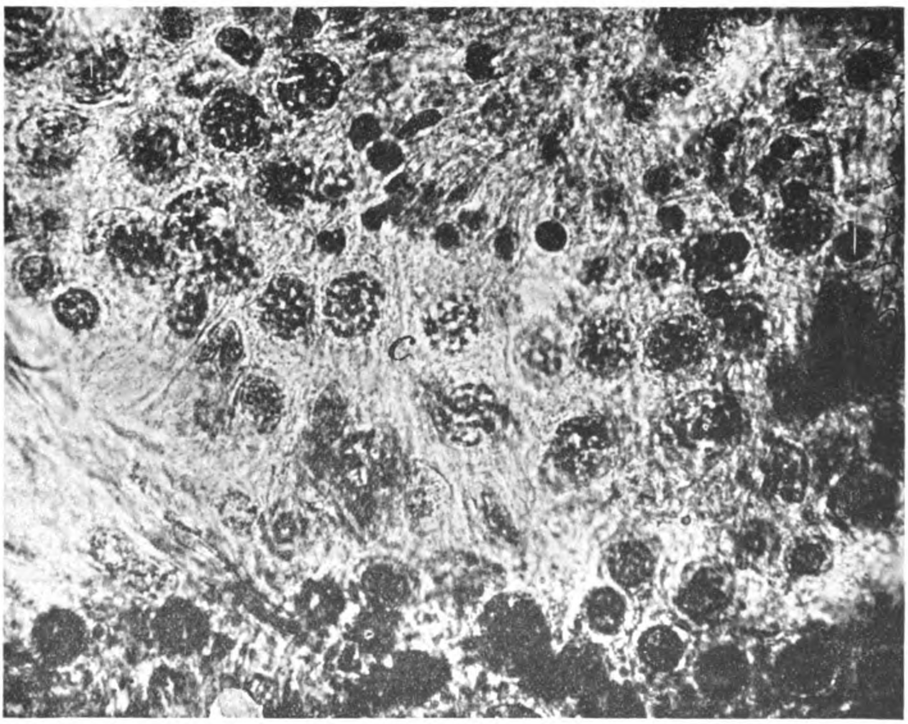


FIG. 1.
A cell from the growing tip of an onion.
(*a*) cell wall; (*b*) spongioplasm; (*c*) hyaloplasm; (*d*) nuclear membrane; (*e*) intranuclear network; (*f*) nuclear matrix; (*n*) nucleolus.



M 1—Microphotograph of a human ovum x 390, illustrating the structure of a typical cell. *a*, protoplasm showing network of spongioplasm; *b*, the nucleus bounded by its nuclear membrane, *c*, nucleolus; *d*, cell wall; *e*, cells of discus proligerus; *f*, cells of membrana granulosa.



M 2 —Microphotograph of a portion of a seminiferous tubule of the testicle of an opossum x 860 illustrating the intranuclear chromatic network in the spermatocytes.

brane being of such a structure, the shape of the cells may change, due to pressure from within the cell. In other cells the limiting membrane is dense, thus giving to the cells definite shapes. The shape of a cell which has a dense cell wall depends upon the pressure from without the cell. If the pressure within a cell increases to any great extent, the cell wall is liable to rupture, as in the case of the goblet cells of the intestines, and of the trachea. If the spongioplasm exist as granules instead of a network, the granules at the periphery come in contact with one another thereby causing the periphery to be more dense than the rest of the protoplasm. This is noticeable in the case of the colorless corpuscles of the blood.

A cell during its life history may undergo certain modification, and become an *atypical cell,* as in the case of the colored corpuscle of the blood, which, in the early part of its life history, has the structure of a typical cell, but at a later period loses its nucleus. Another instance of an atypical cell would be where a cell never, during its life history, possesses all the essential structures of a typical cell, as in the case of the low form of unicellular organisms, the *protamoeba,* which is similar to the *proteus animalcule,* commonly known as the amoeba, except that it has not a nucleus.

A cell has certain functions known as vital, which are *assimilation, elimination, growth, irritability, motion,* and *reproduction.*

Assimilation is the act by which living bodies appropriate and transform into their own substance matters with which they may be placed in contact (Dunglison's Medical Dictionary). The matters thus acquired may be utilized for the nutrition of the cell; or stored up, as such or after certain modification, for future use.

Elimination is the process by which the cell ejects the stored up substances when needed, and the products formed by the katabolic changes, which are continually going on in a living cell.

Growth is the natural sequence to the nutrition acquired by the cell during the process of assimilation.

Irritability is the function by means of which a cell responds to stimulation from within the cell, or from without. This function is highly developed in the cells of the nervous system.

Motion is the process by means of which the portions of a cell are capable of changing their relation. This process, going on within a cell, may cause change in the shape or position of a cell. This function is highly developed in the muscle cells. In some cases the changes in shape of the cell allow the cell to pass from one place to another, producing movements similar to those produced by the proteus animalcule (amoeba); hence in such instances the movements are termed *amoeboid movements.*

Reproduction is the function by which living bodies produce bodies similar to themselves. (Dunglison.) It may be brought about in one of two ways: ***direct division,*** and ***indirect division.***

DIRECT DIVISION is where the nucleus simply divides into two equal parts, followed by a similar division of the protoplasm, each division of the protoplasm enclosing a division of the nucleus, thus forming two daughter cells.

INDIRECT DIVISION is where the nucleus divides after a series of changes has taken place within it. The series of changes is spoken of collectively as *karyokinesis.* (Schleicher.) The process is also known as *mitotic* (Gr. μίτος, a web), the direct division being *amitotic.*

The cycle of changes which take place in karyokinesis may be briefly summarized as follows:

I. The intranuclear network appears to consist of one fibrilla, which is closely coiled, giving the *close skein* stage (Fig. 2, *a*).

II. The skein becomes less compact, the fibrilla being arranged as a loose coil, giving the *loose skein* stage (*b*). At about this time the nuclear membrane disappears, and also the nucleolus, and in the achromatic substance striations

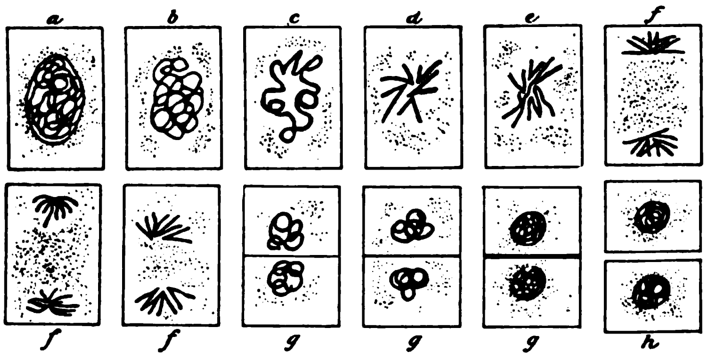


FIG. 2.
Cells from the growing tip of an onion, showing stages of karyokinesis.
(*a*) close skein; (*b*) loose skein; (*c*) rosette; (*d*) aster; (*e*) cleavage; (*f*) diaster; (*g*) di-rosette, and daughter nuclei; (*h*) daughter cells.

(fibres) appear, which start from a central point in each polar field, diverge and become continuous with those of the opposite side, forming the *achromatic spindle* or *amphiaster* (Fig. 5, *A*).

III. The loosely arranged skein becomes arranged around a central clear space, giving the *rosette* stage (Fig. 2, *c*)

IV. The filament now breaks into small portions, usually V-shaped, known as *chromosomes,* which are arranged with their apices toward the central clear space, giving an appearance somewhat similar to that of a star; hence this stage is known as the *aster* stage (Fig. 2, *d*).

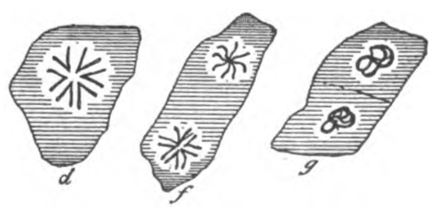
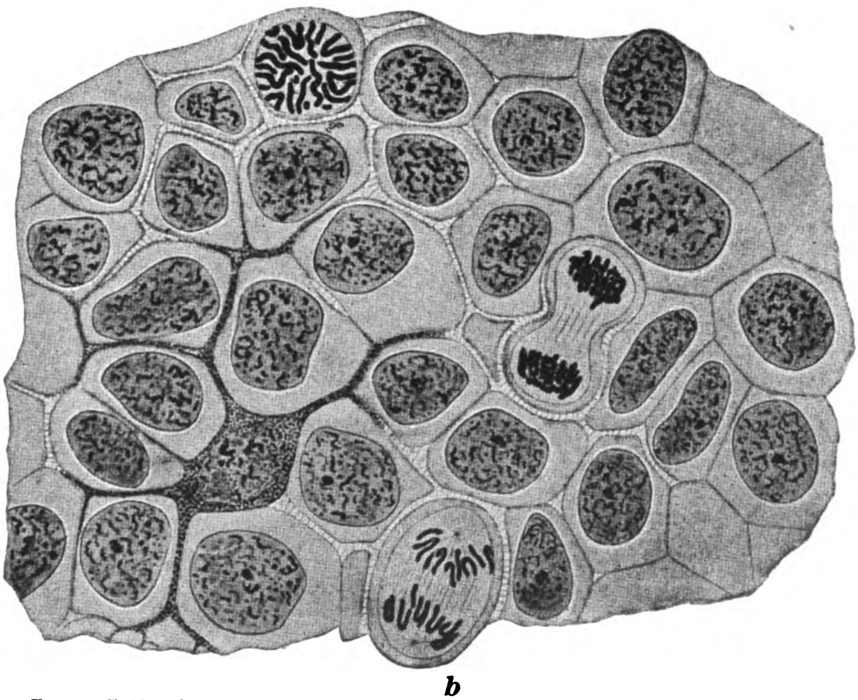


FIG. 3.
Cells from the epidermis of a salamander.
(*d*) aster; (*f*) diaster; (*g*) daughter nuclei.

V. Each of the chromosomes cleaves longitudinally, giving two V-shaped portions. This is known as the stage of *cleavage* (Fig. 5, *A*).

VI. The chromosomes pass to the central particle of each polar field, along the fibres of the achromatic spindle, one chromosome of each pair formed in the previous stage going to each central particle. This is known as the stage of *metakinesis* (Fig. 5 *B*).

a



b

FIG. 4—Epidermis of the salamander. Three cells are in process of division by mitosis. *a*, prophase; *b*, metaphase. The second cell above *b*, whose cell body is in process of fission, presents a stage of the telophase. (After Wilson.)

VII. The chromosomes at each polar field arrange themselves around the central particle, giving a star-like appearance at each pole of nucleus. This is known as the *diaster* stage (Fig. 2, *f*).

VIII. The asters pass through the rosette, loose skein and close skein stages, respectively known as di-rosette, di-loose skein, di-close skein, and become *daughter nuclei* (Fig. 2, *g*).

The protoplasm divides, while the asters are passing through the intervening stages to become resting nuclei, so that by the time that the asters have become daughter nuclei the protoplasm has divided, and two *daughter cells* have been formed (Fig. 2, *h*).

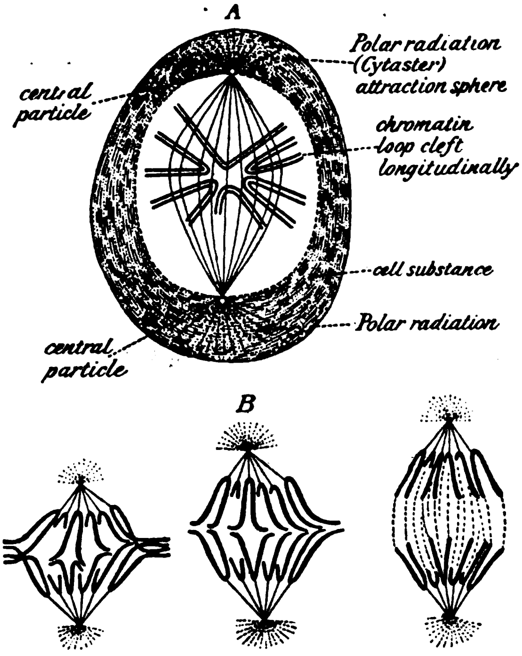


FIG. 5.
Diagrams (after Rabl) showing the achromatic spindle (*A*) and the stage of metakinesis (*B*).

Stages I and II are spoken of collectively as the *prophase;* III to V as the *metaphase;* VI and VII as *anaphase;* and VIII and cleavage of protoplasm as *telophase.*

The student after having procured the apparatus, as required for laboratory work, should examine carefully the staining dishes, slides, cover-slips, teasing needles, section lifter, etc. He should then take the miscroscope to which he has been assigned from its case and carefully examine its various parts: the *foot* (*A*) or base of the stand, by means of which the instrument rests firmly upon the table; the *pillar* (*B*), which is immovably attached perpendicular to the foot; the *arm* (*C*), which is attached to the pillar by means of a *hinge joint,* (*T*), thus allowing the instrument to be bent at an angle; the *stage* (*S*), which is attached firmly to the arm, containing in its centre an opening through which light reflected by the *mirror* (*O*) can pass; the *iris diaphragm* (*Q*), by means of which the amount of light allowed to pass through its opening to that of the stage is regulated; the *clips* (*N*), by means of which the slides are held firmly on the stage; the *main tube* (*D*), in the upper end of which telescopes the *draw tube* (*H*); the upper end of the draw-tube, into which fits the *ocular lens* (*G*); the lower end of the main tube, into which is screwed the *objective lens* (*F*) or the *nose-piece* (*E*); the *rack* (*J*) and *pinion* (*K*) arrangement of the *coarse adjustment screw,* by means of which the lower end of the main tube (carrying the objective lens) is raised from or lowered toward the stage; the *fine adjustment screw* (*L*), by means of which the instrument is focused on the specimen; the *screw* (*R*), by means of which the diaphragm is lowered from or raised to the stage; the *mirror-bar* (*P*), by means of which the mirror may be regulated in order to reflect the light. He should then take the box or boxes containing the lenses from the microscope case, and examine and compare the lenses, noticing the *eye-pieces* (or oculars) and objectives, the number on each lens. He should at all times remember that the lower the number on the lens the lower the magnifying power. If the lens be designated by a fraction, the lower the numerical value of the fraction the higher the magnifying power. (N. B.—The student should appreciate the value of a microscope, and handle it as gently and take as

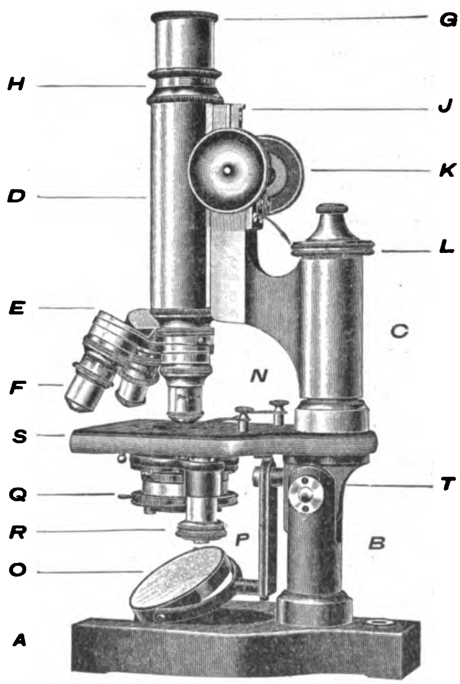


FIG. 6.

B B, Continental Microscope (Bausch and Lomb Opt. Co.)

A, foot or base of stand; *B*, pillar; *C*, arm; *D*, main tube; *E*, triple nose-piece; *F*, objective lens; *G*, eye-piece or ocular lens; *H*, draw tube; *J*, rack; *K*, pinion; *L*, fine adjustment screw; *N*, clip for holding slide upon the stage; *O*, mirror; *P*, mirror attachment arm; *Q*, substage attachment consisting of Abbe condenser and iris diaphragm; *R*, screw for lowering or raising the substage attachment; *S*, stage; *T*, hinge joint.

much pride in its care as if it were his own property. When he starts to work in the laboratory he should take the instrument and its attachments from the case, examine carefully, and if anything be missing or injured notify one of the demonstrators. While using the instrument, he should not jam the objective lens against the stage or specimen, or roughly use the fine adjustment screw. Before leaving the laboratory he should remove the lenses from the instrument and replace them, as well as the microscope, in their respective cases. When using slides and cover-slips, he should be careful to have them *clean*. He should have a good sketch-book, in which he should sketch what he *sees* through the misroscope. He should constantly bear in mind that in order to derive the most benefit from a course in practical histology one must be patient, exact, careful, and use clean apparatus.)

After having studied the construction of the microscope, become familiar with its use by performing the following experiments:

Experiment 1. On a clean slide put a drop of water, in which place a few fibres of linen, and examine with the low power. Sketch the fibres as they appear. Look for air bubbles; if any be found sketch them. Endeavor to look through the microscope with the left eye, keeping the right eye open and looking upon the paper upon which you sketch. As you thus look, sketch the image as it appears to be seen upon the paper.

Exp. 2. As in Exp. 1, prepare a few fibres of silk thread, examine with the low power, and sketch. Then remove the slide from the stage of the microscope, and carefully tease apart the fibres with teasing needles; cover with a cover-slip and examine, first with the low power, then with the high, sketching what is seen under each power.

Exp. 3. On another slide put a drop of a strong solution of sodium chloride (table salt). Allow it to dry, then cover with a cover-slip and examine with both powers, low and high, and sketch the crystals as seen. Repeat the experiment, using a weak solution of sodium chloride. Heating gently over the flame of a Bunsen burner or of an alcohol lamp will facilitate drying.

Exp. 4. In the same manner as in Exp. 3, prepare, examine, and sketch crystals of potassium bichromate.

Exp. 5. In order to measure specimens or portions of specimens a scale should be prepared as follows:

Place a stage micrometer (Gr. μικρὸς, small; μέτρον, to measure) (which is a slide upon which are ruled straight lines $\frac{1}{100}$ and $\frac{1}{1000}$ inch apart, or $\frac{1}{10}$ and $\frac{1}{100}$ mm. apart) upon the stage of the microscope, and with the left eye to the instrument and the right eye looking at a plain card on the desk near the foot of the microscope, examine with the high power. As the lines appear projected on the card, with a sharp-pointed pencil mark their apparent distance from one another, and rule later with ink. On the card, besides the distance of the lines apart, put the number of the eye-piece, that of the objective, and the length of the tube. The scale thus prepared should be frequently used during the course, care being taken that, when measuring objects, the eye-piece, the objective and the length of the tube be the same as when the scale was prepared.

Exp. 6. On a slide put a small drop of milk, and cover with a cover-slip. Examine, measure, and sketch several oil globules, under high power.

Exp. 7. If during the previous experiments you have been unable to observe air bubbles, put a drop of saliva on a slide, cover and examine. Sketch several air bubbles.

Exp. 8. Examine a stained and mounted specimen of an onion tip, or of the larva of a salamander, or of a newt. Study and sketch a cell illustrating the typical structure of a cell.

Exp. 9. In the same specimen as used in Exp. 8, look for and sketch cells showing the different stages of karyokinesis.

CHAPTER II.

THE BLOOD.

The blood is a tissue, in which the cellular and the intercellular substances are of equal importance; but as the intercellular substance is a liquid, the *liquor sanguinis* or *plasma,* it presents no characteristics when viewed with the microscope. Hence the histology of the blood consists of the study of its cellular elements, the *corpuscles.* The corpuscles of the blood are three in variety:

The colored corpuscles.

The colorless corpuscles.

The blood plaques.

THE COLORED CORPUSCLE, commonly known as the red corpuscle, is a small biconcave disc, the average diameter of which is 7.7μ* or $\frac{1}{3200}$ inch, and it is about one-sixth as thick as its diameter. Its surface view appears round; its edge view appears larger at the periphery than at the centre, giving an appearance somewhat similar to the variety of pastry known as "lady-finger." It consists of a pale yellow-colored mass of modified protoplasm, enclosed by a limiting membrane or cell wall, and does not possess a nucleus. The structure of the protoplasm of a colored corpuscle is still a debated question. The theory commonly held, and which has not been replaced, is that there is a highly elastic and pliable, apparently homogeneous network, termed the *stroma,* holding within its meshes the coloring matter, *haemaglobin.* Haemaglobin consists of colorless substance known as *globulin* containing a pigment termed *hematin,* which is a dark brownish red amorphous substance containing all the iron of haemaglobin. If hematin be treated with hydrochloric acid a crystalline substance termed *hemin* or hydrochlorate of hematin, (Teichmann's crystals) is formed. As this occurs even with small quantities of old dried blood it is of great importance in medico-legal cases. Special attention is called to a substance termed haematoidin, which occurs as crystals in old blood-clots retained within the body, as in some cases the crystals may be seen in prepared sections of some of the organs of the body, especially if the organs had been congested before death of the person or animal from whom the organ had been obtained. Singly the corpuscles appear pale yellow in color, while in bulk they appear red. Although a colored corpuscle does not possess a nucleus, on examination an error of supposing it to contain a nucleus might arise due to the peculiar shape of the corpuscle. The surface of the corpuscle being concave, when the microscope is focused on the centre the peripheral portion is not in focus; the centre appears

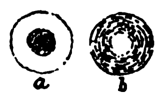


FIG. 7.
The colored corpuscle.
(*a*) periphery in focus; (*b*) centre in focus.

* μ=μικρον—$\frac{1}{1000}$ of a millimeter.

bright, the periphery dark (Fig. 7, *b*). On the other hand, when the instrument is focused on the periphery the central portion is not in focus; the periphery appears bright, the centre dark (Fig. 7, *a*). Thus the colored corpuscle appears to possess a nucleus, but the appearance is due to an error of refraction. The colored corpuscle in its early stages of development, possesses a nucleus which it loses before it enters the circulation, and becomes a "metamorphosed" or *atypical* cell. In blood, soon after it is drawn from the body, the colored corpuscles are attracted to each other, their concave surfaces coming in contact, giving an appearance similar to that of a roll of coin. This is known as the *rouleaux* condition (Fig. 8), which is physical, occurring only under abnormal circumstances, such as having the blood outside the blood vessel. A similar condition may be produced by putting small pieces of cork, which have previously been covered with oil, into water. After a short space of time the rouleaux break apart, and the corpuscles float about singly and as evaporation of the liquid portion of the blood occurs, the colored corpuscles become shriveled or shrunken, and are said to be crenated. The colored corpuscle is *elastic* or pliable, as may be seen on examining a fresh specimen of blood. The corpuscles may be observed to be squeezed through spaces left between neighboring masses of cells (Fig. 9, *a*); or its elasticity may be observed on examining the circulating blood in a capillary network, when a corpuscle may be seen to be caught at the junction of two capillaries, part extending into one capillary, while another portion extends into the other, or a corpuscle may be seen to be squeezed along a capillary, the diameter of which is less than that of the corpuscle. The colored corpuscles are very numerous, as estimated by means of the *haemacytometer* (Gr. αἷμα blood; κῦτος cell; μέτρον to measure), being about five million to the cubic millimeter in man, and about four million five hundred thousand in woman.

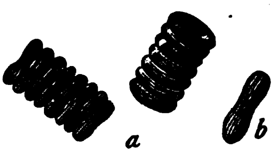


FIG. 8.
Colored Corpuscles.
a, rouleaux; *b*, edge view of a single corpuscle.

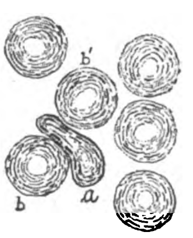


FIG. 9.
Showing elasticity of colored corpuscle.
One corpuscle (*a*) being squeezed, by the current in a freshly prepared specimen of human blood, between two others (*b'* and *b*); after being squeezed through the narrow space, it again assumes its normal shape.

THE COLORLESS CORPUSCLE, also known as the white corpuscle or *leucocyte* (Gr. λευκὸς, white; κῦτος, cell), although found in the blood, is not restricted to it, and may be found in other tissues of the body, especially in the lymphoid structures. It consists of a gelatinous, granular mass of protoplasm, in which is imbedded a nucleus, and sometimes more than one nucleus. A leucocyte which contains one nucleus is termed a mononuclear, and one containing two or more nuclei as a polynuclear

FIG. 10.
Crenated colored corpuscle.

corpuscle. In many leucocytes the nucleus consists of several masses joined to each other by delicate strands, such leucocytes being termed *polymorphonuclear leucocytes.* The leucocyte is a living mass of protoplasm, and is enclosed by a slight condensation of the peripheral portion of the protoplasm, which may be considered as a cell wall. The limiting membrane, probably formed by granules of spongioplasm in close contact, is thin, and allows the corpuscle to assume various shapes due to the movements of the enclosed protoplasm. (See Chapter 1.) The leucocyte possesses the power of movement to a high degree. At rest it is round (Fig. 11, *a*); in motion it assumes various shapes (Fig. 11, *b*), thrusting out arm-like projections, *pseudopodia* (Gr. ψευδὴς false; πόδες feet), resembling in its movements those of an amoeba; hence the movements are termed *amoeboid.* The leucocytes are *larger* than the colored corpuscles, their average diameter being 10μ or $\frac{1}{2500}$ inch, but *fewer* in number, the proportion being about one leucocyte to from three hundred and fifty to five hundred colored corpuscles. The proportion of leucocytes in the blood increases during digestion; diminishes during a fast. As a rule, they are more numerous in venous than in arterial blood. Hemorrhage increases the proportion of the colorless corpuscles to the colored. If freshly-drawn blood be mixed with a few torulae, and the preparation be kept warm by means of a warming stage, the leucocytes thrust out arm-like processes, termed preudopodia, which enclose the torulae. In this manner the colorless corpuscles have the power of taking up substances, and carrying them to be utilized or eliminated. This power of swallowing gives to the leucocytes, which act so, the name *phagocytes* (Gr. φάγω, to devour; κῦτος, cell). The leucocytes, owing to their ability to perform amoeboid movements, are capable of passing out from the blood vessels into the tissues, and vice versa, and are then known as wandering cells, and may be appropriately termed *planetocytes* (Gr. πλανητὸς, wandering; κῦτος, cell). The human leucocyte acts like an amoeba under favorable conditions, being most active at 38° to 40° C., sluggish at 20° C. Its movements are accelerated by an alkaline or neutral medium; retarded and stopped by an acid medium.

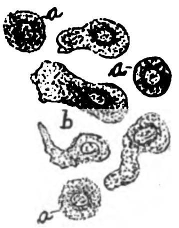


FIG. 11.
Leucocytes of a freshly drawn specimen of blood. (*a*) at rest; (*b*) in motion.

*CLASSIFICATION OF THE LEUCOCYTES.

The leucocytes of normal blood may be divided into the following types:

*In order to understand the classification of the leucocytes, it is necessary to know something about the predilection of certain granules of the protoplasm for certain stains.

The dyes which are used for staining blood may be classed under three heads—acid, basic and neutral.

Acid Dyes are those which have an acid reaction, examples of which are Orange G., Acid Fuchsin, and Eosin. The granules of the protoplasm which take up the acid dyes are said to be *Eosinophilic* or Oxyphilic.

Basic Dyes are those which have an alkaline reaction, examples of which are *Methylene Blue,* Methyl Green and Dahlia. The granules which take up the basic dyes are said to be *Basophilic.*

When one of the basic dyes is added to an acid-dye a neutralization occurs, a precipitate is formed which will stain structures not distinctly colored by either of the dyes which have been brought together. The granules of the protoplasm which stain with this neutral stain are said to be *Neutrophilic* or *Amphophilic.* The neutral color obtained as just mentioned is soluble in an excess of the acid dye; therefore, if care be taken, a staining fluid can be obtained which would have three color values—acid, basic and neutral. Methyl green contains two extra radicals which can unite with acid or acid dyes. This is the principle involved in making up Ehrlich's triacid stain, in which one radical of methyl green unites with Orange G., the other with acid fuchsin.

LYMPHOCYTES—Form about 22 to 25 per cent. of the leucocytes, and vary in size from about 7.5 μ to 14 μ. The smaller ones are known as small lymphocytes, while the larger ones are known as the large lymphocytes. The nucleus nearly fills the cell.

LARGE MONONUCLEAR CELLS—Form about 1 per cent. of the leucocytes, and varying in size from about 14 μ to 20 μ. They possess each an oval nucleus and quite a broad rim of protoplasm. By some they are classed as large lymphocytes.

TRANSITIONAL CELLS—Form about 2 to 4 per cent. of the leucocytes, and are about the size of the preceding type. The nucleus tends to assume a horseshoe shape.

POLYMORPHONUCLEAR NEUTROPHILE CELLS—Form about 65 to 75 per cent. of the leucocytes, and are about 10 μ in diameter. The nucleus may be of an irregular form, usually S shaped, or may consist of several oval portions connected together by delicate chromatic threads. In some cases it is impossible to observe any chromatin filaments connecting the oval portions, thus presenting an appearance of several nuclei, giving a *polynuclear type* of leucocyte. In the protoplasm there are small neutrophile granules.

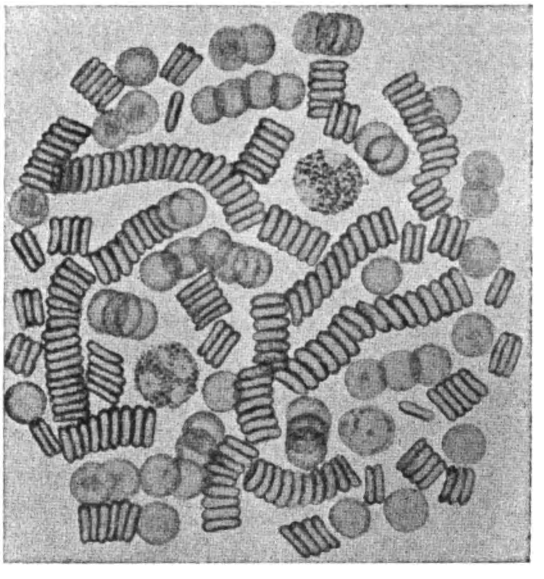


FIG. 12—From a freshly prepared, unstained specimen of human blood. Three leucocytes, an eosinophile, a polynuclear, and a lymphocyte, are represented. Many red blood cells, some "on the flat," some in rouleaux and in profile, are also shown. × 1200, but reduced somewhat in reproduction. (After Schäfer.)

EOSINOPHILE CELLS, occurring in small numbers, are about 2 to 4 per cent. of the leucocytes, and are very similar to the preceding type in size and shape of the nucleus. They are the most actively amoeboid of all the leucocytes and are characterized by the presence in the protoplasm of large, coarse granules, which stain readily with the acid dyes, acid fuchsin and eosin.

BASOPHILE CELLS, being also known as *Mast cells,* are very few in number, being about .25 to .5 per cent. of the leucocytes. They vary in size from 7.5 μ to 10 or 12 μ, and contain in the protoplasm granules, which stain readily with basic dyes, as methylene blue, methyl green and dahlia.

THE BLOOD PLAQUES of Bizzozero, the third variety of blood corpuscles, are flat, circular, colorless particles 2 μ to 3 μ in diameter, or about one-third the diameter of the colored corpuscle, and are present in the proportion of about 1 to 30 colored corpuscles.

If a drop of blood be allowed to coagulate, on microscopical examination a network of fibrin may be observed.

THE ACTION OF REAGENTS ON THE BLOOD CORPUSCLES.

After freshly drawn blood has been kept on a slide for a short space of time the colored corpuscles become shrunken or shriveled up, giving an appearance known as *crenated.* This condition may also be brought about by passing a stream of air under the cover slip, or by treating blood with a solution of sodium chloride.

- **Sodium chloride...**
  - **weak solution...**
    - **causes crenation of colored corpuscles.**
    - **no effect on colorless corpuscles.**
  - **strong solution**
    - **causes marked crenation of the colored corpuscles.**
    - **causes slight shrinkage of the colorless corpuscles.**

- **Water.....**
  - **on the colored corpuscle..** — **causes it to swell, lose its discoidal form and become spherical. At the same time the coloring matter passes out, leaving an almost transparent limiting membrane, the "ghost" of the corpuscle.**
  - **on the colorless corpuscle** — **the amœboid movements cease, the processes of the cell are retracted, the cell becoming spherical. The protoplasm becomes more granular, the granules exhibiting the Brownian movements due to being suspended in a liquid of less density than that of the plasma. The nucleus appears clear or slightly granular. Swelling of the cell may be so great as to cause rupture.**

- **Acetic acid......**
  - **on the colored corpuscle, acts similar to water.**
  - **on the colorless corpuscle, the protoplasm becomes clear, and the nucleus more pronounced.**

- **Tannic acid, on the colored corpuscle**
  - ***weak solution*—the coloring matter escapes, and coagulates, adhering to the limiting membrane.**
  - ***strong solution*—the coloring matter coagulates within the corpuscle, and presents the appearance as if the corpuscle possesses a nucleus.**

The coloring matter of the colored corpuscle may also be driven out of the corpuscle by heating the blood to a temperature of about 60° C.; by freezing and thawing the blood; by chloroform or ether vapor, and by introducing the serum of one animal into the blood of another, which is probably due to a difference in density or alkalinity.

Experiment 10. After having cleaned a slide and a cover-slip, prick with a sharp-pointed needle the end of a finger, or the lobe of an ear. Press the cover-slip against the bleeding point, and quickly put it upon the slide, so that the drop of blood will be between the cover-slip and the slide. Examine with the high power. (*a*) Notice the numerous colored corpuscles; the color of a single corpuscle. Sketch a colored corpuscle seen flat, and one seen in profile. Measure two or three. (*b*) Focus on the periphery of a colored corpuscle, then on its centre, and sketch. (*c*) Notice and sketch rouleaux. (*d*) Look for colorless corpuscles, and notice the scarcity of, and the difficulty experienced in finding, them. (*e*) Compare a colorless corpuscle with a colored one, noticing the difference in size and color. Measure two. (*f*) Look for crenated colored corpuscles and blood plaques. The best results can be obtained by using the $\frac{1}{12}$ objective.

Exp. 11. A fresh specimen of blood should be obtained, as in Exp. 10, the cover-slip taken off, and the specimen laid aside for ten minutes, then examined. Notice and sketch a portion of the network of fibrin.

Exp. 12. Stain a specimen of blood by the eosin-methylene blue, Ehrlich's, Jenner's, or Wright's method (see appendix). Look for colored corpuscles, the different types of leucocytes, and blood plaques, and sketch several when found. Notice the darker-stained rim at the periphery of the protoplasm of the leucocytes. Sketch.

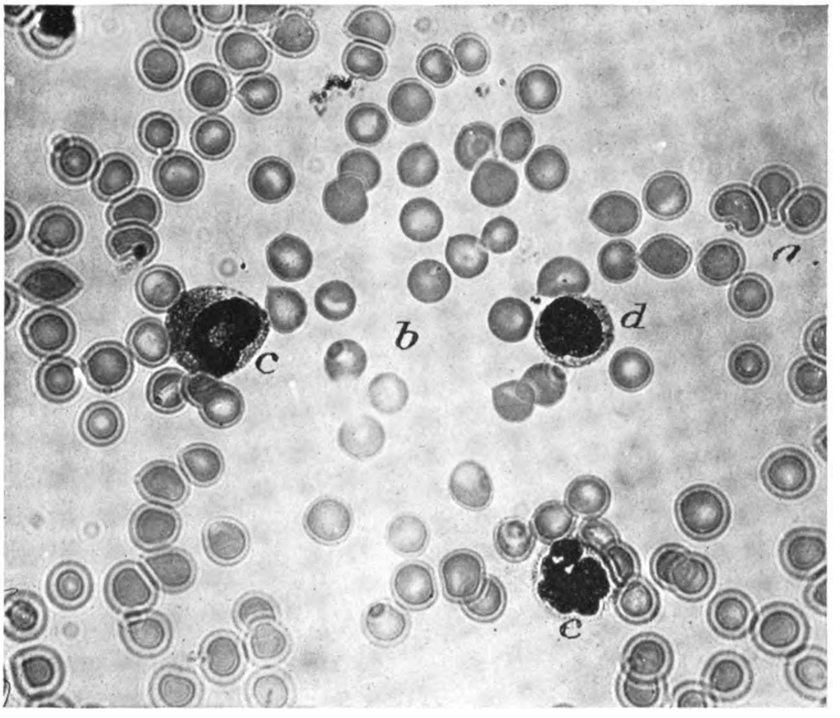
Exp. 13. Stain, mount, and preserve a specimen of blood as follows:

Obtain a fresh specimen of blood on a cover-slip as in Exp. 10, and quickly put the cover-slip against another slip, so that the blood will be between the slips. Press them firmly together, and gently draw apart, and pass them through the following process:

1. Put into alcohol (95 per cent.) for thirty seconds.
2. Transfer to haematoxylin for two or three minutes.
3. Rinse in distilled water.
4. Then into eosin for two minutes.
5. Rinse in distilled water.
6. Transfer to alcohol (95 per cent.) for one minute.
7. Blot with bibulous water.
8. Put on a drop of balsam, and gently lower the slip, blood side down, upon the slide, and label.

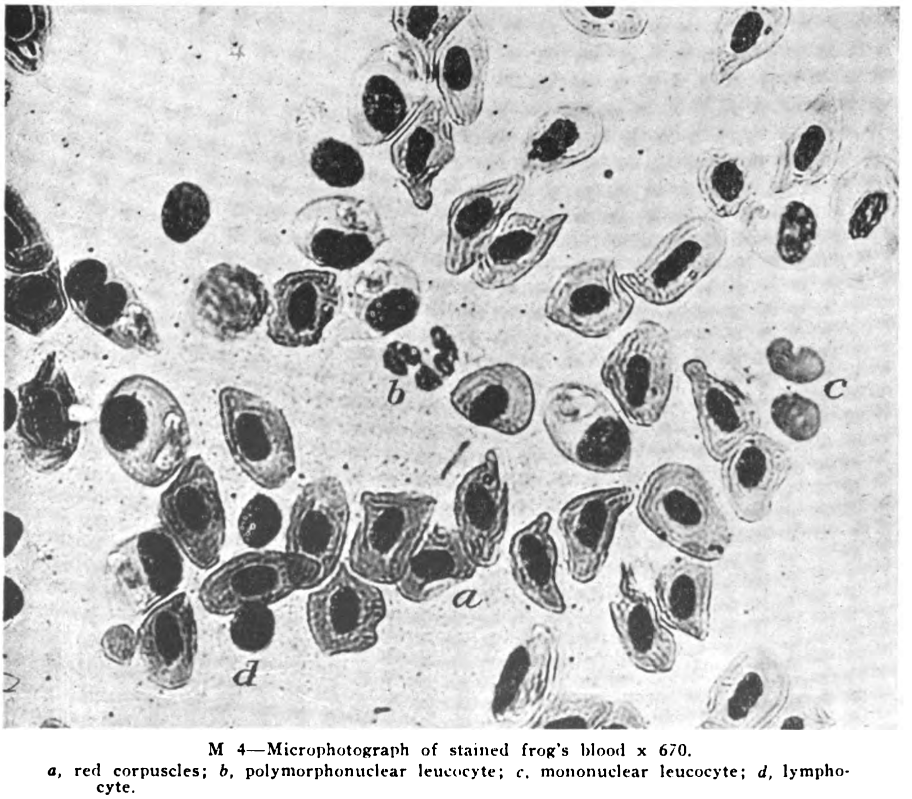
Sketch several of the colored and colorless corpuscles. Look for an eosinophile.

If the specimen be not colored enough, it may be left a longer length of time in either or both stains, as the time required for proper staining depends upon the strength of the staining solutions used.



M 3—Microphotograph of stained human blood x 850.

b, red corpuscles in focus showing light centre; *a*, red corpuscles, centre not in focus, appearing dark; *c*, mononuclear leucocyte; *d*, large lymphocyte; *c*, polymorphonuclear leucocyte.



M 4—Microphotograph of stained frog's blood x 670.

a, red corpuscles; *b*, polymorphonuclear leucocyte; *c*, mononuclear leucocyte; *d*, lymphocyte.

Exp. 14. Obtain a drop of frog's blood and examine it as in Exp. 10. Notice the biconvex shape of the colored corpuscle as seen on edge view, and look for leucocytes undergoing amoeboid movements.

Exp. 15. Stain a cover-slip film of frog's blood by the eosin-methylene blue method. Examine under the high power and notice the differences between the colored corpuscles and those of the human blood. Look for the different kinds of leucocytes. Sketch.

Exp. 16. A fresh specimen of blood should be examined on a warming stage (using an oil-immersion objective lens), and the ameboid movements of the colorless corpuscles closely observed. Sketch various shapes which you see. Instead of human blood, the blood of a frog can be used without the need of a warming stage.

Exp. 17. Estimate the number of colored and colorless corpuscles in a cubic millimeter by means of a haemacytometer* under the supervision of one of the demonstrators.

Exp. 18. Notice and sketch the effects produced on the corpuscles of the blood by a solution of sodium chloride; by water, by acetic acid; by tannic acid (weak and strong solutions).

*A description of the haemacytometer and its use is given in the appendix.

CHAPTER III.

EPITHELIUM.

Covering the exterior of the body and those surfaces (mucous membranes) which are directly or indirectly continuous with the exterior, there is a tissue termed epithelium. This tissue is composed principally of cells, which rest on a condensed portion of the underlying connective tissue, which condensed portion is termed the *membrana propria,* or basement membrane. The intercellular portion of the tissue is very scant, consisting of cement substance sufficient to hold the cells together. Epithelium possesses no blood vessels, its nourishment being obtained by absorption of nutritive material by the cells from the underlying tissue. Nerves have been demonstrated between the epithelial cells, but it is as yet doubtful whether they terminate between or within the cells. When the epithelium consists of a single layer of cells it is termed *simple* epithelium; when it consists of several layers it is termed *stratified* epithelium. Of each kind there are two varieties, depending upon the shape of the cells, which are *squamous* (L. *squama,* a scale) and columnar. Of each variety there may be modified forms, termed *modified epithelium.*

THE CLASSIFICATION OF EPITHELIUM:

Simple { **squamous.** / **columnar.**

Stratified { **squamous.** / **columnar.**

Modified {
- **transitional epithelium.**
- **goblet cells.**
- **ciliated epithelium.**
- **cuboidal "**
- **rod "**
- **neuro "**
- **glandular "**

SIMPLE SQUAMOUS EPITHELIUM—This type occurs as a single layer of scale-like cells, each cell being flat, polygonal in shape, possessing a distinct cell wall and nucleus. When viewed in their undisturbed relation, they present an appearance similar to that presented by a pavement; hence this type of epithelium is sometimes termed *pavement* or *tessellated.*

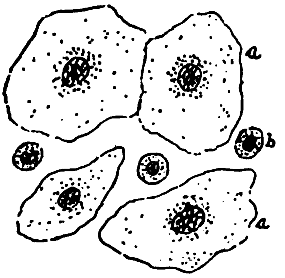


FIG. 13.
Cells contained in human saliva. (*a*) squamous epithelial cells; (*b*) salivary corpuscles.

This type of epithelium occurs only in a few localities, the chief of which are the alveoli of the lungs and the Malpighian bodies of the kidneys.

STRATIFIED SQUAMOUS EPITHELIUM—This type of epithelium is composed of several layers or strata, the topmost consisting of squamous cells. The lowest stratum, that resting upon the basement membrane, is composed of cells which are irregular cuboidal in shape. There is a gradual change in shape from the cuboidal to the squamous in the successive strata passing from the lowest layer to the free surface. Depending upon the surrounding conditions, the topmost layers may be composed of cells containing protoplasm and nuclei, or of cells which have lost their nuclei, and whose protoplasm has been converted into a horny-like material, termed *keratin*, the cells appearing as horny threads.

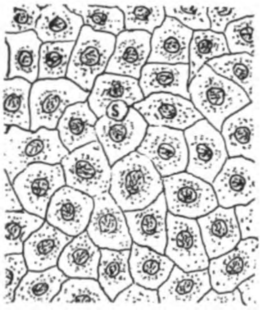


FIG. 14.
Surface view of stratified squamous epithelium of a frog's skin, showing the tessellated arrangement and a stoma (*s*).

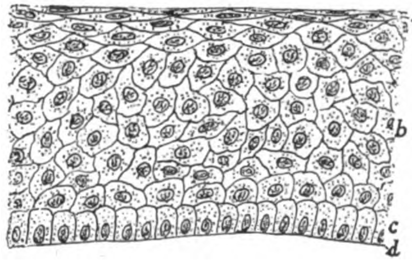


FIG. 15.
Stratified squamous epithelium of a specimen of human vagina
(*a*) uppermost layer consisting of flat cells; (*c*) lowest layer consisting of cuboidal shaped cells; (*b*) the intervening strata consisting of irregular shaped cells; (*d*) basement membrane.

The former type of stratified squamous epithelium occurs as a covering to those surfaces which are kept moist by secretions, as in the mouth, oesophagus, vagina, etc. The latter type occurs where the tissue is exposed to the atmosphere, as on the skin. Stratified squamous epithelium occurs more widely distributed in the body than the simple squamous variety, its chief localities being on the lining membrane of the mouth, oesophagus, and vagina and on the skin.

SIMPLE COLUMNAR EPITHELIUM—This type occurs as a single layer of cells resembling in shape small cylinders or columns. Each cell has a distinct nucleus, cell wall, and recticular protoplasm. On the free border of some of the columnar cells there is a striation, the striations running for a short distance perpendicular to the free border, giving a *striated border* or *cubicular seam.* The cells of the small intestine have the striated border. Probably the striae have an important bearing on the physiological process of absorption, and are little canals leading from the free surface of the cell to its interior, dividing the border into cubical masses of protoplasm. The chief localities where simple columnar epithelium occurs are the stomach and the intestines.

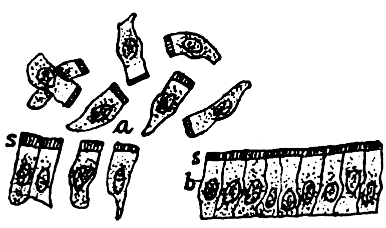


FIG. 16.
Simple columnar epithelicem of the intestine of a rabbit.
(*a*) isolated cells obtained by teasing; (*b*) a layer of cells in situ; (*s*) striated border or cubicular seam.

STRATIFIED COLUMNAR EPITHELIUM—This type consists of several layers or strata of cells, the topmost of which is composed of columnar-shaped cells; the lower layers of irregular polygonal-shaped cells. This variety occurs in few localities, the chief of which being a portion of the male urethra.

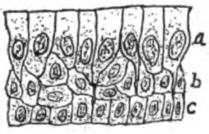


FIG. 17.
Stratified columnar epithelium of the vas deferens of a dog.
(a) uppermost layer of cells (columnar); (c) lowest layer (cuboidal); (b) middle layer (irregular).

MODIFIED EPITHELIUM usually occurs as modifications of simple or stratified columnar epithelium.

There is a type of stratified epithelium known as *transitional* epithelium, on account of the cells of the lower layers rapidly assuming the form of the cells of the topmost layer. The topmost layer consists of cells which are flat with depressions in their under surface to fit over the large ends of the pear-shaped cells of the next layer. This type of epithelium appears to be a modification of stratified columnar epithelium, in which some of the cells of the columnar layer (pear-shaped) extend out and become flattened against the remaining pear-shaped cells, the under surface of the flattened cells becoming moulded over the upper ends of the cells of the underlying layer. This type is found in the ureter, bladder, and the prostatic portion of the urethra.

FIG. 18.
Tarnsitional epithelium of the bladder of a rabbit.
(a) uppermost layer consisting of large flattened cells; (b) middle layer composed of pear shaped cells; (c) cuboidal shaped cells resting upon a basement membrane making up the lowest layer.

CILIATED EPITHELIUM in the human body is a modified form of simple or stratified columnar epithelium. The *ciliated simple columnar* type is found in few localities, the chief of which being the ventricles of the brain, the central canal of the spinal cord, and the oviducts. The *ciliated stratified columnar* type is found in the trachea and the epididymis. The *cilia* are protoplasmic projections from the free border of the cell, being about twenty to each cell. The length of the cilia varies, depending upon the locality of the cells. In the epididymis, the cilia are longer than those of the trachea. The cilia possess the power of movement. The movements are of two kinds: a primary or sudden, and a secondary, which is the gradual return of the cilia to their original position. One cilium moves, then the motion is taken up by the next cilium, and so on, giving a resemblance to a field of wheat as a flaw of wind passes over it. The cilia act most readily at the temperature of the body, and act sluggish if the temperature be gradually lowered, ceasing to act at 0° C. Their action is increased if the temperature be raised to 42°-46° C., and influenced by the presence of oxygen. Among the waste products formed during their activity is carbon dioxide. Narcotic reagents, as chloroform and ether, cause their movements to become

FIG. 19.
Ciliated epithelial cells isolated by teasing from the trachea of a rabbit.
(a) columnar shaped cells; (c) cilia; (g) goblet cells expelling mucus.

sluggish. Poisons, such as nicotine, when constantly applied to the cilia, retard their movements and eventually cause their cessation and death.

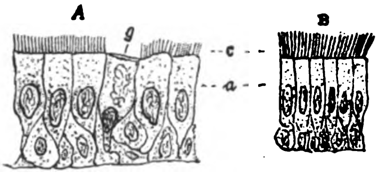


FIG. 20.
Ciliated stratified columnar epithelium.
(*A*) of the trachea of cat; (*B*) of the epididymis of a rat; (*a*) columnar shaped cells; (*c*) ciliated border; (*g*) goblet cell.

GOBLET CELLS are modified forms of columnar cells, and may occur in simple columnar epithelium (intestines) or in the topmost layer of stratified columnar epithelium (trachea). The goblet cells originally exist as columnar-shaped cells whose protoplasm contains mucigen. The cell absorbs water, which acts on the mucigen, forming mucin, which causes a swelling of the protoplasm to such an extent that the cell wall ruptures. The rupture takes place at the free border of the cell, that being the place of least resistance. The rupture of the cell wall allows the mucin to escape, the cell remaining somewhat goblet-shaped, with its protoplasm and nucleus in the portion of the cell near the basement membrane. There are other forms of modified epithelium, such as the *cuboidal,* which is composed of a layer of cube-shaped cells, modified forms of columnar cells; *rod epithelium,* which are columnar-shaped cells, striated at their outer border; "glandular epithelium," and "neuro epithelium," which are epithelial cells modified for the purpose of performing special functions.

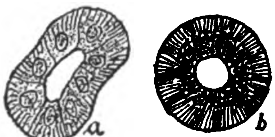


FIG. 21.
Rod epithelium.
(*a*) of a convoluted tubule of the kiney; (*b*) of a duct of salivary gland.

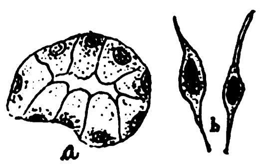


FIG. 22.
Specialized epithelium.
(*a*) glandular epithelium of an acinus of a mucous gland; (*b*) neuro-epithelium of a taste bud of the tongue of a rabbit.

ENDOTHELIUM.

Endothelium is a tissue similar to simple squamous epithelium, but occurs as a lining to the cavities which are not continuous with the exterior of the body. It is found lining the serous cavities, blood-vessels and lymphatics. It consists of a layer of flat polygonal-shaped cells, held together by cement substance. In the cement substance are small openings, known as *stomata,* and collections of cement, known as pseudo-stomata, or *stigmata.* Stomata are not restricted to endothelium, as they may exist in epithelium and may be found in the cement sub-

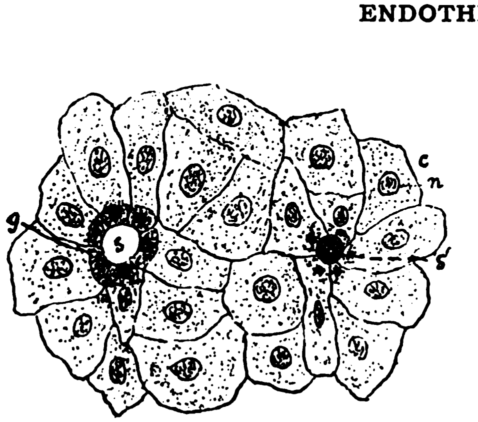


FIG. 23.
Endothelium from mesentery or a cat.
(*c*) endothelial cell; (*n*) nucleus; (*s*) stoma; (*s'*) stigma; (*g*) rim of small granular cells around the stoma.

stance between the cells on the surface of the skin of a frog (Fig. 14), and between the simple squamous epithelial cells lining the alveoli of the lungs (Fig. 24). Therefore, the main difference between endothelium and simple squamous epithelium is one of location, the former existing as a lining to cavities not exposed to the atmosphere (serous cavities and vessels); the latter as a lining to some of the surfaces which are in communication with the exterior of the body.

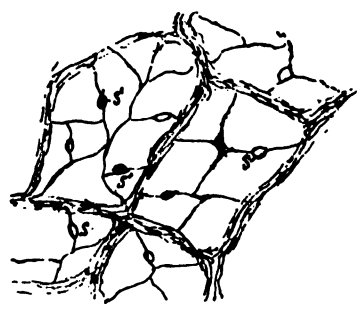


Fig. 24.
Several alveoli of the lung of a kitten which has been stained with silver nitrate, showing the outlines of the simple squamous cells in whch are stomata (*s*) and stigmata (s^1).

Exp. 19. Put a drop of saliva on a clean slide, cover, and examine. Look for the squamous cells. When found, notice the distinct cell wall, the nucleus, and the protoplasm. Measure and sketch several. If any be found united together, sketch them. Look for salivary corpuscles, and notice the similarity which exists between them and the colorless corpuscles of the blood. Notice the air bubbles. Allow a drop of eosin to run under the cover-slip, and examine the specimen again.

Exp. 20*. Examine a strip of skin which has been peeled from the body of a frog, stained with carmine or by the Van Gieson method, and mounted. Notice the pavement-like arrangement of the cells. Look for stomata. Sketch.

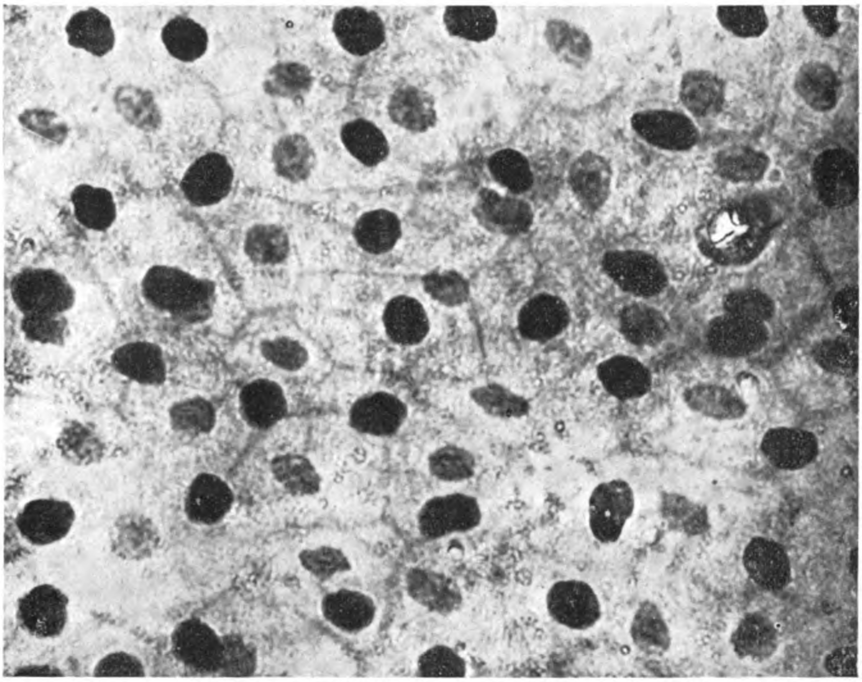
Exp. 21. Stain with haematoxylin and eosin, and mount a section of mucous membrane of the vagina cut perpendicular to the surface, or one of the tongue, or of the oesophagus. Examine with the high power and notice the cells arranged in layers or strata. Notice the gradual change in shape from the cuboidal to the flat, as you examine the successive layers from the basement membrane to the surface. Notice that the cells on the surface possess nuclei and protoplasm. Sketch.

Exp. 22. Upon a clean slide put a drop of glycerin, and into it put the scraping from the inner lining of a small piece of a rabbit's intestine which has been in a solution of potassium bichromate or 33 per cent. alcohol for twenty-four hours. With teasing needles tease apart the scrapings; add a drop of haematoxylin, and examine. Notice the simple columnar cells held together and singly. Measure and sketch. Cement the cover-glass and label. For a temporary mount the scrapings may be put into a drop of water or normal salt solution on a slide, covered and examined.

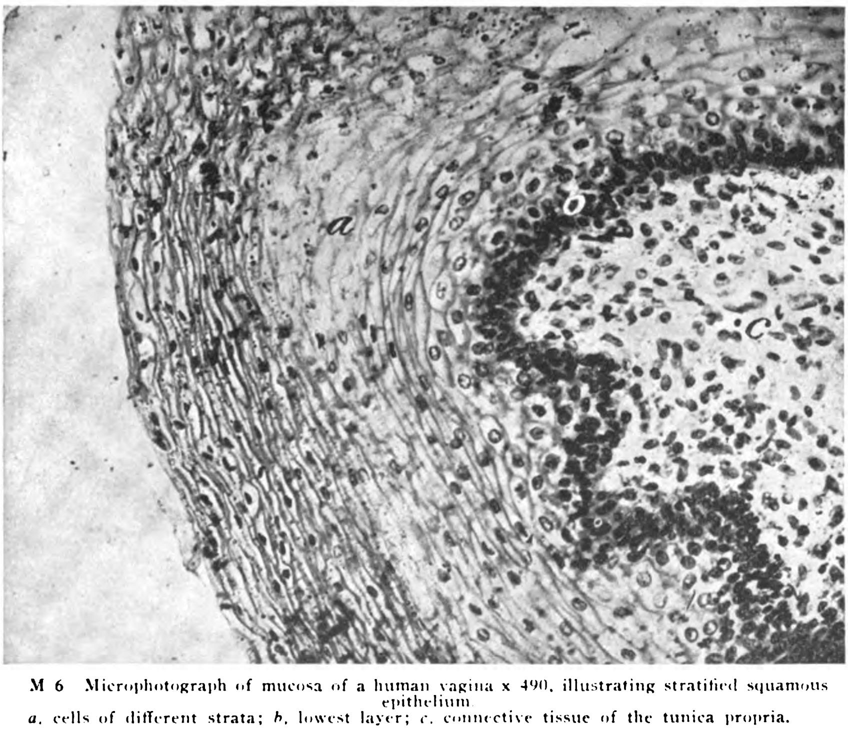
Exp. 23. Stain and mount a section of small intestine. Look for and sketch under both powers the simple columnar epithelium as seen on the sections of the villi.

Exp. 24. Examine a stained section of a rabbit's bladder or ureter, the section having been cut perpendicular to the surface. Sketch the transitional epithelium as seen in situ.

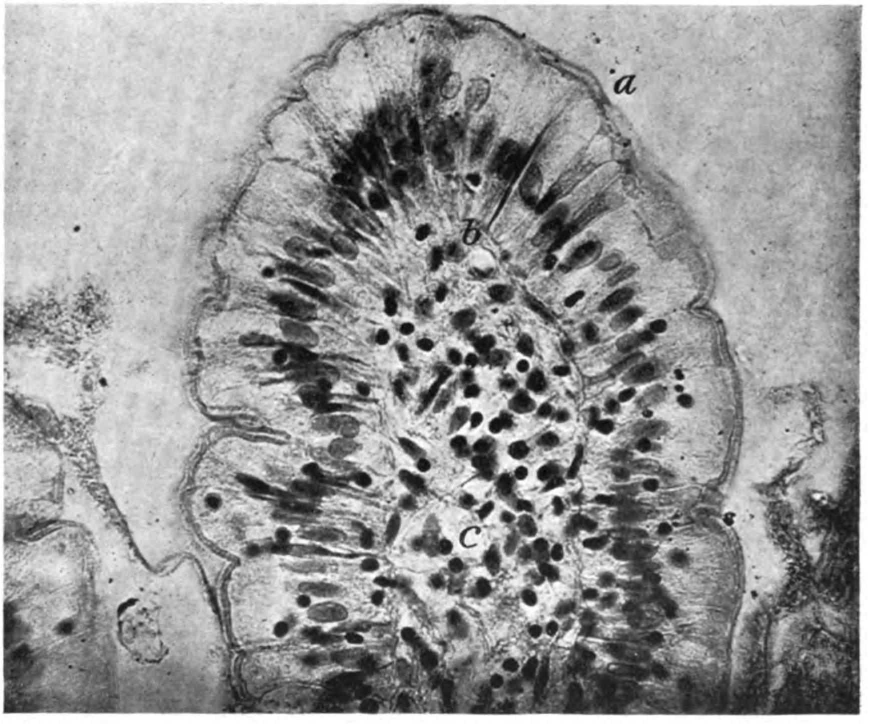
*The methods for preparing specimens are given in the appendix.



M 5 Microphotograph of a piece of the upper layer of a frog's "shed," illustrating the pavement like arrangement of squamous epithelium x 772.

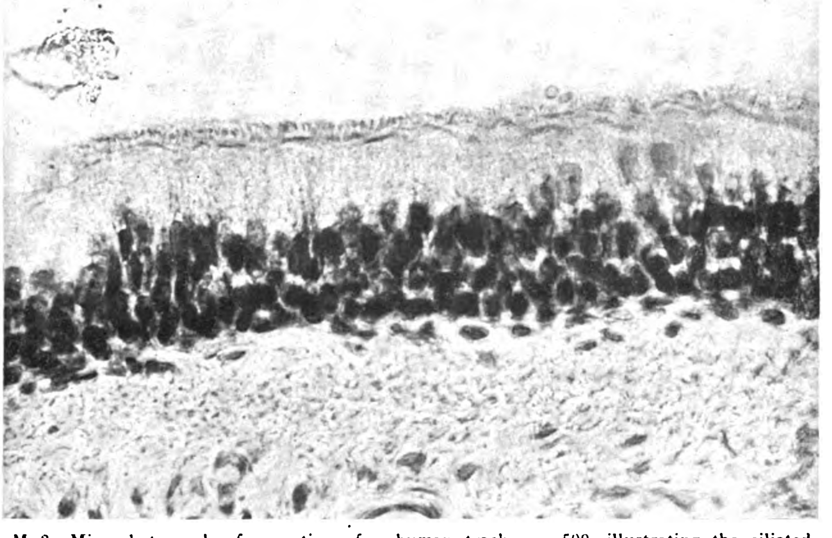


M 6 Microphotograph of mucosa of a human vagina x 490, illustrating stratified squamous epithelium.
a, cells of different strata; *b*, lowest layer; *c*, connective tissue of the tunica propria.

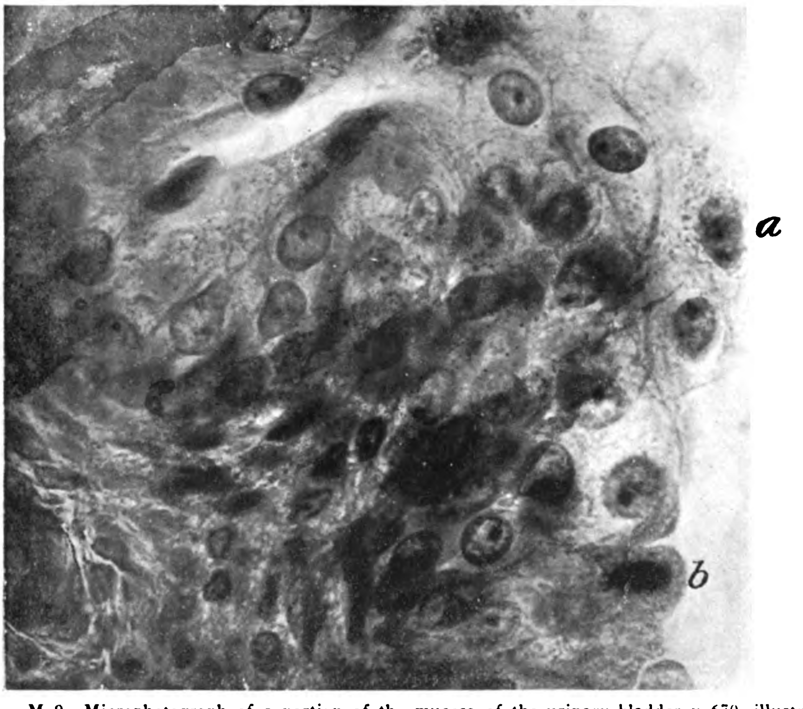


M 7—Microphotograph of an intestinal villus x 390.

a, epithelial portion of the mucosa, illustrating the simple columnar epithelial cells and their striated border and goblet celis, one of which is especially distinct at the lowest part of the left border of the villus; *b*, transverse section of a capillary blood vessel near the membrana propria; *c*, tunica propria showing connective tissue, iymphoid cells, and vessels.



M 8 —Microphotograph of a section of a human trachea x 500, illustrating the ciliated stratified columnar epithelium of the mucosa.



M 9—Microphotograph of a portion of the mucosa of the urinary bladder x 670, illustrating transitional epithelium.

a, topmost flattened cells; *b*, pear-shaped cell of layer next to the topmost layer.

Exp. 25. As in Exp. 22, prepare scrapings from a cat's trachea. Look for ciliated and goblet cells. Sketch.

Exp. 26. Examine the scrapings from the tongue of a living frog which have been teased apart in a drop of a dilute solution of potassium bichromate on a slide. Look for cilia in action, and notice that the ciliated cells are squamous and not columnar, as in the human body.

Exp. 27. Examine a stained transverse section of the trachea. Look for and sketch ciliated stratified columnar epithelium and goblet cells.

Exp. 28. A piece of the frog's mesentery should be rinsed in distilled water, then treated with a 1 per cent. solution of silver nitrate, rinsed again, put into alcohol and exposed to the sunlight. When of a brown color, it should be removed from the alcohol, carefully spread upon a clean slide and mounted with balsam. Examine for endothelial cells. Notice that the cement substance is stained brown, showing the outlines of the cells. Look for stomata and stigmata. Sketch.

CHAPTER IV.

SUPPORTING TISSUES.

In progressive evolution, as we pass from the study of the unicellular organisms in which the vital functions are performed by a mass of undifferentiated protoplasm to that of the higher classes of animals, we find certain tissues set apart for the performance of each of those functions. There is one set of tissues for the purpose of assimilation, another for elimination, another for motion, etc. To bind the various sets of tissues together, furnishing a means of connection and support, there is a set of tissues termed by some *connective;* by others, *supporting.* To avoid the confusion which might arise by giving to a set of tissues, and a subdivision of the set, the same name, in this work the term *supporting* is applied to the set of tissues, reserving the term *connective* for a subdivision of the set. The supporting tissues may be arranged in five classes:

1. Connective tissue.
2. Anomalous connective tissue.
3. Cartilage.
4. Bone.
5. Dentine.

These tissues are derived from the mesoblast of the embryo, and have a genetic relation; i. e., as a rule, cartilage replaces connective tissue, which in turn is replaced by bone. This relation can be better seen by observing analogous structures in different animals. In the human subject the *tendo Achilles* is composed of connective tissue; in the frog it is composed of cartilage; in fowls the tendons of the leg muscles are composed of bone.

In these tissues the cellular elements are more or less similar, while the intercellular substance varies. In the supporting tissues of the embryo the cellular elements are numerous and can be easily observed, while the intercellular substance is scant. As the tissues pass on to their adult forms, the cellular elements become less conspicuous; while the intercellular substance becomes greater in amount and more conspicuous, so that in the adult forms of the supporting tissues the intercellular substance is more abundant and seems to be of more importance than the cellular. Depending upon the requirements of the tissues, the intercellular substance may be tough, elastic, resistant or hard.

CONNECTIVE TISSUE.

This variety of supporting tissue is widely distributed throughout the body, and consists of cells termed *connective tissue corpuscles,* and an intercellular substance composed of fibres.

Connective tissue is arranged into five varieties:

White fibrous tissue.
Yellow fibrous or elastic tissue.
Areolar tissue.
Adipose tissue.
Retiform tissue.

WHITE FIBROUS connective tissue occurs chiefly in tendons. It is composed of parallel bundles of fibres. The fibers are composed of smaller fibres termed fibrillae, which are held together by cement substance. A fibrilla appears as a fine, delicate, wavy line; is 0.5 μ to 1 μ or $\frac{1}{50000}$ to $\frac{1}{25000}$ inch in diameter, and does *not* branch. Although a fibrilla does not branch, it may pass from one fibre into another giving an appearance as if it did branch. Between the fibres are the connective tissue corpuscles, which appear flat on surface view, and appear to possess projections when seen on edge view; the projections of the cells and the cells separate the neighboring fibres from one another.

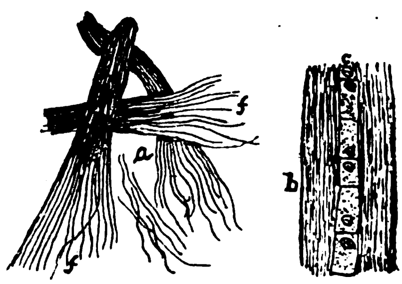


FIG. 25.
White fibrous tissue from a tendon of rat's tail. (*a*) obtained by teasing in dilute salt solution. (*b*) by staining· (*c*) connective tissue corpuscles; (*f*) fibrillae.

On cross-section a tendon would be seen to be composed of bundles of fibres, termed *fasciculi,* and each fasciculus composed of fibres between which are the connective tissue corpuscles, and each fibre composed of fibrillae between which is cement substance. Between the fasciculi is areolar connective tissue. The white fibrous tissue yields gelatin on boiling. When treated with acetic acid the fibres become swollen and indistinct. White fibrous tissue is tough, inelastic, opaque and glistening white.

YELLOW FIBROUS TISSUE, sometimes termed elastic tissue, is found chiefly in the ligaments.

It also occurs in blood-vessels, being well marked in the large arteries. It consists of bundles of fibres; the bundles and the component fibres branch. The bundles of fibres are smaller than those of the white variety. The fibres are composed of smaller fibres, the *fibrillae,* which, as compared with the fibrillae of the white fibrous tissue, are larger, being $\frac{1}{25000}$ to $\frac{1}{3000}$ inch in diameter; have more distinct outlines; possess pronounced

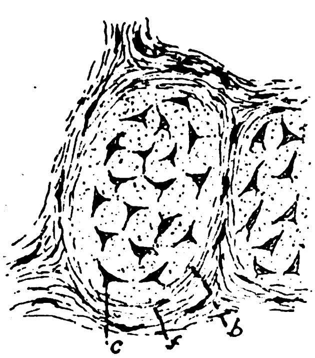


FIG. 26.
(*a*) transverse section of white fibrous connective tissue from a specimen of the skin of the finger; (*f*) areolar connective tissue surrounding a bundle or fasciculus (b) of fibres; (*c*) connective tissue corpuscles of white fibrous tissue, dividing off the fibrillae into fibres.

curves, and branch. On transverse section each fibrilla can be distinctly seen. This variety of tissue is tough, elastic and of a yellowish color, and contains an albuminoid substance termed elastin.

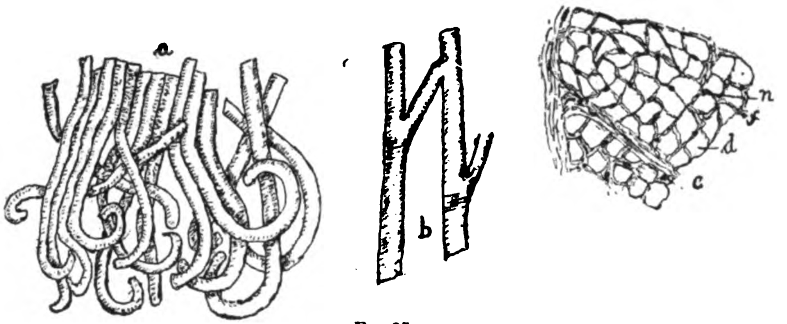


FIG. 27.
Yellow fibrous tissue from the ligamentum nuchae of an ox.
(*a*) fresh specimen teased apart showing the fibrillae; (*b*) branching fibrillae; (*c*) a transverse section of ligamentum nuchae showing cross sections of the fibrillae (*d*); f, net work of areolar connective tissue; (*n*) nucleus of connective tissue corpuscle.

Elastic tissue (yellow fibres), in some instances, instead of being disposed in bundles, forms a network, in which are small spaces, forming what is termed a *fenestrated membrane*. If there be no spaces left between the fibres, a membrane is formed, such as Descemet's membrane of the eye.

AREOLAR TISSUE consists of white and yellow fibrous tissue, the former predominating. The fibrillae, instead of being arranged in parallel bundles, run in all directions, forming a delicate, close-meshed network. In the network some of the fibrillae may be collected together forming fibres. Connective tissue corpuscles exist in the network, occupying irregular-shaped spaces between the fibrillae.

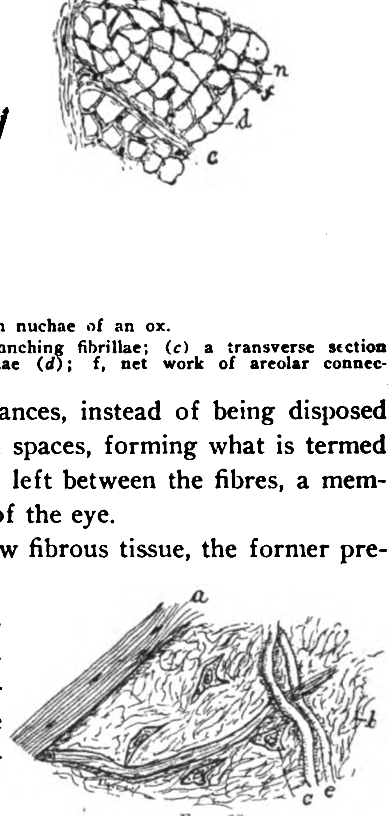


FIG. 28.
Areolar connective tissue obtained from the subcutaneous tissue of a cat, stained with haematoxylin.
(*a*) bundle of white fibrous tissue; (*b*) network of fibrillae; (*c*) connective tissue corpuscle; (*e*) elastic fibres.

ADIPOSE TISSUE is areolar tissue, in which the connective tissue corpuscles have been invaded by fat. Small globules of fat are depos-posited in the protoplasm of the connective tissue corpuscles and coalesce, the amount increasing to such an extent that the protoplasm and the nucleus are pushed toward the cell wall. If the tissue be treated with ether the fat will be dissolved, and the protoplasm and nucleus of each cell will be seen as a layer closely applied to the cell wall.

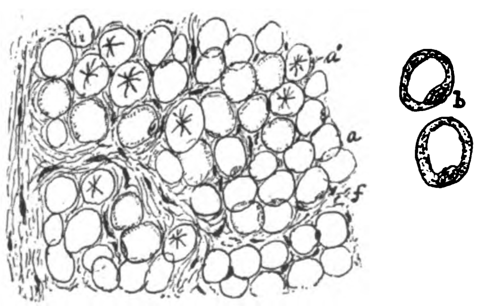
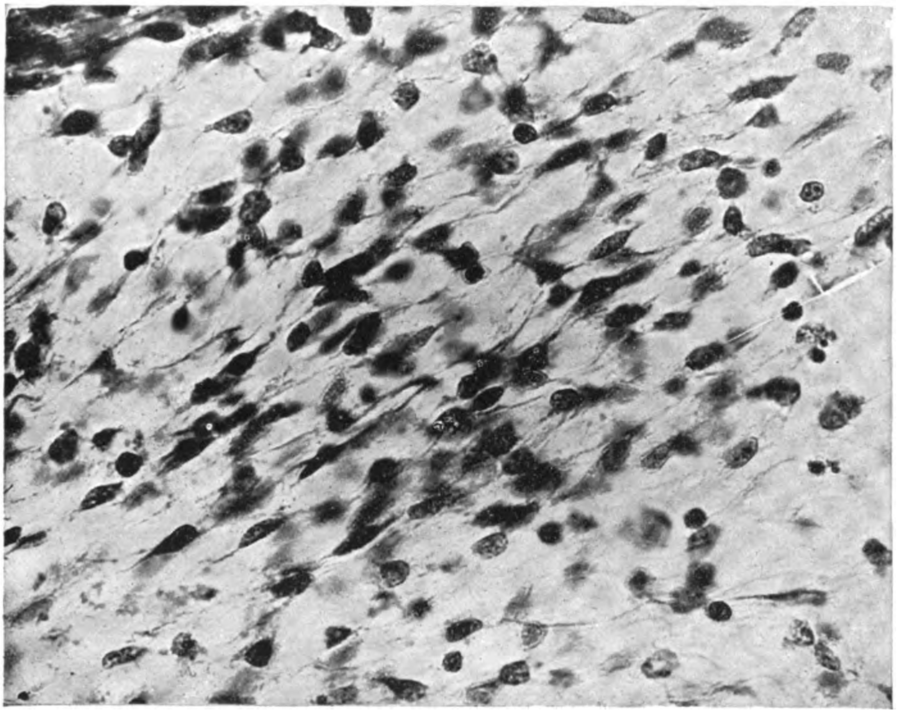
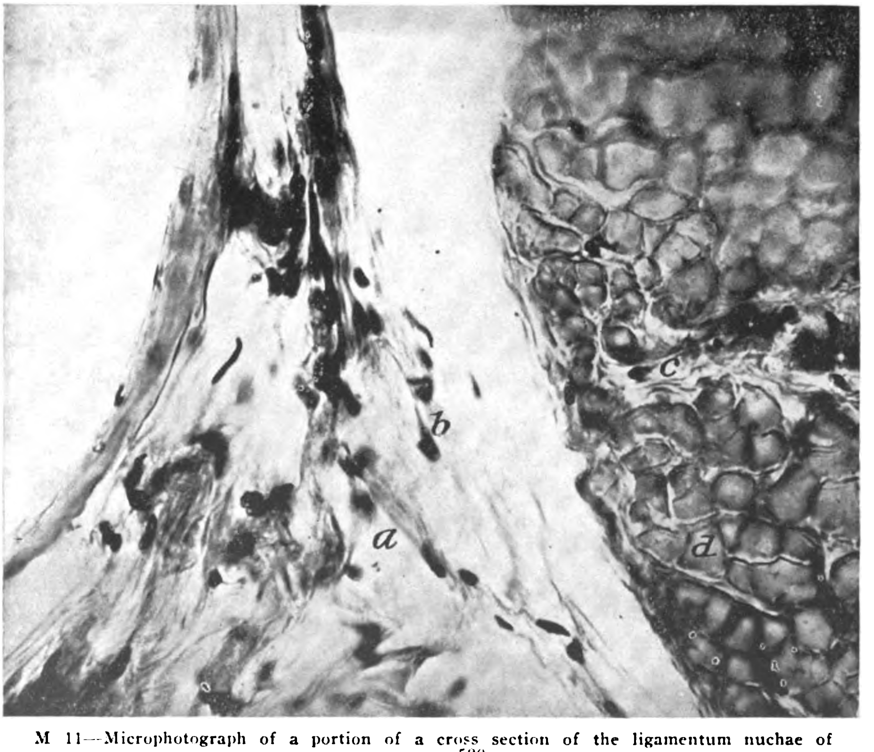


FIG. 29.
Adipose tissue from the mesentery of a cat.
(*a*) fat cells; (*a'*) fat crystals; (*b*) fat cells more highly magnified showing protoplasm and nucleus pushed to the cell wall; (*f*) areolar tissue network containing connective tissue corpuscles.

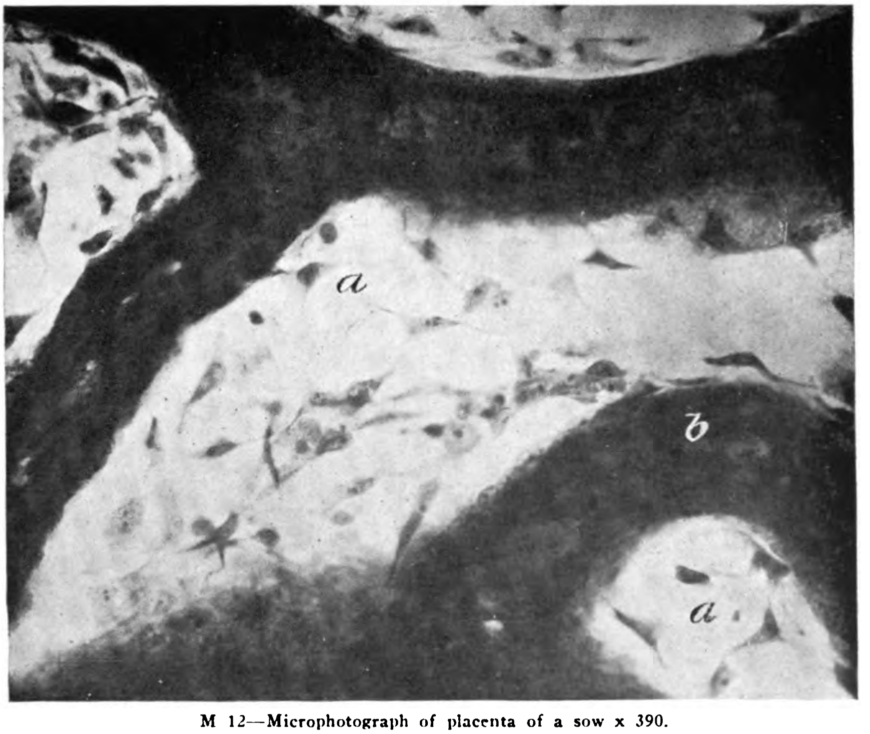
RETIFORM TISSUE is similar to areolar tissue, except that the fibrillae form a loose network instead of a close one.



M 10—Microphotograph of a portion of a section of pig-embryo x 490, illustrating embryonic connective tissue.



M 11—Microphotograph of a portion of a cross section of the ligamentum nuchae of an ox x 580.
a, areolar connective tissue; *b*, connective tissue corpuscles; *c*, extension of connective tissue separating bundles of fibres; *d*, transverse section of elastic fibre.



M 12—Microphotograph of placenta of a sow x 390.
a, myxomatous tissue cells; *b*, blood vessels.

ANOMALOUS CONNECTIVE TISSUE.

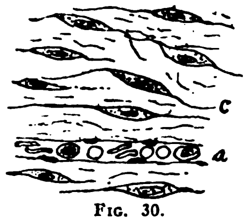


FIG. 30.
Embryonal connective tissue of an embryo-pig.
(a) connective tissue corpuscle; (a) capillary containing blood corpuscles.

Anomalous connective tissue is connective tissue which, while passing from the embryonal to the adult form, becomes arrested in its development, or has diverged from the normal mode of development. There are three varieties:

Vitreous.
Myxomatous.
Adenoid.

VITREOUS TISSUE (L. *vitrum,* glass) starts as a mass of cells, which secrete an albuminous intercellular substance, and then disappear. As the structure of this tissue cannot be seen with the microscope on account of its transparency, it is said to have no histological structure. It occurs as the vitreous humor of the eye.

MYXOMATOUS (Gr. μύξα, mucous; ὁμὸς, like), or mucoid tissue, starts as a mass of cells, which secrete a mucous-like intercellular substance, and branch, the branches joining branches of neighboring cells. The tissue consists of a network of branching cells, between which is a mucous-like secretion, found in the umbilical cord as the "jelly of Wharton" and in the placenta.

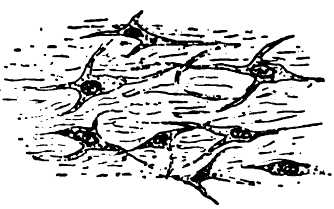


FIG. 31.
Myxomatous tissue obtained from a human umbilical cord.

ADENOID (Gr. αδὴν, a gland) tissue consists of cells which send out projections which join and form a network. In many instances the cells cannot be recognized, and appear as enlargements on the fibres of the network. *Lymphoid* tissue is adenoid tissue in the meshes of the network of which there are lymph corpuscles.

FIG. 32.
A portion of splenic pulp showing adenoid tissue (a) and lymphoid tissue (b).

Experiment 29. Take a tendon from the tail of a recently-killed rat, and notice that it is composed of bundles of fibres. Tease apart a fibre in a normal solution of sodium chloride on a slide, being careful while teasing to tease the fibre lengthwise, and examine with the low and then the high power. Notice the wavy fabrillae. Notice that they do not branch. Sketch.

Exp. 30. Take a fresh fibre and place it in a normal solution of sodium chloride for about fifteen minutes, then transfer to alcohol (95 per cent.) for ten minutes, water for one minute, haematoxylin for three minutes, water for thirty seconds, alcohol (95 per cent.) five minutes. Carefully place the fibre upon a slide, put upon it a drop of balsam and cover. Look for and sketch the connective tissue corpuscles.

Exp. 31. Stain by the Van Gieson method a longitudinal and a transverse section of a tendon. Sketch under the high power, connective tissue corpuscles, and fibrillae.

Exp. 32. Examine a stained section of a portion of an embryo, and sketch the embryonic connective tissue cells.

Exp. 33. Tease apart in a drop of normal saline solution on a slide a piece of the ligamentum nuchae of an ox. Notice the difficulty experienced in teasing it apart, and the elasticity of the fibres and fibrillae. Examine with the low and high power, and notice the distinct outlines and curves of the fibrillae. Look for branched fibrillae and cross-striations on the fibrillae. Sketch.

Exp. 34. Examine and sketch a stained cross-section of the ligamentum nuchae. Notice the shape of the sections of the fibrillae, and the network of areolar tissue containing connective tissue corpuscles, between, and holding together, the fibrillae. Sketch. If a cross section of the ligamentum nuchae is not available, cross sections of yellow fibrous tissue can be observed in stained sections of the spleen (or lymph glands).

Exp. 35. Stain with Van Gieson stain a section containing areolar and adipose tissue. Sketch under both powers.

Exp. 36. From a recently-killed animal obtain a small piece of the mesentery and spread upon a clean slide. Moisten with normal saline solution, cover and examine with the high power. Notice the membranous structure of areolar tissue. Look for adipose tissue. Sketch.

Exp. 37. Stain another piece of mesentery with silver nitrate, mount and examine. Notice the irreguar shaped clear spaces for the connective tissue corpuscles in the brown-stained membranous network.

Exp. 38. Stain a piece of mesentery with osmic acid. Measure the fat cells and sketch.

Exp. 39. Examine a piece of adipose tissue which has been in ether for twenty-four hours, and then stained with haematoxylin and eosin. Notice the cells with the protoplasm and the nucleus arranged as a layer against the cell wall. Sketch.

Exp. 40. Sketch a portion of retiform tissue as seen in a stained and mounted section of the spleen.

Exp. 41. Stain with haematoxylin and eosin and mount a transverse section of the umbilical cord or a vertical section of a placenta. Examine and sketch the jelly of Wharton.

Exp. 42. Examine the specimen used in Exp. 40 for adenoid tissue. Sketch.

CARTILAGE.

Cartilage is a more dense form of supporting tissue than the connective tissues. It is opaque, of a bluish-white appearance in thick slices, transparent in thin slices. It may be easily cut, and is flexible, firm and somewhat elastic. When allowed to dry it loses about three-fifths of its weight, showing that about 60 per cent. is water. In the embryo, cartilage is widely distributed. That which is replaced by bone as the embryo advances in its life history is termed *temporary cartilage,* and that which is not replaced by bone is termed *permanent cartilage.* In the embryo, cartilage consists of cells in contact with each other; but as the cartilage passes on to the adult form the cartilage cells increase in number and deposit the intercellular substance, so that in adult cartilage the cells and the intercellular substance are of equal importance. Cartilage is usually covered by a membrane termed the *perichondrium,* which is tough and vascular, affording protection and nourishment to the cartilage. Depending upon the structure of the intercellular substance, cartilage is divided into three varieties:

Hyaline cartilage.
White fibro-cartilage.
Yellow fibro-cartilage.

HYALINE (Gr. ὑάλινος, glassy) CARTILAGE occurs more widely distributed throughout the body than either of the other varieties, its chief localities being on the ends of bones, as articular and costal, in the nose and the trachea. It consists of cells imbedded in an intercellular substance termed the *matrix.* The matrix appears as a homogeneous substance, which has a glassy appearance, and in some instances appears to be fibrillated. The cells possess distinct cell walls, protoplasm, nuclei, and nucleoli. The cell is separated from the matrix by a capsule. The spaces in the matrix lined by the capsules are termed *lacunae,* which are occupied by the cells. In living or fresh cartilage, the cells fill the lacunae, while in prepared specimens they may not, due to the shrinkage of the cell caused by the reagents used during the preparation of the specimens. In a lacuna there may be one, two, three or four cells. One cell reproduces another, each of which reproduces another; thus at first there is one cell in the lacuna, then two, and finally four. After the cell has divided into two, one daughter cell may divide more rapidly than the other, which explains how it is that a lacuna may contain three cells. The capsules form the matrix, new capsules being formed around the newly-formed cells. Although articular and costal cartilages belong to the hyaline variety, there are some differences between them. Costal cartilage has a perichondrium; the articular has not. The cells of costal cartilage, as a rule, are larger than those of articular cartilage, and sometimes may contain oil globules in the protoplasm. The outermost cells of costal cartilage do not form a continuous layer, while those of

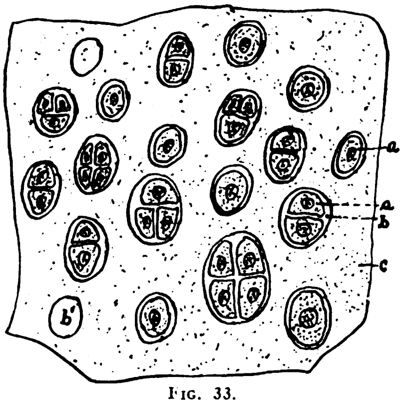


FIG. 33.
A slice of articular cartilage showing cartilage cells (*a*) contained in lacuna (*b*); the matrix (*c*); and a lacuna (*b'*) from which the cell was lost during the preparation of the specimen.

articular cartilage do. The matrix of adult costal cartilage appears to be split up into rods or fibrillae, while of articular cartilage it does not, although it may appear slightly fibrillated. The matrix of hyaline cartilage, in the aged, may become rigid and hard, due to a deposition of lime salts, the process being termed *calcification*, which is very different from ossification.

FIG. 34.
A portion of a section of the trachea showing hyaline cartilage.

FIG. 35.
A portion of a section of costal cartilage showing cells containing globules of fat.

WHITE FIBRO-CARTILAGE is similar to hyaline cartilage, except that the matrix has been invaded by white fibrous connective tissue. It is found as interarticular cartilage of the intervertebral discs, and of the temporo-maxillary articulation, and lining grooves on the surface of bones.

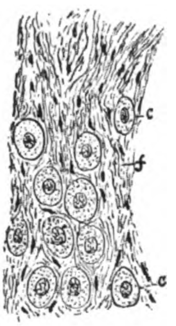


FIG. 36.
White fibro-cartilage from the intervertebral disc.
(*c*) cartilage cells; (*f*) white fibrous connective tissue.

YELLOW FIBRO-CARTILAGE is similar to hyaline cartilage, except that the matrix has been invaded by yellow fibrous connective tissue. Its chief localities are the external ear and the epiglottis.

Experiment 43. With a sharp razor moistened with saline solution cut several thin slices of articular cartilage. Put them in normal saline solution on a slide, cover, and examine with the high power. Notice the cells singly and in groups. Look for empty lacunae. Sketch.

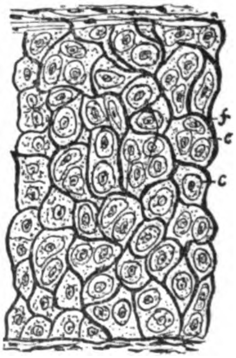


FIG. 37.
Yellow fibro-cartilage from the ear of a cat.
(*c*) cartilage cells; (*f*) yellow fibrous connective tissue.

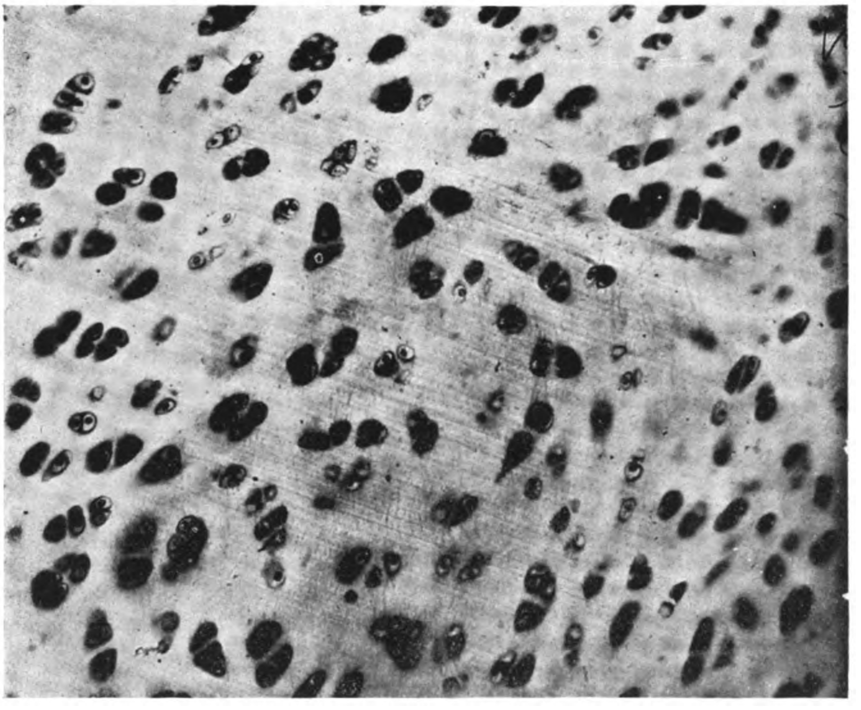
Exp. 44. Compare stained specimens of articular cartilage, preferably cut perpendicular to the surface, and of costal cartilage cut transversely. Sketch both, showing main points of difference.

Exp. 45. Stain and mount a section of an intervertebral disc. Examine with the high power, and notice the cells and the matrix. Notice especially the white fibrous tissue in the matrix. Sketch.

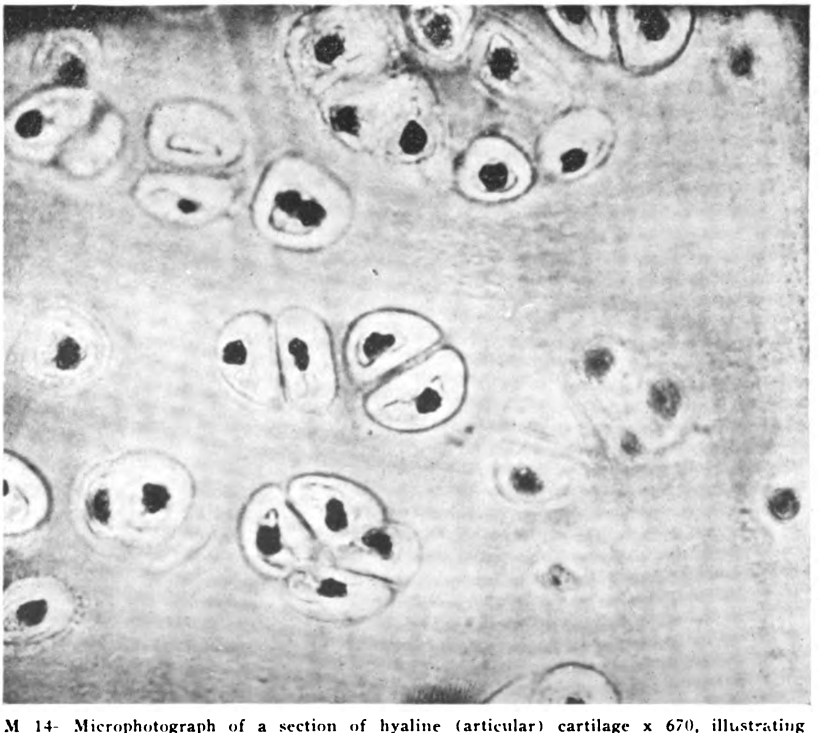
Exp. 46. Examine a stained and mounted specimen of the external ear or of the epiglottis. Notice and sketch the cells and the matrix containing yellow fibrous tissue.

BONE.

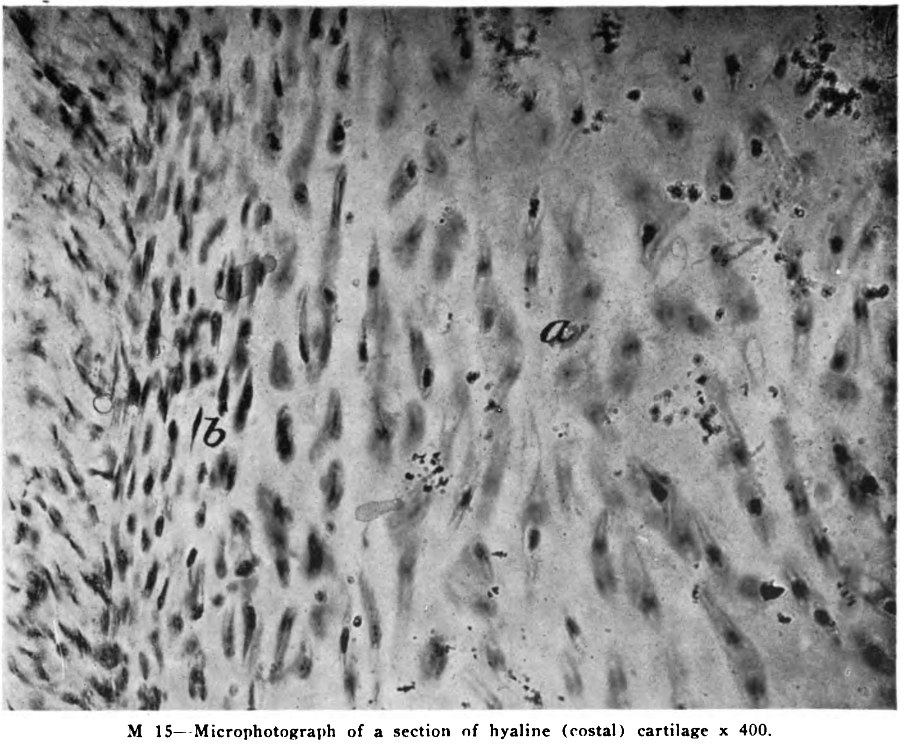
Bone, the hardest of the supporting tissues, is second in hardness of all the tissues of the body, enamel being the hardest. In the fresh condition it is covered by a membrane termed the *periosteum*, which covers the bones of the body except



M 13 Microphotograph of a section of hyaline (articular) cartilage x 152, illustrating cartilage cells and matrix.

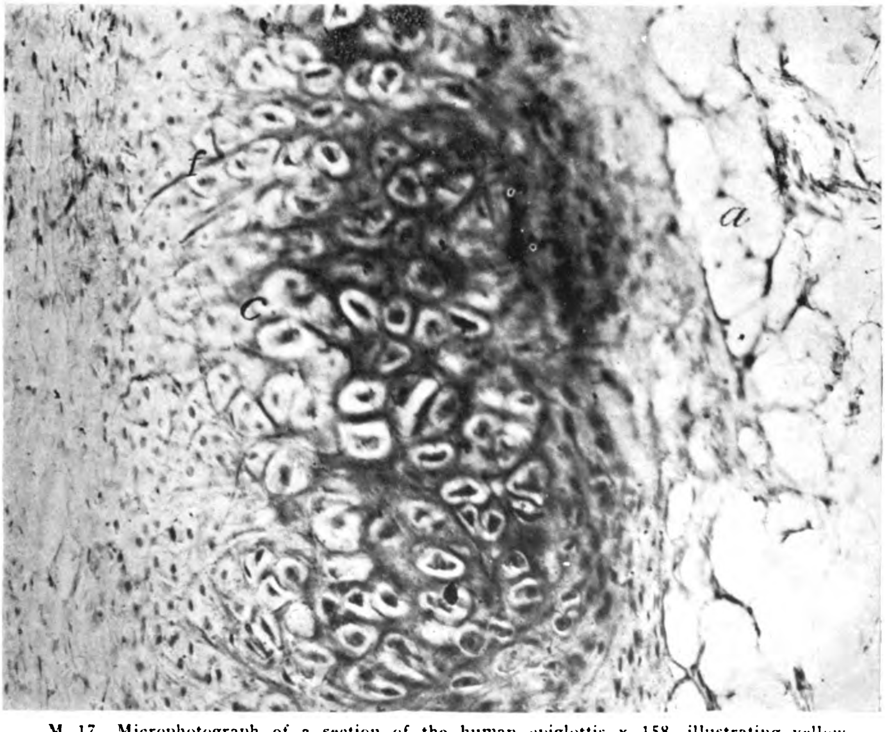


M 14- Microphotograph of a section of hyaline (articular) cartilage x 670, illustrating cartilage cells, singly and in characteristic groups, the lacunae and the matrix.



M 15—Microphotograph of a section of hyaline (costal) cartilage x 400.
a, cartilage cells showing characteristic shape, and in some cases oil globules in protoplasm; *b*, perichondrium.

M 16—Microphotograph of a section of white fibro-cartilage x 152.



M 17 Microphotograph of a section of the human epiglottis x 158, illustrating yellow fibro-cartilage.

a. adipose connective tissue; *c*. cartilage cells; *f*. yellow fibrous tissue.

at their articular ends. In the fresh state it has a pinkish hue, due to the small blood-vessels which permeate its substance, and possesses flexibility and elasticity. Dry bone is opaque, white, and somewhat brittle. Bone consists of a cellular portion, termed the *bone corpuscles,* and an *intercellular substance.* The intercellular portion predominates and gives to bone its characteristic physical properties, and consists of a foundation of organic matter, in which are deposited mineral salts, the chief of which is calcium phosphate. About one-third of bone is organic matter, the remaining two-thirds inorganic.

The chemical composition of bone, according to Berzelius is:

Organic matter,		33.30%
Inorganic matter—		
Calcium phosphate,	51.04%	
Calcium carbonate,	11.30%	
Calcium fluoride,	2.00%	
Magnesium phosphate,	1.16%	
Sodium carbonate and sodium chloride,	1.20%	
		66.70%
		100.00%

By allowing bone to remain in dilute solution of a mineral acid, as hydrochloric or nitric, for twenty-four hours or longer, the mineral matters will be dissolved and the organic matter left. A bone treated in this manner will retain its original shape, but instead of being hard and resisting it will be flexible and elastic; so flexible that it can be tied into a knot, and when untied it assumes its original shape, due to its elasticity. If a bone be heated, without access of air to the bone, the organic matter will be decomposed while the mineral matter will not be affected. The bone thus treated retains its shape, but appears as a dark, honey-combed mass, which readily crumbles, breaking up into particles, which are hard and brittle. Thus it is evident that the characteristic properties of bone depend upon the organic *and* the inorganic substances present in a definite proportion.

The intercellular substance is arranged in layers termed lamellae, and according to the arrangement of the lamellae bone is divided into two varieties, *compact* and *cancellous.* In the former variety the lamellae are arranged in layers closely applied to each other. In the latter variety the lamellae are arranged as a sponge-like network, in consequence of which this variety of bone is also termed *spongy* bone. Compact bone occurs in the shafts of the long bones and in the tables of the skull bones. Cancellous bone occurs to a small extent in the shafts of the long bones, in the extremities of the long bones, in the skull bones between the tables, and in the centre of the ribs and inferior maxilla.

On studying the structure of the shaft of a long bone it will be found to contain a canal running lengthwise in its centre, termed the *medullary canal.* Encircling the canal are layers or lamellae of bone, their long axis parallel with the long axis of the bone. The system of lamellae thus formed is termed the *perimedullary system.* Next to the perimedullary system of lamellae, there is a comparatively small amount of *cancellous* bone. At the periphery of the bone there are several layers of bone, termed the *circumferential* system of lamellae. The portion of bone between the circumferential system and the cancellous bone consists of two sets of lamellae, the *Haversian* and the *interstitial* systems. The

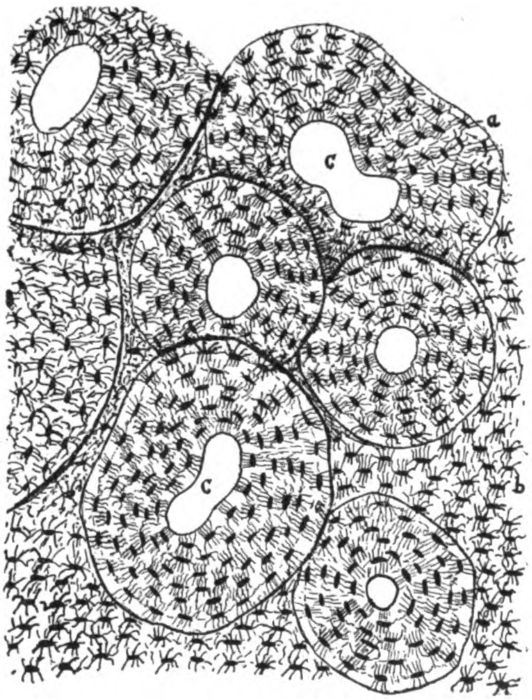


FIG. 38.
A porton of a transverse section of the femur.
(*a*) an Haversian system; (*b*) interstitial system; (c) Haversian canals.

Haversian systems consists of canals which run lengthwise of the bone and communicate with one another by means of branches, surrounded by lamellae of bone. The interstitial systems consist of lamellae which are more or less parallel to the lamellae of the circumferential system, and fill the interstices between neighboring Haversian systems.

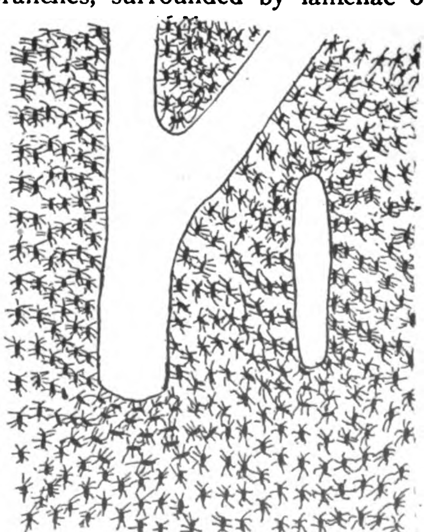


FIG. 39.
A portion of a longitudinal section of the femur showing an Haversian canal cut lengthwise and dividing into branches.

AN HAVERSIAN SYSTEM consists of a central canal, termed the *Haversian* canal, which, when seen in transverse section, appears as a round opening. It varies in diameter from $\frac{1}{1000}$ to $\frac{1}{250}$ inch, and in living bone contains marrow, blood-vessels and nerves, but in prepared specimens of bone they usually appear dark, on account of containing dirt obtained during their preparation. Around the canal are concentrically arranged lamellae of bone, about six in number. Between the lamellae are small irregular-shaped cavities, termed *lacunae,* from which little canals, termed *canaliculi,* extend. The canaliculi of one lacuna branch and join those of neighboring lacunae. The canaliculi of the outermost row of lacunae of one Haversian system communicate with the canaliculi of the outermost row of a neighboring Haversian or interstitial system. The lacunae nearest to the Haversian canal, communicate with it by means of canaliculi. In living bone the lacunae are occupied by the cellular elements of the tissue, the *bone corpuscles,* which send protoplasmic projections into the canaliculi. By means of this arrangement, the bone corpuscles nearest to the canal can absorb nourishment from the canal and transmit it throughout the Haversian system. Lacunae and canaliculi exist also in the other systems, the perimedullary circumferential, and interstitial.

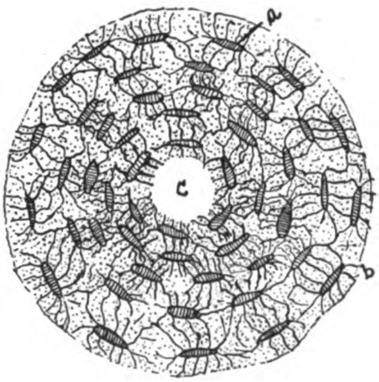


FIG. 40.
An Haversian system highly magnified showing the canal (*c*) surrounded by six lamellae, with lacunae (*a*) and canaliculi (*b*).

CANCELLOUS BONE consists of lamellae arranged in plates; between the lamellae of the plates there are lacunae, with their canaliculi. The plates join each other, enclosing irregular-shaped spaces.

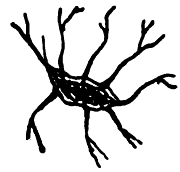


FIG. 41.
A bone corpuscle.

The *periosteum* is composed of fibrous tissue arranged in two layers—an outer as a dense network, and an inner as a loose network. In the periosteum blood-vessels ramify, the ramifications extending into the substance of the bone to the Haversian canals. On the inner surface of the periosteum of young bones there is a layer of bone-forming cells termed *osteoblasts.* Some of the fibres of the periosteum extend for a short distance into the substance of the bone, and are termed the *perforating fibres of Sharpey.*

Experiment 47. Examine with the unaided eye, a cross-section of a long bone. Notice the medullary canal in the centre, the zone of cancellous bone, the narrow, compact zone between the cancellous bone and the canal, and the mass of dense bone beyond the cancellous. Saw through the head of a long bone, and notice the sponge-like arrangement of the cancellous bone. Notice the weight of the piece sawed off, and compare it with the weight of compact bone. With a fresh bone, notice the yellow marrow in the medullary canal, and the red marrow in the cancellous bone. Observe the pinkish hue of a fresh bone, and the periosteum.

Exp. 48. Prepare a cross-section, and one longtitudinal, of bone in the following manner: Saw as thin a section as possible, which rub on a fine file to the thickness of ordinary cardboard, and then rub on an oil stone until as thin as tissue paper, or until printed letters may easily be seen through it. Mount in glycerin, fixing the cover-slip with cement. If it be desired to mount the specimen in balsam instead of glycerin, after it has been rubbed to the proper thinness, put it into a vessel containing dilute acetic acid for thirty seconds, then into alcohol (95 per cent.) for three minutes, then on the slide; cover with balsam and a cover-slip. The section may be stained by placing it, after having rubbed it down to desired thinness, into a solution of fuchsin for 24 hours; then after being rinsed again with water, it should be placed in 95 per cent. alcohol 2 minutes, dried with bibulous paper, and mounted with balsam and cover-slip.

Exp. 49. In the specimen of a cross-section of bone, notice and sketch, under the low power, the systems which are seen. Sketch under high power an Haversian system, and measure two Haversian canals. Notice the lacunae and canaliculi. Sketch portions of the other systems.

Exp. 50. Examine the longitudinal section of bone. Notice the Haversian canals running lengthwise, giving off branches. Notice the disposition of the lamellae and lacunae along the canals. Sketch.

MARROW.

Contained in the canals, medullary and Haversian, of compact bone, and in the enclosed spaces of cancellous bone, there is a substance termed *marrow,* of which there are two varieties, *yellow* and *red.* In the human body the yellow variety occurs in the canals of compact bone, and the red variety in the spaces of cancellous bone.

Yellow marrow contains fat, a small amount of connective tissue, and a few blood-vessels. It is of a pale yellow color, due to the presence of the fat, which is about 96 per cent. of the marrow, 3 per cent. of the remaining 4 per cent. being water.

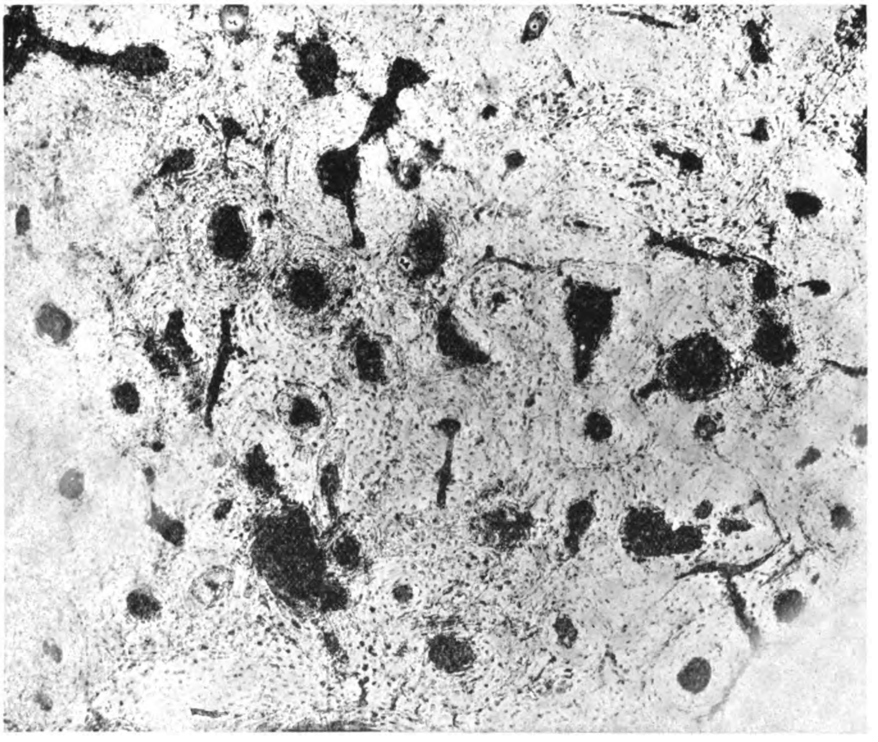
FIG. 42.
Red marrow from the rib of a dog.
(a) myelocyte or marrow cell; (b) erythroblast; (c) myeloplax or giant cell with a large irregular shaped nucleus; (c') a myeloplax with several nuclei.

Red marrow consists of a loose network of connective tissue and capilliaries, containing within its meshes connective tissue corpuscles, and three kinds of cells, which are the marrow cells, the giant cells, the colored blood-corpuscle-forming cells.

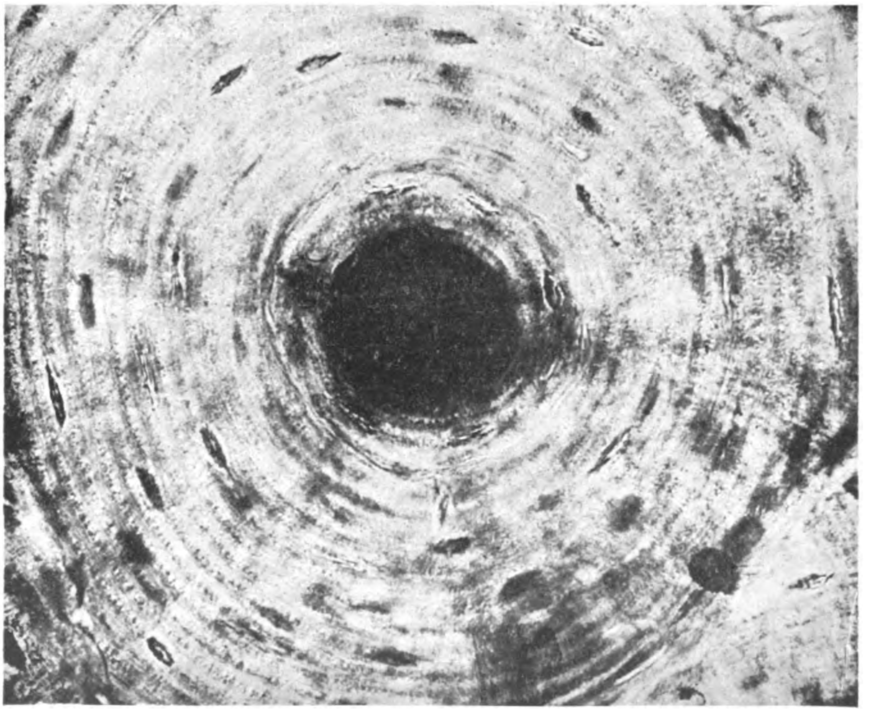
The *marrow cells* or *myelocytes* are similar to the colorless corpuscles of the blood.

The *giant cells, myeloplaxes* (Gr. μυελὸς, piece; πλὰξ, marrow) *of* **Robin,** are large, irregular-shaped masses, some of which contain several nuclei, while others contain one large irregular-shaped nucleus.

The third kinds of cells, termed *erythroblasts* (Gr. ερυθρὸς, red; βλαστέω, to produce), are similar in appearance to the nucleated colored corpuscles of the

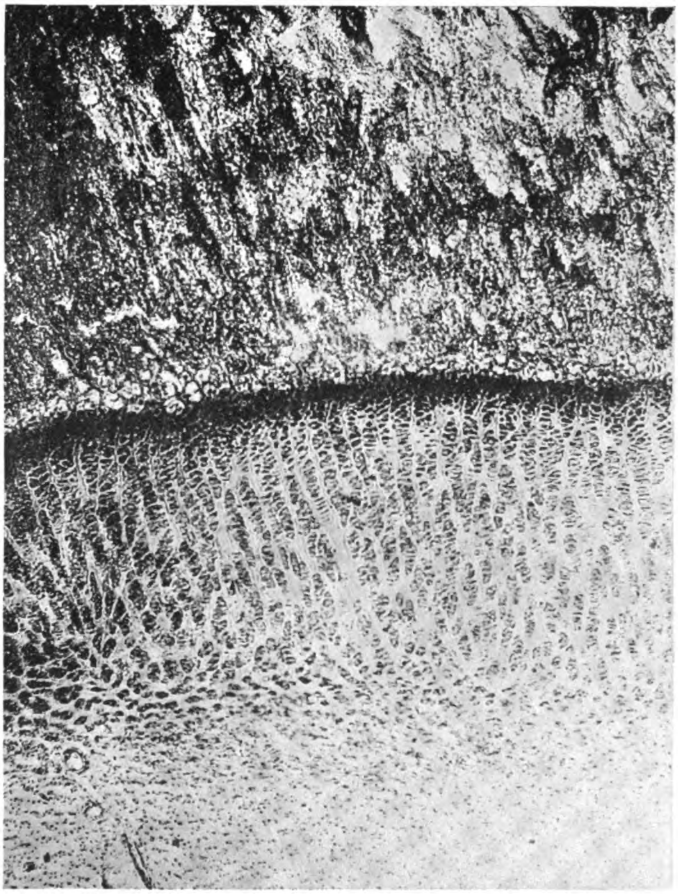


M 18 -Microphotograph of a section of human bone x 5, illustrating Haversian and interstitial systems of lamellae.

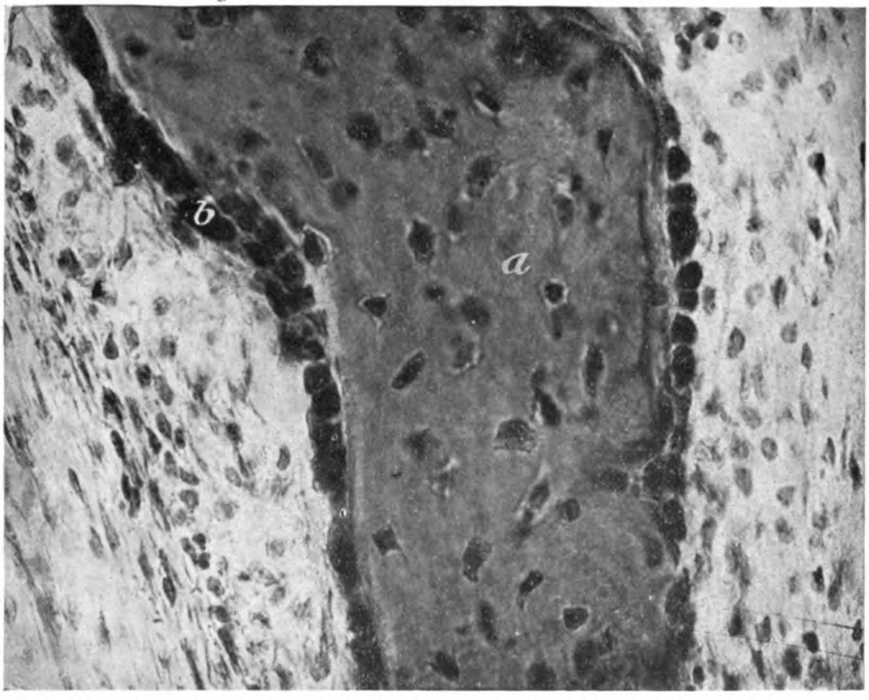


M 19—Microphotograph of a portion of a transverse section of a human bone x 290, illustrating an Haversian system of lamellae.

M 20—Microphotograph of a section of cancellous bone x 45.
a, lamellae; *b*, red marrow.



M· 21—Microphotograph of a section of developing bone of a kitten x 45, illustrating rearrangement of the cartilage cells, secondary areolae, and new bone.



M 22—Microphotograph of developing bone of the head of a pig-embryo x 490. *a*, newly formed bone showing bone corpuscles; *b*, osteoblasts.

embryo. They reproduce others termed ***normoblasts,*** which lose their nuclei to become colored blood-corpuscles. Red marrow contains about 75 per cent. water and about 25 per cent. solids. Of the solids are albumin, salts, and fat.

Experiment 51. Put a small piece of yellow marrow into a drop of normal saline solution on a slide, and tease it apart with teasing needles. Examine, and notice the numerous globules of fat, and the connective tissue reticulum.

Exp. 52. In the same manner as in Exp. 51, prepare some red marrow obtained from a rib of a recently killed animal. Look for, sketch and measure the marrow cells, giant cells, and small nucleated cells.

Exp. 53. Stain a cover-slip smear of the marrow obtained from the rib of a recently killed animal, by eosin-methylene blue method. Examine and sketch.

THE DEVELOPMENT OF BONE.

All of the bones of the body are developed from cartilage, except the bones of the cranial vault, of the face and the inferior maxilla.

Intracartilaginous or Endochondral Ossification.

Cartilage does not *become* bone, but is removed and bone is formed in its stead. The cartilage which is to be ossified is of the hyaline variety, and, being embryonal, is composed of numerous cartilage cells and a small amount of cartilage matrix. Surrounding the cartilage there is a membrane termed the *perichondrium,* which consists of three layers—an outer dense fibrous, a middle loose fibrous which is vascular, and an inner layer composed of bone-forming cells, the *osteoblasts.* An osteoblast is an irregular, generally quadrilateral-shaped, cell, of which the protoplasm appears granular, the nucleus oval. The cycle of changes which take place during ossification may be briefly summarized as follows:

1. Stage of *rearrangement* of the cartilage cells.—The cartilage cells at the centre of ossification become larger, somewhat flattened and arranged in rows, the rows usually running parallel with the long axis of the cartilage (Fig. 44, *b*).

2. Stage of *vascularization.*—Synchronous with the first stage, the periosteum sends inshoots into the cartilage, which consist of the inner and middle periosteal layers. The inshoots divide and subdivide, in consequence of which the cartilage is permeated by the vascular channels thus formed, and is said to be vascularized. A section of one of the channels would show that it contains capillaries, areolar tissue, leucocytes, and osteoblasts in the areolar tissue and

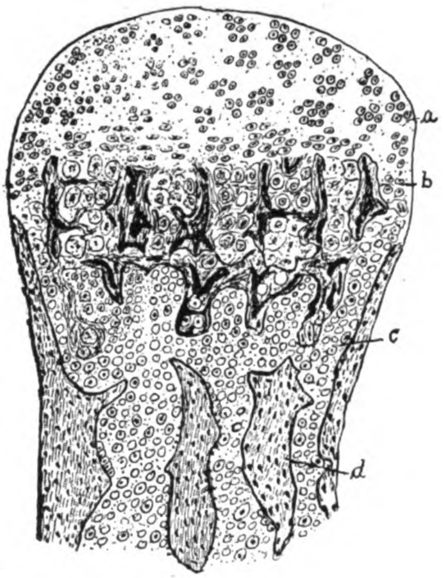


FIG. 43.
A portion of developing bone from child's finger. (*a*) cartilage; (*b*) region of primary and secondary areolae; *c*, vascular channels containing besides blood corpuscles, osteoblasts; (*d*) newly formed bone.

lining the channel (Fig. 44, *c*). In the long bones, one of the channels permeates the central core of the shaft to become the future medullary canal.

3. Stage of *granularization* of the matrix.—After the cartilage cells have become enlarged and arranged in rows the matrix becomes granular in appearance (Fig. 44, *d*).

4. Stage of *fibrillation* of the matrix.—The matrix becomes fibrillated, the fibrillae enclosing the cells in quadrilateral shaped spaces.

5. Stage of *primary areolae* of Sharpey.—The spaces formed in stage 4 become larger, the partitions thicker and the cartilage cells appear to be degenerating. The spaces are now termed primary areolae (Fig. 44, *e*).

6. Stage of *irruption*.—The vascular channels by this time having reached the primary areolae cause disintegration of some of the partitions and pass into the large spaces formed, which are termed *secondary areolae*. A section of developing bone at this stage would show the remains of the fibrous partitions very similar in appearance to pieces of scroll work, and the spaces to contain blood corpuscles, osteoblasts and connective tissue (Fig. 44, *f*).

7. Stage of *ossification of the partitions*.—Osteoblasts from the spaces penetrate into the remains of the fibrous partitions, form bone, and are caught between the lamellae to become bone corpuscles (Fig. 44, *g*). *In this manner the remnants of the partitions are ossified and exist in fully-developed bone as the interstitial systems.*

8. Stage of *formation* of the *Haversian* and the perimedullary systems.—The osteoblasts arrange themselves as a layer between the contents of the canals and the trabeculae of bone formed in stage 7, and deposit successive layers or lamellae of bone, some of the cells becoming caught between the lamellae become bone corpuscles. In this way the Haversian and perimedullary systems are formed (Fig 44, *h*). Why the osteoblasts do not continue to lay down lamellae until no canal be left is not known. It may be due to the following factors:

1. Owing to the fact that many of the osteoblasts are left between the lamellae to become bone corpuscles, the number of osteoblasts is continually being

diminished, the diminution being in excess of the reproduction, *if* the cell reproduces while performing its bone forming function.

2. By the time the last lamella is deposited the remaining osteoblasts, if there be any, may be so weakened by their labor as to be unable to form more bone.

3. The increasing amount of pressure in the canals as they become smaller may become too great for the osteoblasts to overcome.

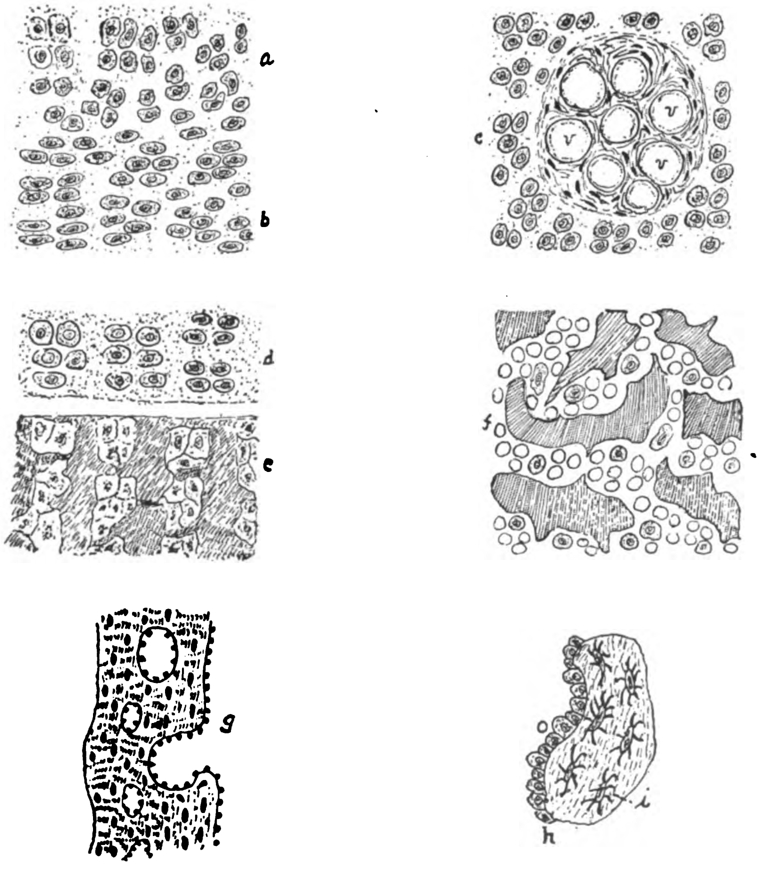


FIG. 44.
Portion of the specimen used in Fig. 43, showing some of the stages in the development of bone from cartilage.
(*a*) hyaline cartilage; (*b*) state of rearrangement of the cartilage cells; (*c*) stage of vascularization showing vascular channel with blood vessels (*v*); (*d*) stage of granularization of the matrix; (*e*) stage of primary areolae; (*f*) stage of irruption; (*g*) stage of ossification; (*h*) newly formed bone showing bone corpuscles (*i*) and osteoblasts (*o*).

In the long bone, ossification, near the central core of the shaft, may pass through the seventh stage and stop, leaving a small area of cancellous bone. In the same way the cancellous bone in the extremities of long bones is formed. The bone grows lengthwise, by means of the cartilaginous plate between the shaft and the extremities of long bones (epiphyseal cartilage).

During the endochondral ossification, ossification also goes on at the exterior of the bone termed *periosteal.* The osteoblasts of the perichondrium deposit lamellae of bone around the circumference of the shaft, forming the circumferential system of lamellae.

Intramembranous ossification is very similar to the sub-periosteal ossification. A membrane which is to become bone consists of two dense fibrous layers, between which is a loosely-arranged fibrous network. Among the fibres are osteoblasts which deposit lamellae, some of them becoming caught between the lamellae remain as bone corpuscles. In the dense layers compact bone is formed; in the loose fibrous network cancellous bone is formed. The fully-developed bone consists of two tables of compact bone, between which is cancellous bone, the *diploe.*

Experiment 54. Stain a section of a decalcified developing bone. Examine and sketch the different stages of ossification shown by the specimen.

Dentine, the remaining variety of supporting tissue, will be considered in the article on the teeth.

CHAPTER V.

MUSCULAR TISSUE.

Widely distributed throughout the body there is a set of tissues the function of which is to perform the various movements of the body. This set of tissues is known as *muscle*. There are two varieties of muscle:

1. The first variety includes the muscles which are under the control of the will, and are termed the *voluntary muscles*.

2. The other variety includes the muscles which are not under the control of the will, and are termed the *involuntary muscles*.

VOLUNTARY MUSCLE.—The chief muscles of this variety are the skeletal and the diaphragm. Enveloping a voluntary muscle there is a sheath composed of areolar connective tissue termed the *epimysium*. The sheath sends inshoots into the muscle, termed *perimysium*, which divide the muscles into bundles of fibres termed the *fasciculi*. From the perimysium projections extend into the fasciculi, and divide them up into small, irregular-shaped usually quadrilateral, compartments, each of which is occupied by a muscle fibre. The inshoots from the perimysium are known collectively as *endomysium*.

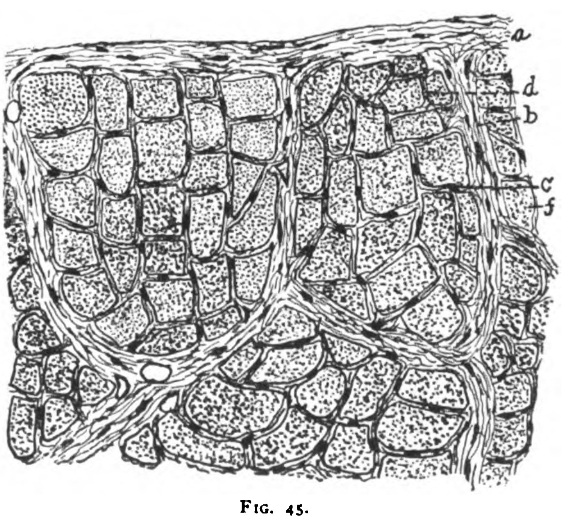


FIG. 45.
A transverse section of voluntary muscle.
(*a*) epimysium; (*b*) perimysium; (*d*) endomysium; (*c*) connective tissue corpuscles; (*f*) muscle fibre.

An isolated voluntary muscle fibre is round, about one to one and one-half inch long and about $\frac{1}{150}$ inch in diameter. In a short muscle the fibres may be as long as the muscle, but in long muscles the fibres are dovetailed together to make the desired length. The fibre is a long cell, pointed at its ends, the protoplasm of which is modified in order to perform its function, which is *contraction*. The cell wall or fibre sheath is termed the *sarcolemma*. The *nucleus* is in the protoplasm just beneath the sarcolemma. The protoplasm presents the appearance as if traversed transversely by alternating light and dark bands, on account of which appearance this variety of muscle is also termed *cross-striated* muscle. Midway be-

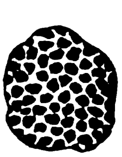
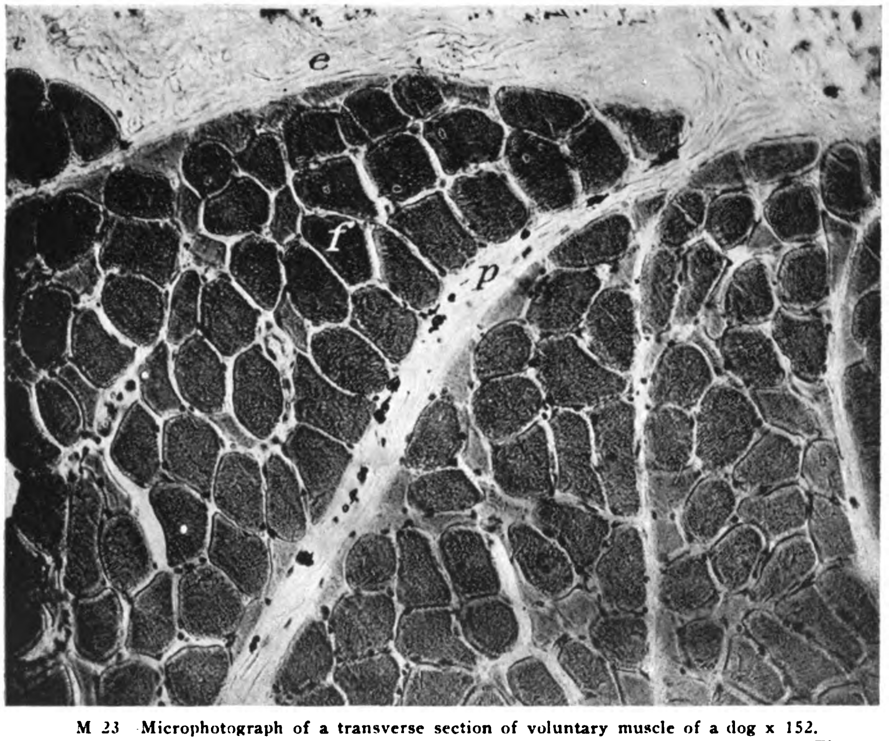


FIG. 46.
Transverse section of a voluntary muscle fibre highly magnified shewing areas of Cohnheim.

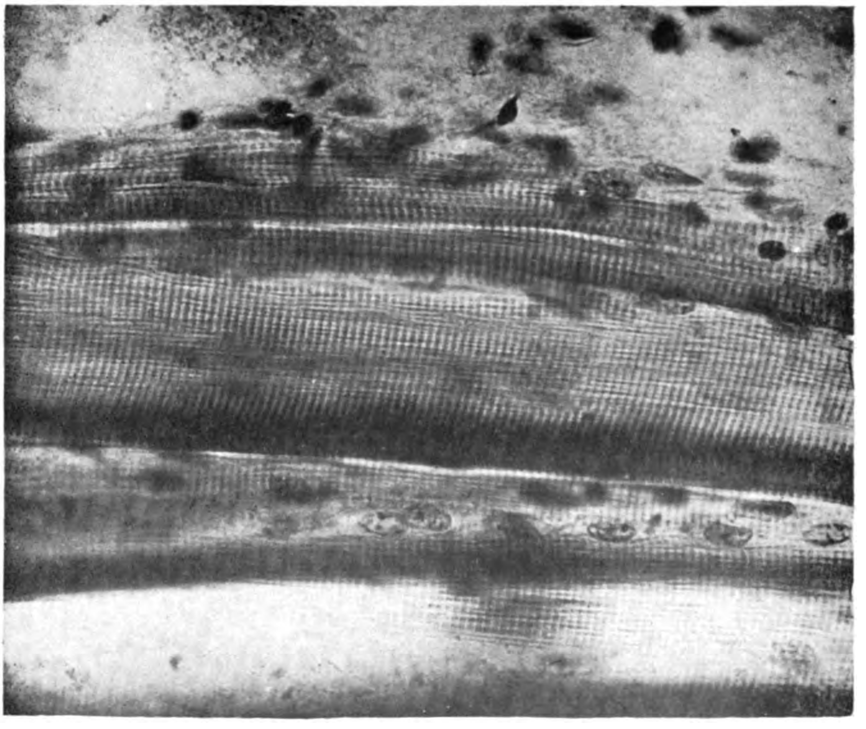
tween the dark bands, each clear region is traversed by an interrupted granular-looking line, termed the ***intermediate disc,*** or the ***membrane of Krause.*** The portions of the light band between the intermediate discs and the dark bands are termed the *lateral discs*. The dark bands are composed of dark masses, with narrow, clear streaks between them. The clear substance also occurs in the lateral discs and between the particles of which the membranes of Krause are composed. Running lengthwise of the fibre appear parallel streaks which indicate that the fibre is made up of fibrillae. In regard to the structure of the protoplasm of the muscle fibres, different theories have been advanced. According to Rollett's theory the dark-appearing portions of the protoplasm are *contractile* masses, parallel to each other and arranged lengthwise in the fibre.

FIG. 47.
Voluntary muscle fibres, from a fresh specimen teased apart, showing cross striation; longitudinal fibrillation; nucleus (*n*) and sarcolemma (*s*).

These masses are spindle-shaped and taper at their ends, terminating in enlargements. The enlargements constitute the membrane of Krause (the intermediate disc); the bodies of the masses of contractile substance constitute the dark bands. Filling up the spaces left between the contractile masses is a semi-fluid transparent substance, termed the *sarcoplasm*. It seems more probable that the fibre is made up of fibrillae separated from each other by a semi-fluid substance termed sarcoplasm, which fibrillae are made up of cubes of granular substance termed contractile masses, separated from each other above and below by the transparent sarcoplasm. Midway between the cubical masses occur small granular particles which with those of the neighboring fibrillae make up the intermediate discs. Thus, according to either theory, the protoplasm appears to be composed of contractile *fibrillae,* corresponding to spongioplasm, and a semi-fluid substance, *sarcoplasm,* corresponding to hyaloplasm. On cross-section of a fibre, dark areas



M 23 Microphotograph of a transverse section of voluntary muscle of a dog x 152.
e, epimysium; *p*, perimysium; *f*, transverse section of muscle fibre in a fasciculus. The endomysium is shown between the fibres, containing connective tissue corpuscles and sections of capillary blood vessels.



M 24—Microphotograph of a portion of a longitudinal section of a tadpole x 490, illustrating longitudinal sections of voluntary muscle fibre, their cross striations and nuclei, and the connective tissue corpuscles of the endomysium.

are seen, which are separated by clear substance. The areas are the *areas of Cohnheim* and correspond to cross-sections of the fibrillae, the intervening clear substance being the sarcoplasm. The fibres of voluntary muscle do not branch, as a rule, an exception being some of the fibres of the tongue and of the eye. The *tendons* are continuous with the muscles, the sarcolemmae becoming blended with the fibrous tissue of the tendon, and the areolar tissue septa of muscle with those of the tendon, and the epimysium with the *peritendineum,* the connective sheath of the tendon. The *blood supply* to voluntary muscle is large. The arterioles penetrate the epimysium, extend into the muscle with the perimysium and terminate in the endomysium as a capillary network around the muscle fibres. The veins arise from the capillary network and pass from the muscle in the same manner as the arteries enter. The lymphatics arise in the clefts in the fibrous connective tissue of the endomysium, perimysium and epimysium. The *nerves* which go to voluntary muscle are of the medullated variety and terminate beneath the sarcolemma as motor *end-plates.*

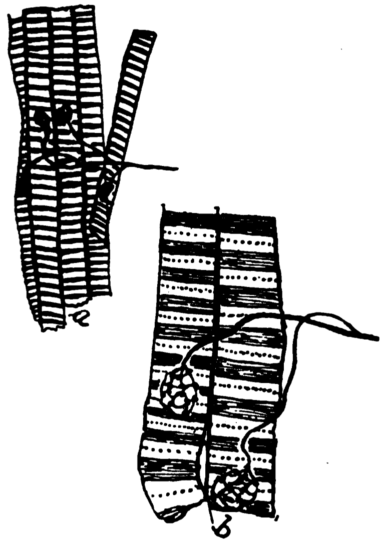


FIG. 49.
Voluntary muscle fibres containing motor end plates.
(a) low power; (b) high power.

INVOLUNTARY MUSCLE.—This variety occurs widely distributed throughout the body, existing in the alimentary canal, blood-vessels, ureters, bladder, uterus, etc. It consists of bundles of fibres, the bundles being held together by means of areolar tissue and ramifying blood-vessels. The fibres are spindle-shaped cells, each having a cell wall composed of a delicate homogeneous sheath. In the protoplasm is an elongated nucleus the long axis of which is parallel with the long axis of the cell. The neighboring cells are held together by a small amount of cement substance. They are about $\frac{1}{400}$ inch long and $\frac{1}{4000}$ inch in diameter. In transverse sections of involuntary muscle the fibres appear

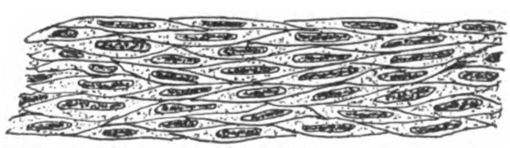


FIG. 51.
A portion of the circular layer of the muscular coat of the small intestine of a cat, showing involuntary muscle fibres cut lengthwise in situ.

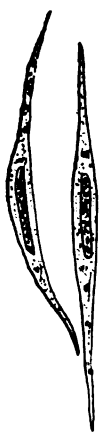


FIG. 50.
Isolated involuntary muscle fibres obtained by teasing apart a portion of a piece of a rabbit's intestine after having immersed it in Muller's fluid for twenty-four hours.

usually as irregular quadrilateral shaped areas of different sizes. The small areas appear homogeneous and represent sections of the tapering ends of the fibres; the large areas have a dark spot in the centre and represent sections of the fibres through the nucleus.

FIG. 52.
A portion of the longitudinal layer of the muscular coat of the small intestine of a cat, showing involuntary muscle fibres cut transversely. It will be noticed that some of the sections shew nuclei while others do not.

CARDIAC MUSCLE.—The muscle of the heart belongs to the involuntary variety of muscle, although in structure it resembles the voluntary variety in some respects. The fibres are usually short, cross-striated and branched. The nucleus of a fibre is in the centre of the protoplasm. The fibres have sarcolemmae, not so well marked as the sarcolemmae of voluntary muscle fibres.

The blood-vessels to involuntary muscle form a capillary network around the bundles of fibres. Lymphatics arise in the areolar tissue between the bundles. The nerves are of the non-medullated variety. They form a plexus between the layers of muscle, from which fibrillae extend between the bundles of fibres and possibly to the fibres.

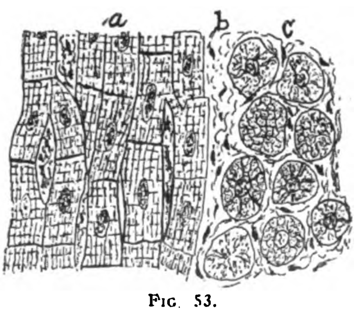


FIG. 53.
A portion of a section of the heart showing cardiac muscle fibres cut lengthwise (*a*) and transversely (*c*) held together by areolar connective tissue (*b*).

Experiment 55. Tease apart a small piece of a fresh skeletal muscle which has been in 35% caustic potash solution for 1 hour; cover and examine. Look for fibres showing cross-striations and sarcolemmae. Notice the fibrillation lengthwise. Sketch.

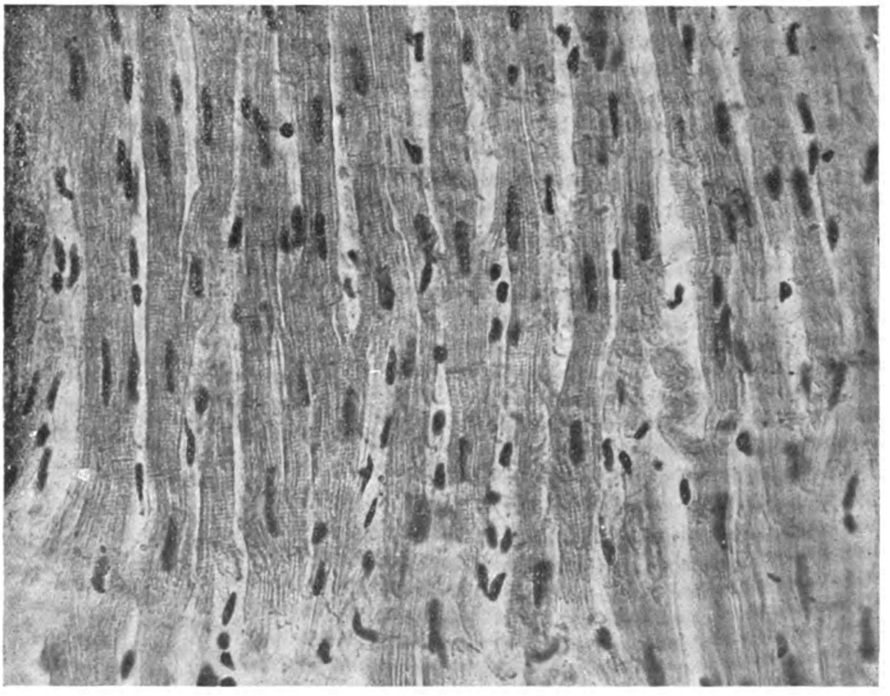
Exp. 56. Examine the voluntary muscle of a longitudinal section of a tadpole, the specimen having been stained with haematoxylin and eosin. Look for cross striations and nuclei. Sketch.

Exp. 57. Examine a cross-section of voluntary muscle which has been stained as in Exp. 56. Notice the epimysium, perimysium, and endomysium, and the shape of the sections of fibres. Sketch. Measure two cross-sections of fibres.

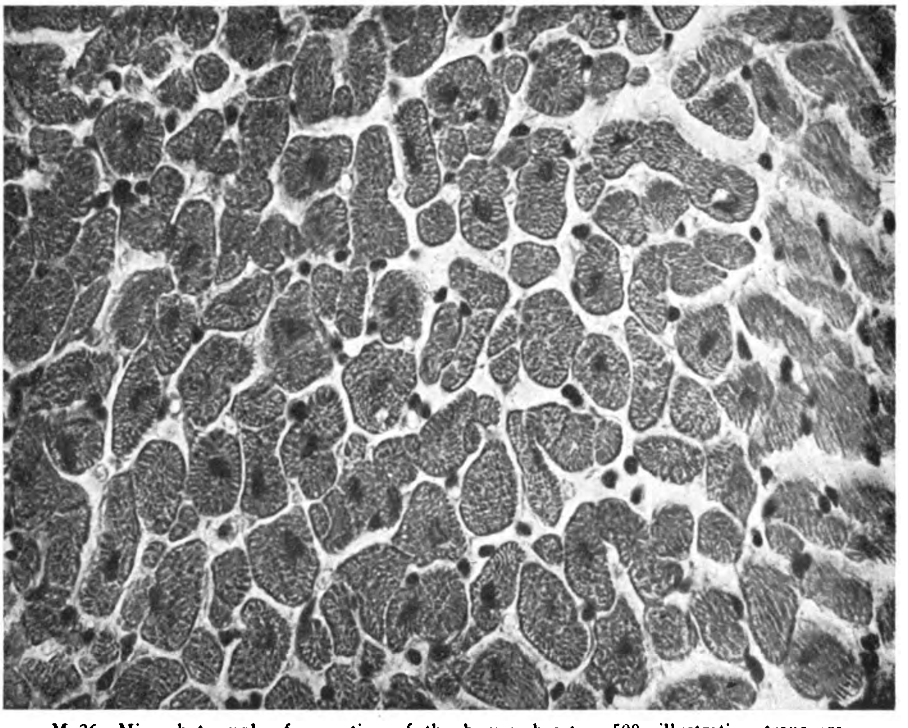
Exp. 58. Gently tease apart, in a drop of glycerin on a slide, a piece of voluntary muscle, the arteries of which have been injected. Examine with the low and then with the high power. Sketch.

Exp. 59. Examine a prepared specimen of voluntary muscle, showing the termination of nerve fibres in the muscle.

Exp. 60. From a piece of intestine of a rabbit or frog, which has been in a dilute solution of potassium bichromate for twenty-four hours, tear off shreds, working from the outer surface. Tease apart in a drop of glycerin or weak saline solution on a slide; cover and examine. Look for the spindle-shaped involuntary muscle fibres; notice the nuclei. Sketch and measure.



M 25—Microphotograph of a section of a human heart x 300, illustrating the cross striations and branching cardiac muscle fibres.



M 26—Microphotograph of a section of the human heart x 500, illustrating transverse sections of cardiac muscle fibres.

Exp. 61. Examine the specimen of the rabbit's bladder or ureter used in Exp. 24. Look for involuntary muscle fibres cut longitudinally and transversely. Sketch.

Exp. 62. Tease apart a small piece of the heart muscle, which has been in 35% caustic potash solution for 1 hour, on a slide. Add a drop of haematoxylin solution, cover and examine. Look for cross striations, nuclei, and branching fibres. Sketch.

Exp. 63. Stain a section of the heart by the Van Gieson method. Examine under both powers, and sketch.

CHAPTER VI.

NERVOUS TISSUE.

Nervous tissue consists of three parts:

1. Nerve cells for generating or modifying impulses.
2. Nerve fibres for conveying impulses.
3. Neuroglia and connective tissue framework.

THE NERVE CELLS are found in the gray matter and ganglia of the nervous system, and are from 10 μ to 100 μ in diameter. They consist of granular-looking protoplasm, in which there is a distinct nucleus containing a nucleolus. The shape of the cells differ, depending upon their location. Some are spherical or angular, as in the spinal cord and cerebrum; others are stellate, as in the spinal cord; others, flask-shaped or pyriform, as in the cerebellum. The cells may have one or more protoplasmic projections. A cell which has only one projection is termed a *unipolar;* one which has two, a *bipolar;* one with more than two, a *multipolar* cell. The processes are of two kinds, *axis cylinder* and *branched.* The former are termed the processes of Deiter, neuraxes, neurites, neuraxones, or axones. The process of a unipolar cell is an axis-cylinder process; of the bipolar, one is an axis cylinder, the other a branched process; of the multipolar all are branched, except one, which is an axis-cylinder process. The branched processes, known as *dendrites,* form a communicating network. The entire nerve cell with its processes is termed a neurone, neura, or neurodendron. The terminal groups of branches of a dendrite or of a neuraxis are known as a telodendron. Each axis-cylinder process becomes the essential portion of a nerve fibre..

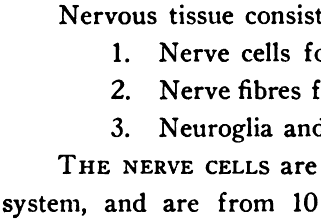


FIG. 54.
Nerve-cells.
(*A*) unipolar; (*B*) bipolar; (*C*) multipolar; (*a*) axis cylinder process; (b) branched processes.

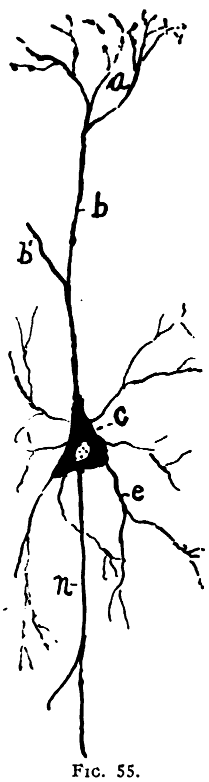
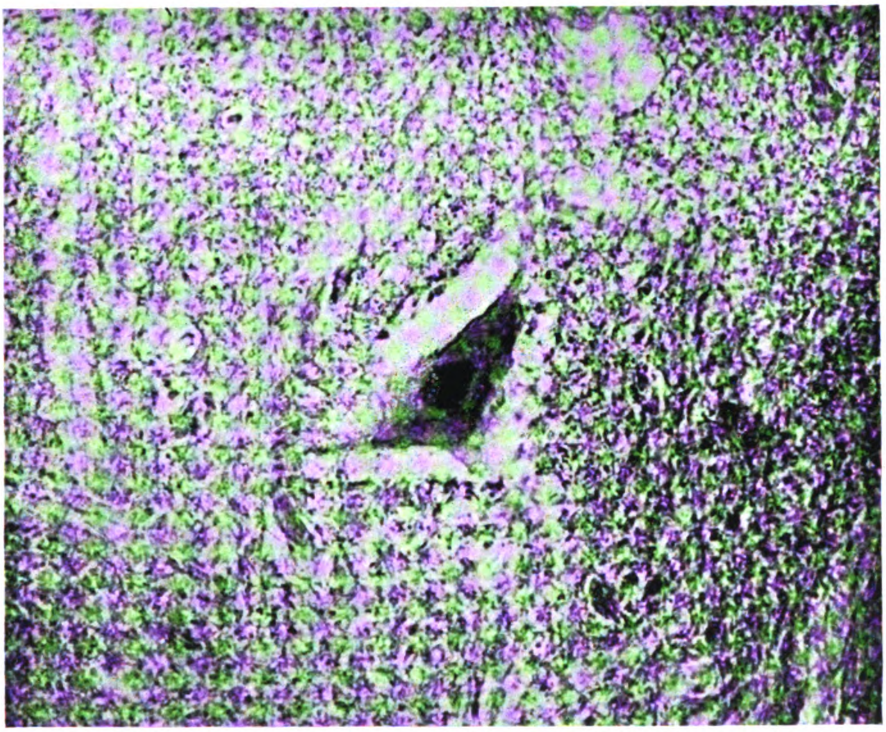
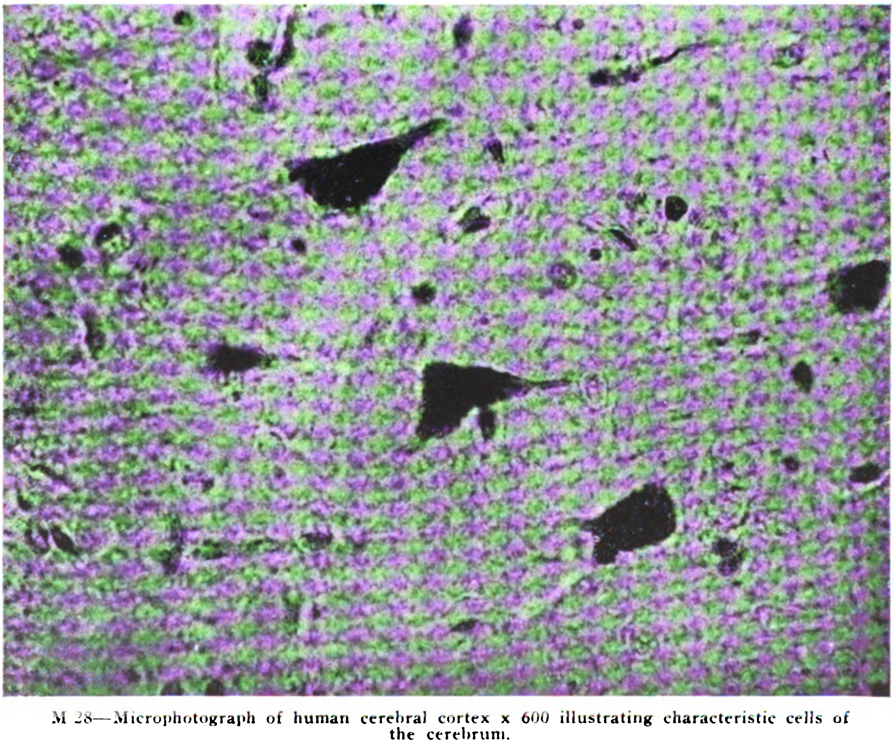


FIG. 55.
A cell from the cerebrum, termed a neurone. (*c*) cell body; (*b*) dendrite, with secondary dendrite (*b'*) branching oft from it; (*a*) telodendron of main dendrite; (*c*) a basal dendrite; (*n*) neuraxis.

THE NERVE FIBRES are of two varieties, medullated or white, and non-medullated or gray.



M 27—Microphotograph of a portion of a section of the spinal cord x 490, illustrating structure of a cell in the anterior cornu of the gray matter.



M 28—Microphotograph of human cerebral cortex x 600 illustrating characteristic cells of the cerebrum.

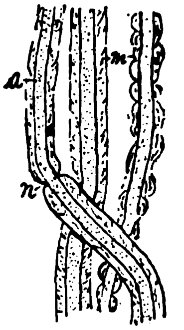


FIG. 56.
Medullated nerve fibres from a fresh specimen teased apart in normal salt solution. *a*, axis cylinder; *m*, medullary sheath; (n) node.

THE MEDULLATED OR WHITE NERVE FIBRES vary in length, and are about $\frac{1}{2000}$ inch in diameter. The fibre consists of a rod-shaped central portion termed the *axis cylinder* of Purkinje, a sheath around the axis cylinder termed the *myelin* or *medullary sheath,* or white substance of Schwann, and a sheath around the medullary substance termed the *primitive sheath,* or *neurilemma.*

THE AXIS CYLINDER is a continuation of the axis-cylinder process of a nerve cell, and consists of a number of fibrillae termed the *primitive fibrillae* of Schultze, held together by a granular cement substance termed *neuroplasm* (Kölliker). Surrounding the axis-cylinder, according to Kühne, there is a delicate sheath termed the *axilemma.* This sheath is probably a continuation of the limiting membrane of the nerve cell, from which the axis-cylinder is derived. The axis-cylinder proceeds to the area to be supplied by it, and then divides into its primitive fibrillae.

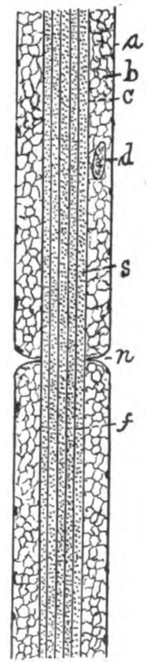


FIG. 57.
A diagrammatic representation of a medullated nerve fibre.
(*a*) primitive sheath or neurilemma; (*b*) medullary sheath or white substance of Schwann; (*c*) axilemma (of Kühne); (*d*) nucleus; (*s*) neuroplasm (of Kölliker); (*f*) fibrillae (of Schultze); (*n*) node (of Ranvier.)

THE MEDULLARY SHEATH, also known as the white substance of Schwann, consists of a semi-fluid fatty substance embedded in a fine network composed of *neurokeratin.* At regular intervals (about $\frac{1}{25}$ inch) along the fibre the medullary sheath is absent. These places where the medullary substance is not present, are known as the *nodes* of Ranvier. The portions between the nodes are termed *internodes.* In each portion of the medullary substance, about midway between the nodes, there is a nucleus.

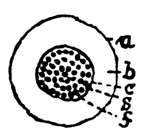


FIG. 58.
A diagrammatic representation of a transverse section of a medullated nerve fibre.
(*a*) neurilemma; (*b*) medullary sheath; (*c*) axilemma; (*s*) neuroplasm; (*f*) fibrilla.

THE PRIMITIVE SHEATH, *neurilemma,* or nucleated sheath of Schwann, bears a relation to the nerve fibre similar to that borne by the sarcolemma to the muscle fibre. It is closely applied to the medullary sheath, and consists of a thin membrane, on the internal surface of which there is a layer of endothelioid cells. At the nodes the neurilemma dips in to the axis cylinder. In the nodes there exist collections of cement substance, which probably have some influence upon the nourishment of the axis cylinders. The medullated fibres may lose their medullary sheath and become non-medullated fibres.

THE NON-MEDULLATED, OR GRAY FIBRES, the fibres of Remak, are essentially the same as the white fibres, except that they have not a medullary sheath. A gray fibre consists of an *axis cylinder* which is fibrillated lengthwise. Around the axis cylinder there is a sheath, in which are oval-shaped nuclei. These fibres are smaller than the white variety, being about $\frac{1}{3000}$ inch in diameter. The gray fibres branch; the medullated do not, except near their termination. These fibres are found making up the sympathetic system, very few existing in the cerebro-spinal system, while the other variety makes up the cerebro-spinal system of fibres.

Holding the cells and fibres of the brain and spinal cord together, there is a framework composed of connective tissue derived from the pia mater, and *neuroglia*. The neuroglia (Gr. νεῦρον nerve; γλία glue) consists of cells which are irregular in shape and have ramifying projections. These cells are known as neuroglia cells. Their filament-like projections intermingle and form a secondary network.

THE NERVE TRUNKS consist of nerve fibres collected together into bundles, which in turn make up the nerves. The nerves of the cerebro-spinal system are composed of the medullated variety of fibres. In many respects a nerve on cross-section resembles a cross-section of voluntary muscle.

Surrounding the nerve there is an areolar connective tissue sheath termed the *epineurium*, which sends inshoots into the nerve, dividing it up into bundles of fibres, the inshoots being termed *perineurium;* the bundles of fibres, *funiculi*. From the perineurium projections termed the *endoneurium* extend into the funiculi, dividing them up into small compartments, which are occupied by the nerve fibres. The main points of difference between a cross-section of a nerve and one of voluntary muscle are shown by the fibres. In muscle the fibres are irregularly quadrilateral in shape; in nerve they are usually round. The cross-section of a muscle fibre appears as a dense, solid mass, surrounded by the sarcolemma; that of a nerve fibre appears as a round area, with a round area (axis cylinder) in its centre, with a clear zone (the medullary substance) between the central area and the cell wall (neurilemma). If the section of the nerve should pass through a node or a gray fibre, if there be any gray fibres in the nerve, only a dark spot, the cross-section of the axis cylinder, would be observed representing the fibre.

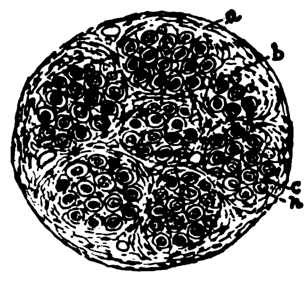
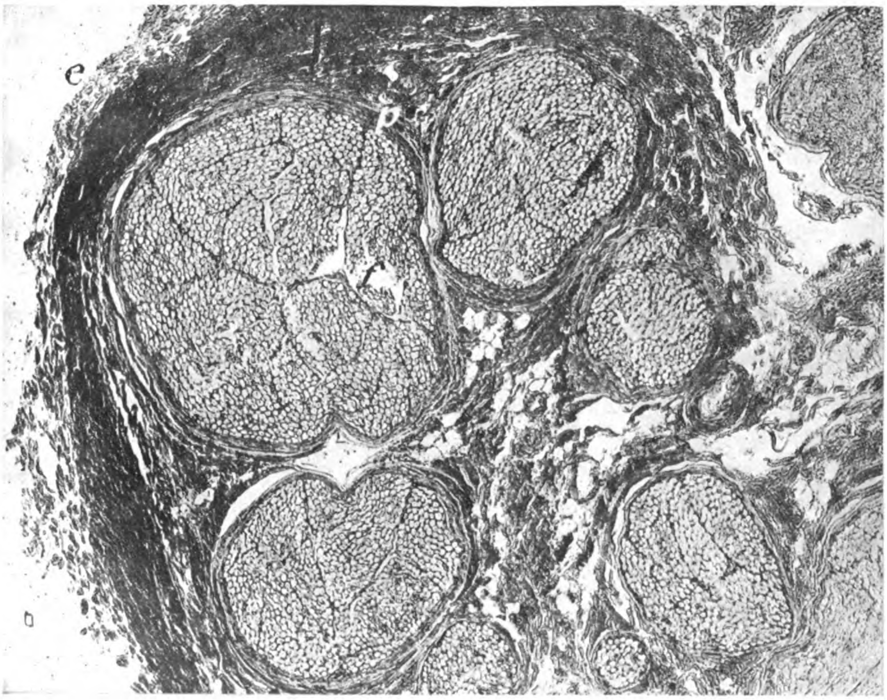


FIG. 59.
A transverse section of a nerve as observed in a section of the skin of the finger.
(*a*) epineurium; (*b*) perineurium enclosing the funiculi or bundles of nerve fibres; (*c*) endoneurium; (*n*) nerve fibre cut transversely.

As a funiculus nears its termination the fibres diverge from each other, each fibre receiving an extra sheath derived from the endo- and perineurium, which sheath is termed the sheath of Henle.

THE BLOOD VESSELS—the *vasa nervorum*—pass into the epineurium, and send off branches into the peri- and endoneurium, forming a capillary network around the fibres, as in muscle.



M 29—Microphotograph of a transverse section of a nerve x 45.
e, epineurium; *p*, perineurium; *f*, funiculus, in which may be observed the sections of medullated nerve fibres, among which is the endoneurium.

M 30--Microphotograph of a spinal ganglion of a pig-embryo x 100.

_a_, subdural space between dura mater and the spinal cord; _g_, ganglion; _b_, posterior root of spinal nerve passing into the ganglion; _c_, anterior root of spinal nerve passing outside of ganglion; _d_, the spinal nerve formed by the union of the two roots; _c_, cartilage of lateral half of n.ural arch; _f_, cartilage of body of vertebra.

Lymphatics arise in the clefts in the fibrous tissue of the endoneurium, join and communicate with the larger clefts in the epineurium, which in turn communicate with the clefts of the surrounding areolar tissue.

The *nerves* which pass to the larger trunks, the *nervi nervorum,* pass into the epineurium, where, according to Horsley, they terminate in bulbous enlargements.

Experiment 64. Stain and mount a cross-section of the spinal cord, preferably from an ox. Notice the gray matter and the white. In the gray matter, look for uni-, bi- and multipolar cells. Sketch and measure four of the cells.

Exp. 65. In the white matter of the cord, look for cross-sections of nerves. Notice the numerous sections of medullated nerves. Notice the frame work which holds the fibres together. Look for neuroglia cells. Sketch.

Exp. 66. Examine a stained section of the cerebellum. Look for and sketch under both powers the pyriform shaped cells of Purkinje.

Exp. 67. Stain with Van Gieson stain a transverse section of a large nerve. Examine and notice the points of resemblance and the points of difference between it and muscle. Sketch.

Exp. 68. From a recently-killed animal take a nerve, and tease apart lengthwise in a drop of normal salt solution. Cover and examine. Notice and sketch the axis cylinders, medullary sheaths, nodes and internodes.

Exp. 69. Obtain a portion of a nerve which has been in a dilute solution of osmic acid (5 per cent.) for about thirty-six hours, and gently tease it apart in a drop of glycerin on a slide. Examine with the high power, and look for nuclei beneath the primitive sheath. Sketch. Cement the cover-slip on the slide.

Ganglia occur on some of the cranial nerves, on the posterior roots of the spinal nerves, and as the sympathetic ganglia. The ganglia are nerve centres occurring on the nerves, and act as relays, aiding or modifying the impulses as they pass through them. A spinal ganglion consists of fibres and nerve cells. The nerve cells are usually near the surface of the ganglion, some being round, others unipolar, bipolar or multipolar. The processes extend from the cells to the nerve fibres which they join. Each cell has a nucleated cell wall, which is continued around the process as a sheath. The ganglia arranged as a chain along each side of the vertebral column, which form the trunk of the sympathetic system, receive medullated fibres (rami communicantes) from the spinal cord. From the

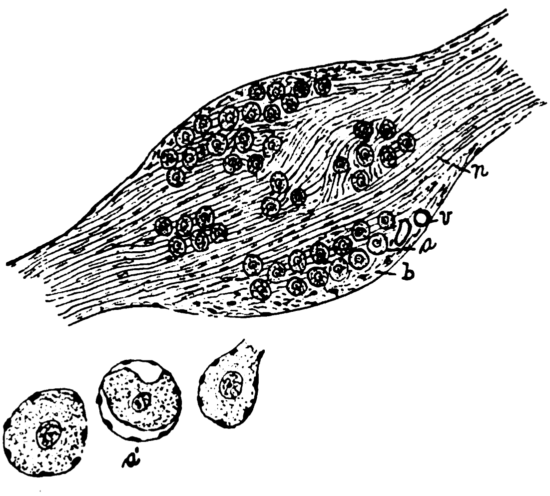


Fig. 60.
A longitudinal section of a spinal ganglion
(*a*) ganglion cells; (*a'*) ganglion cells highly magnified; (*b*) fibrous connective tissue; (*n*) nerve fibres; (*v*) blood vessels.

ganglia non-medullated nerves pass as the sympathetic nerves. In the sympathetic ganglia of the frog, pear-shaped cells have been observed which have, passing from their small end, two fibres, one medullated, the other non-medullated, from which it may be inferred that the medullated fibre enters the cell, loses its medullary sheath, and merges as a non-medullated fibre. In this manner it is probable that the ganglia of the sympathetic trunk act upon the medullated fibres received from the spinal cord, in which case the sympathetic system would not be an independent one, but one derived from the cerebro-spinal system.

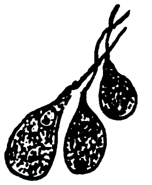


FIG. 61.
Ganglion cells from a transverse section of the ganglionic commissure of an earthworm.

Experiment 70. Stain and mount a longitudinal section of a spinal ganglion. Examine and notice the cells and nerve fibres. Try to find processes of the cells joining the nerve fibres. Sketch.

THE PERIPHERAL NERVE TERMINATIONS.

The terminations of the sensory nerves* may be simplex or complex. The nerves may terminate as a fibrillar network from which fibrillae may pass to the cells to be supplied, terminating between or within the cells. There are some of the sensory nerves, especially those for the perception of the sensation of touch, which terminate in a special manner, the special endings being termed *end-organs,* the chief of which are:

Tactile corpuscles.

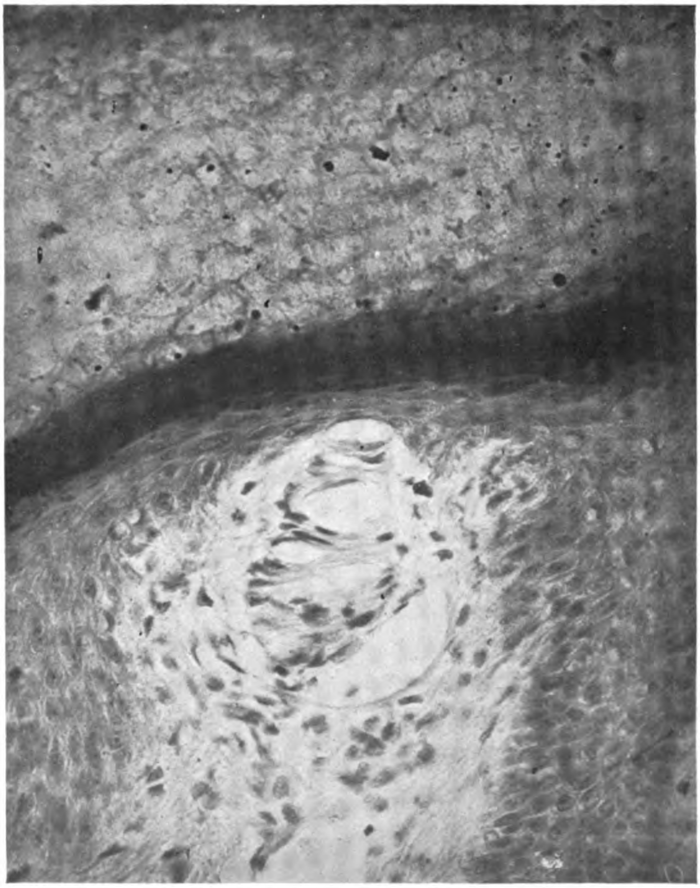
End-bulbs.

Pacinian corpuscles.

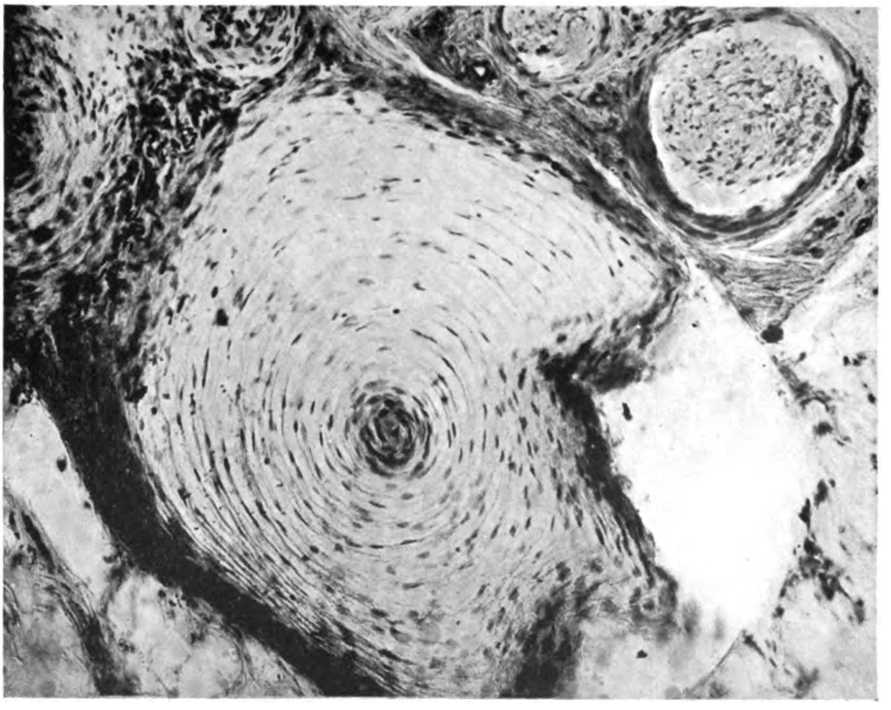
FIG. 62.
A tactile corpuscle within a papilla of the skin of the hand.
Chloride of gold preparation. (Ranvier.)
(*a*) varicose fibrillae; (*n*) nerve fibre; (*f*) fibrous tissue of the papilla.

THE TACTILE CORPUSCLES, also termed the corpuscles of Meissner and of Wagner, occur in some of the papillae of the skin, and are most numerous in the localities where the sensation of touch is highly developed, as in the skin of the palmar surface of the fingers. The nerve fibre loses its medullary sheath, the axis cylinder divides, the fibrillae formed by the division continue and make numerous coils, giving an appearance somewhat similar to the pineapple. Upon the fibrillae small enlargements can be observed, which look like nuclei. The neurilemma of the fibre extends around the coiled mass as a capsule, which is in close contact with the surrounding fibrous connective tissue.

*The consideration of the termination of the nerves for the appreciation of the sensations of sight, hearing, smell and taste will be taken up with the corresponding organs which contain them.



M 31—Microphotograph of a vertical section of the skin of a finger illustrating a tactile corpuscle.



M 32—Microphotograph of a portion of the subcutaneous connective tissue of the skin of a finger x 157 showing a Pacinian corpuscle, and sections of nerves and vessels.

THE END-BULBS are usually round or oval in shape, their chief localities being in the conjunctiva, termed the *conjunctival end-bulbs;* in the external genital organs termed the *genital corpuscles;* and in the neighborhood of articular surfaces of joints, termed the *articular corpuscles.* An end-bulb consists of a coiled network of fibrillae, derived from the axis cylinder of a medullated fibre, and is surrounded by a nucleated capsule. The fibrillae also appear to be nucleated.

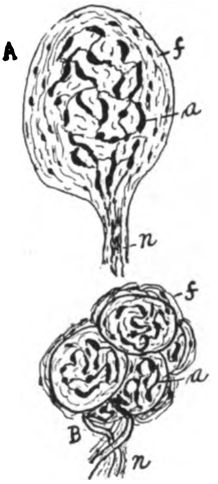


FIG. 63.
End-bulbs (after Krause). (*A*) simple variety (conjunctival); (*B*) compound variety (genital); (*a*) varicose fibrillae; (*f*) fibrous tissue; (*n*) nerve fibres.

THE PACINIAN BODIES, or *corpuscles* of *Vater,* are found chiefly in the subcutaneous tissue of the fingers and toes, but occur also in the mesentery, genital organs and joints. They are somewhat almond-shaped, and large enough to be seen with the unaided eye. The nerve going to form the corpuscle first loses its sheath of Henle, the perineural portion becoming arranged in layers or lamellae, the endoneural portion also as lamellae internal to the perineural lamellae. The primitive sheath blends with the inner lamellae of the endoneurium. The lamellae are about thirty in number, and appear to be nucleated. On entering the corpuscle, the medullary sheath becoming lost, the axis cylinder passes in the long axis of the corpuscle, and terminates near its smaller end in several fibrillae, which possess enlargements.

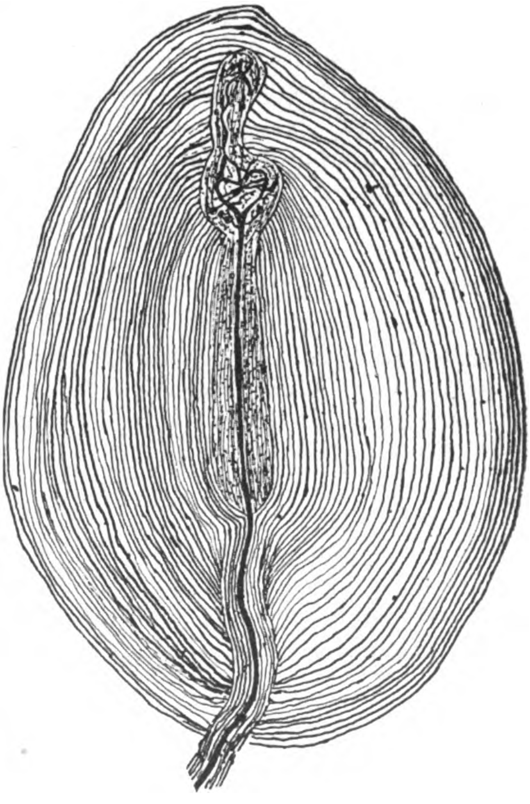


FIG. 64.
A Pacinian corpuscle from the mesentery of a cat (after Ranvier.)

FIG. 65.
A Pacinian corpuscle observed in the subcutaneous tissue of the foot.

THE MOTOR NERVES to voluntary muscle end in the *motor end-plates*. The axis cylinders divide into fibrillae, which have enlargements upon them.

THE SYMPATHETIC NERVES (gray fibres) terminate in plexuses, which send off branches to the different parts to be supplied. At the junctions of the fibres of a plexus there are irregular-shaped collections of gray matter similar to that composing the axis cylinders.

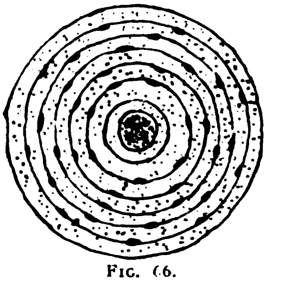


FIG. 66.
A transverse section of a Pacinian corpuscle observed in the subcutaneous tissue of the finger.

Experiment 71 Stain with haematoxylin and eosin and mount a section of skin from the palmar surface of a finger. Notice the papillae beneath the stratified squamous epithelium. In the papillae, look for tactile corpuscles. Sketch a tactile corpuscle under the high power. In the subcutaneous tissue look for a Pacinian corpuscle and when found sketch it under both powers.

Exp. 72. Look for small oval-shaped bodies in the mesentery of a cat. When one is found, remove it carefully and put into a dilute solution of osmic acid for twenty-four hours. Then put it into a drop of glycerin on a slide, around it place a hair; cover and examine, first with the low, then with the high power. Sketch the outlines of the Pacinian corpuscle under the low power. Under the high power sketch portions of the centre and the lamellae.

CHAPTER VII.

THE VASCULAR SYSTEM.

THE HEART.

The heart is a muscular organ which is for the purpose of receiving the blood from the veins and forcing it through the arteries to the capillaries. It is composed of three coats enclosing the cavities of the organ, termed the *endocardium,* the *myocardium,* and the *pericardium* or *epicardium.*

THE ENDOCARDIUM, the innermost coat, is a serous memberane which lines the walls of the cavities of the heart, and is continuous with that lining the lumen of the arteries and of the veins. It consists of a layer of endothelium resting upon a layer of white and yellow fibrous tissue, among the fibres of which are a few involuntary muscle fibres. Next to this is a layer of yellow fibrous tissue which connects this coat with the next, the myocardium. The valves of the heart are folds or reduplications of the endocardium. At the insertions of the *chordinae tendinae,* the white fibrous tissue is well developed and assumes a tendinous consistency.

THE MYOCARDIUM, the middle and thickest coat, consists of cardiac muscle fibres held together by areolar connective tissue. The muscles of the auricle are arranged as two layers of circularly-disposed fibres, the outer layer enclosing both auricles, the inner layer enclosing each auricle. Between the muscle of the auricles and that of the ventricles there is a ring of densely arranged white fibrous tissue containing some elastic fibres, which is termed the *annulus fibrosus atrioventricularis,* or the auriculo-ventricular ring. The muscle fibres of the ventricle are arranged as two sets, with a superficial and deep set, the fibres of which arise from the auriculo-ventricular ring and wind spirally around the heart to terminate in the tendons of the papillary muscles of the opposite ventricle.

THE PERICARDIUM, the most external coat of the heart, consists of two layers. The *epicardium* is the inner or visceral layer and is closely applied to the myocardium, while the parietal (or outer) layer loosely encloses the heart and is continuous at the upper border of the heart with the visceral layer. These layers are serous membranes, with the endothelial layer of each toward that of the other.

The blood supply of the heart is by means of the coronary arteries, which ramify and form a capillary network in the areolar connective tissue network between the muscle fibres, from which the coronary veins arise. There are also small vessels which open on the surface of the endocardium, directly from the cavities of the heart, and pass to a system of small vessels which communicate with the coronary arteries and veins by means of capillaries, and with the veins by larger vessels.

Lymphatics arise in the endo- and pericardium.

The nerve supply is by means of medullated and non-medullated fibres which pass to the three coats of the heart.

Experiment 73. Examine under the low power a stained transverse section of the heart of a small animal and notice the three coats, and under the high power sketch a portion of each.

THE BLOOD VESSSELS.

The blood is conveyed to and from the tissues and organs of the body by three sets of vessels—the arteries, capillaries, and veins. The *arteries* are the vessels which convey blood to the different parts of the body; the *capillaries,* the continuations of the arteries, form anastomosing networks in the tissues and organs of the body; the *veins,* the vessels which convey the blood from the capillaries to the heart.

AN ARTERY (Gr. αὴρ, air; τηρέω, to hold) received its name by the ancients, who believed that it was for the purpose to carry air, because after death it was found open and empty. It is composed of three tunics arranged around a central opening, termed the *lumen:*

The tunica adventitia, or external coat.

The tunica media, or middle coat.

The tunica intima, or inner coat.

THE TUNICA ADVENTITIA consists of yellow fibrous tissue, most of the fibres running circularly around the vessel, a few running longitudinally. In addition to the yellow fibrous tissue there is a small amount of the white fibrous variety and connective tissue corpuscles. The outer layers of this coat gradually blend with the areolar connective tissue which composes the sheath of the artery. Some of the yellow fibrous tissue of the adventitia in the larger-sized arteries is arranged as a distinct layer next to the middle coat, termed the *external elastic membrane,* which is seen in prepared specimens as a glistening convoluted band. Also in the larger-sized arteries the longitudinally-disposed yellow fibres may be arranged in bundles. In some of the larger arteries, as in the renal, some involuntary muscle fibres occur in this coat arranged in longitudinally disposed bundles. In the large arteries the tunica adventitia is arranged in two zones, the inner of which consisting of dense elastic tissue, the outer of loosely arranged

FIG. 67.
A portion of a transverse section of a small artery.
(*a*) tunica adventitia; (*b*) tunica media; (*c*) internal elastic membrane; (*e*) endothelial layer of the tunica intima.

white fibrous tissue in which there are some elastic fibres. The nourishing vessels, the *vasa vasorum*, of the large arteries run in the outer zone of the tunica adventitia.

THE TUNICA MEDIA consists of involuntary muscle fibres among which is some yellow fibrous connective tissue. In the small-sized arteries the involuntary muscle fibres are circularly disposed around the vessel, among which are a few scattered elastic fibres. As the artery increases in size more elastic tissue appears in the media, the amount of elastic tissue in the media being greater the larger the artery, so that in the aorta the media is composed almost entirely of elastic connective tissue. As a consequence the small arteries possess much contractile power and some elasticity, while the larger arteries possess much elasticity, and a small amount of contractility. Also in some of the large arteries some of the muscle fibres run longitudinally, in some instances collected into layers which may run internal to the circular layer, as in the subclavian, or external to the circular layer, as in the renal, or internal and external to the circular layer, as in the umbilical artery.

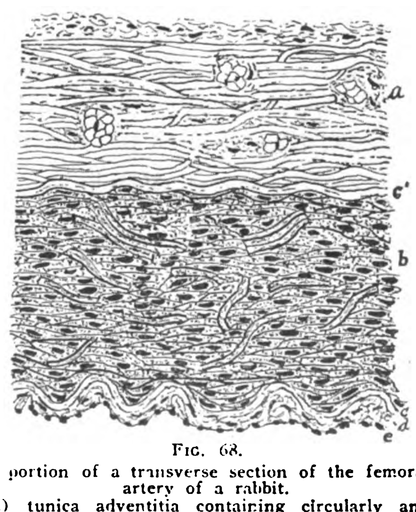


FIG. 68.
A portion of a transverse section of the femoral artery of a rabbit.
(*a*) tunica adventitia containing circularly and longitudinally disposed elastic fibres; (*b*) tunica media containing some elastic fibres among the muscle fibres; (*c*) internal elastic membrane; (*a*) subendothelial, and (*e*) endothelial layers of tunica intima; (c') external elastic membrane.

THE TUNICA INTIMA consists of three layers:

1. The *internal elastic membrane*, which consists of yellow fibrous tissue, occurs as a dense layer next to the inner border of the media. The tissue is arranged as a closely woven membrane, in which are very small openings forming a fenestrated membrane (Henle). This layer of the intima appears in prepared specimens as a glistening convoluted band.

2. Next to the internal elastic membrane there is a loose network of connective tissue, indistinct in small vessels, distinct in large ones, known as the ***subendothelial layer***.

3. Next to the subendothelial layer and lining the lumen of the vessel there is a layer of nucleated, flat, elongated, irregular-shaped cells, arranged with their long axis more or less parallel with the long axis of the vessel, termed the ***endothelial layer***. As the arteries decrease in size the tunics become more distinct, and then as they approach the region to be nournished they gradually lose the adventitia, then the media, so that just before becoming capillaries they are termed arterioles, and consist of the intima surrounded by a few muscle fibres of the media. When the arterioles lose the muscle fibres the vessels are termed capillaries.

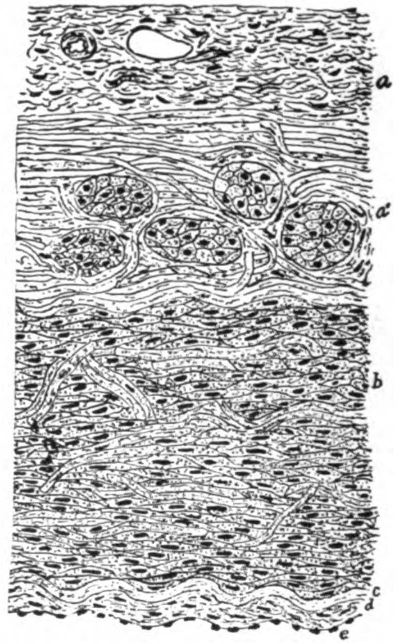


FIG. 69.
A portion of a transverse section of a (human) renal artery.
(a) outer zone of the tunica adventitia containing vasa vasorum; (a') inner zone of the tunica adventitia containing bundles of involuntary muscle fibres longitudinally disposed; (b) tunica media containing circularly disposed involuntary muscle fibres and elastic tissue; (c) internal elastic membrane; (d) subendothelial, and (e) endothelial layers of the tunica intima.

THE CAPILLARIES consist of a layer of endothelial cells, held to the surrounding tissue by the remains of the internal elastic membrane and subendothelial tissue which become blended with the surrounding tissue. The capillaries are about $\frac{1}{3000}$ inch in diameter, and form anastomosing networks, and by virtue of their structure allow their contents to pass from the vessels into the tissues, and substances to pass from the tissues into their interior (vide endothelium, Chapter III). The capillaries of a network do not diminish in size, although in some networks, as of bone and liver, the capillaries may be of greater diameter than those of other networks, as of the brain and muscle. The capillary network may be close-meshed, as of the lung, or wide-meshed, as of serous membranes and tendons. The capillaries passing from the network receive a covering of muscle fibres, then one of fibrous tissue, to become veins.

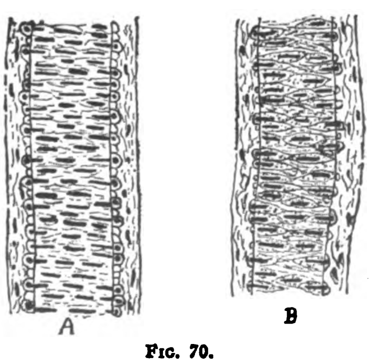
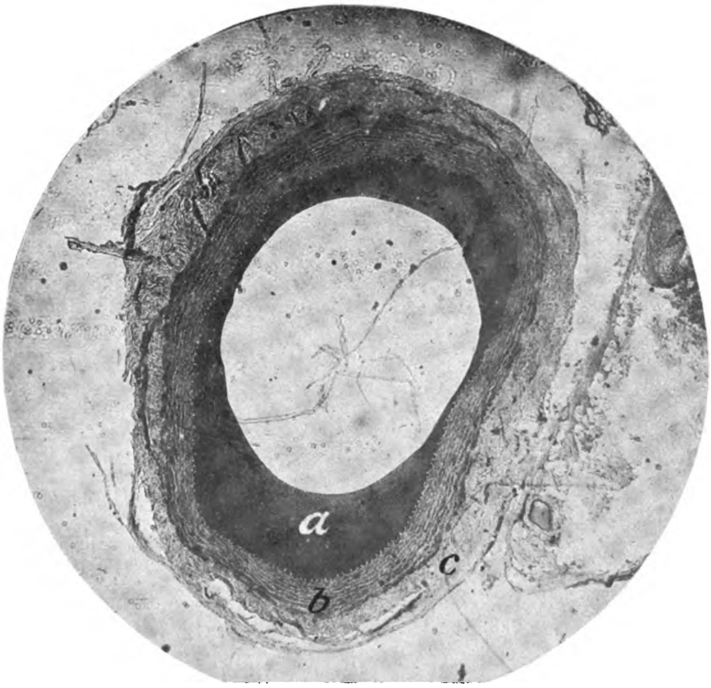


FIG. 70.
(A) a longitudinal section of an arteriole; (B) a longitudinal section of a venule.



M 33—Microphotograph of a transverse section of an artery x 20, illustrating the tunics. *a*, coagulated blood in the lumen; b, muscular tunica media separated from the blood by the glistening internal elastic membrane of the tunica intima; *c*, tunica adventitia.

M 34—Microphotograph of an artery of a dog x 45.
***a*, blood; *b*, internal elastic membrane; *c*, tunica media; *d*. tunica adventitia.**

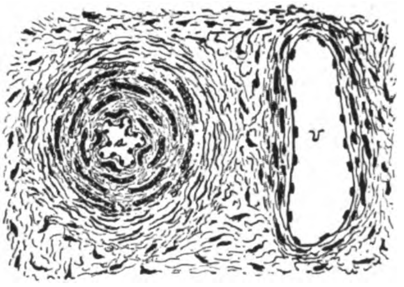


FIG. 71.
A transverse section of (a) small artery; (v) small vein.

In some parts of the body arterioles do not terminate as capillaries as in the case of the *retia mirabilia,* where the arteriole divides into several branches which again unite to form a vessel which then passes on to form a capillary network, as in the glomeruli of the kidney; and in the case of *sinuses* where the arterioles empty directly into irregularly shaped spaces, which in turn open into venules, the spaces being lined with endothelium continuous with that of the arterioles and venules, as in the spleen, the penis and the nasal mucous membrane.

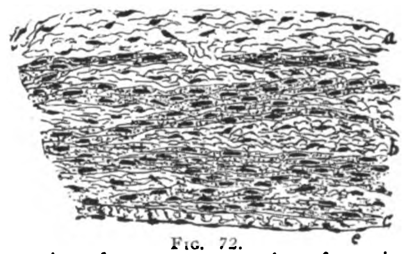


FIG. 72.
A portion of a transverse section of a vein. (a) tunica adventitia; (b) tunica media: (c) tunica intima; (e) endothelial cells.

A VEIN (L. *veneo,* to come) is so termed because it conveys the blood returning to the heart. It has three tunics, like an artery, but they are less distinct, and thinner than the corresponding tunics of an artery. In the connective tissue of an artery there is a preponderance of yellow fibrous tissue, while of a vein there is a preponderance of the white fibrous variety, the elastic fibres being few in number. Consequently the veins are tough, but not elastic, and generally appear in prepared specimens more or less collapsed and filled with blood, due to their lack of elasticity and contractility. The *adventitia* consists of white fibrous tissue, among which is a small amount of the yellow variety. The media consists of involuntary muscle fibres, a large amount of white fibrous connective tissue and a few elastic fibres. In the small veins the muscle fibres are disposed circularly around the vessel, but in the larger veins, as in arteries, longitudinally-disposed muscle fibres occur in the media, which may be collected into layers, in some veins internal to the circular layer, as in the femoral, in others external to the circular layer, as in the inferior vena cava and the hepatic. In some veins the muscular coat is almost entirely absent, as in the upper part of the inferior vena cava. In some veins, as those of the brain, spinal cord, bone and venous sinuses, there is no muscular coat. In many veins, especially in those of the lower extremity, in order to prevent regurgitation of the blood, there are reduplications of the intima, termed *valves,* which are pocket-shaped projections strengthened by fibrous tissue, and

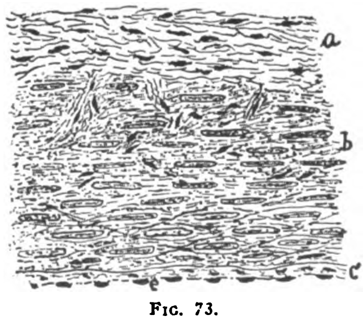


FIG. 73.
Portion of a transverse section of a medium sized vein.
(a) tunica adventitia; (b) tunica media; (c) tunica intima.

in some instances by muscle fibres derived from media. The valves are so arranged that the concavities are toward the heart. In the *intima* of a vein the internal elastic membrane is less distinct than in an artery, and the endothelial cells are less elongated than those of an artery, and are arranged with their long axis *not* paralleled with the long axis of the vein, but oblique to it.

Experiment 74. Stain with haematoxylin and eosin and mount a transverse section of a small artery. Examine with the low power and sketch the three tunics. With the aid of the high power sketch portions of the adventitia, media and intima.

Exp. 75. Prepare as in Exp. 74 a transverse section of a large artery, as the femoral or the renal. Notice the elastic tissue in the media and the two zones of the adventitia. Look for cross-sections of longitudinal muscle fibres and of elastic fibres. Notice the vasa vasorum. Look for and study the three layers of the intima. Sketch.

Exp. 76. Examine the specimen of the umbilical cord used in Exp. 41. Find artery, and look for the cross-sections of the longitudinal layers of involuntary muscle fibres, internal and external to the circular layer. Sketch.

Exp. 77. Stain and mount a section of the aorta. Examine and notice the large amount of elastic fibres in the media. Sketch.

Exp. 78. Stain with haematoxylin and eosin and mount a piece of areolar tissue, preferably the subcutaneous tissue. Look for small arteries (arterioles) and small veins cut longitudinally. Sketch.

Exp. 79. Open lengthwise a small artery; cut away as much of the wall as possible without injuring the lining of the vessel. Stain the lining with silver nitrate and examine. Notice the dark brown lines marking out the boundaries of the endothelial cells. Sketch.

Exp. 80. Stain and mount a transverse section of a vein with Van Giesen stain. Examine and compare with a section of an artery. Notice the large amount of white fibrous tissue. Sketch.

Exp. 81. Examine the mesentery or web of a living frog (curarized). Notice the blood circulating in the capillary network. Look for leucocytes within and outside the vessel. By careful examination leucocytes may be observed passing through the capillary walls.

Exp. 82. Examine the specimens which have been stained and mounted for the preceding experiments, and look for blood vessels. Study the vessels and endeavor to distinguish small arteries, veins, and capillaries from each other.

CHAPTER VIII.

THE LYMPH CHANNELS AND THE MEMBRANES.

THE LYMPH CHANNELS may be regarded as extensions from the veins, as the larger-sized channels are similar in structure to, and terminate in, the veins. The lymph channels possess valves which are more numerous than those of the veins. They convey the lymph from the tissues to the veins. The *lymph* consists of a liquid, the *liquor lymphae,* and *lymph corpuscles.* The liquor lymphae is the liquor sanguinis, which has exuded from the capillary blood-vessels into the neighboring tissues. The lymph corpuscles are leucocytes which have passed from the capillary blood-vessels with the liquor sanguinis, and cells which have been added to the lymph as it passes through the lymphoid structures. The variety of leucocytes of the blood which have been termed lymphocytes may be regarded as lymph corpuscles which have passed into the blood vessels. The lymph, after having given nourishment to, and taken up various substances from the tissues, passes into the venous system directly by means of the capillary blood-vessels, or indirectly by means of the lymphatic channels.

The lymph channels arise as *lymph spaces,* which exist in the clefts in connective tissue termed the interfascicular clefts. The clefts join one another and form *lymph capillaries,* which at first are lined by an incomplete layer of connective tissue corpuscles, but as the vessels become more distinct they are lined by a layer of endothelial cells. In some instances the interfascicular clefts in the fibrous tissue of blood-vessels, nerves and ducts join one another and form distinct enclosing canals in their outer coat, termed respectively perivascular (as in the liver), perineural (as in the brain and spinal cord), and periductular (as in the salivary glands) lymph channels. Into the interfascicular clefts of the fibrous tissue, beneath the endothelium of serous membranes, the excess of serous secretion passes, and is conveyed away by the lymphatic channels. In the small intestine the interfascicular clefts of the mucosa join to form club-shaped vessels termed *lacteals,* or chyliferous vessels, which, during absorption, contain a fluid similar in appearance to milk, which is due to the lymph containing a large amount of finely-divided fat globules.

The lymph capillaries terminate in lymph vessels, which possess, besides an intima, some involuntary muscle fibres. As the vessels become larger the muscular coat becomes more distinct, and they acquire an outer fibrous coat, which is composed chiefly of white fibrous connective tissue, so that in the largest-sized vessels there are three coats, as in the veins, but thinner than the corresponding coats of the veins. For example, a transverse section of the THORACIC DUCT would exhibit three coats—an intima, media, and adventitia. The *intima* consists of an endothelial and a well-developed subendothelial layer, and an internal elastic membrane. The *media* consists of involuntary muscle fibres circularly disposed, mixed with which is white fibrous connective tissue. The *adventitia* consists of white fibrous tissue, some elastic fibres, and a longitudinal layer of involuntary muscle near the media. The lymph channels, before reaching their termination, pass through lymphoid tissue, loosely arranged or collected into nodules or glands.*

SEROUS MEMBRANES line the cavities which are not exposed to the exterior, such as the peritoneal, pericardial, and pleural. A serous membrane, besides lining the cavity, is reflected over the organs contained in the cavity, the portion lining the cavity being termed the *parietal,* that covering the organs the *visceral* layer.

The serous membranes are strong, elastic, of a glistening white appearance, and consist of two portions, an *endothelial* and a *subendothelial.* The subendothelial layer consists of loosely arranged fibro-elastic tissue in which there may be some lymphoid tissue, which blends with the fibrous tissue of the subserous membrane. The endothelial portion consists of a single layer of flat, irregular-shaped cells, held together by cement substance. In the cement substance are small openings, *stomata,* and collections of cement substance, pseudostomata, or *stigmata.* The serous secretion is watery, and contains serum albumin. The excess of the secretion can readily pass through the stomata into the interfascicular clefts of the subendothelial tissue and be conveyed away by the lymphatic channels. The blood-vessels which go to the serous membranes form a capillary network in the subendothelial tissue.

SYNOVIAL MEMBRANES are the membranes which cover the movable surfaces of joints and line the tendon-sheaths and bursae. They consist of connective tissue and the accompanying connective tissue corpuscles. To the synovial membranes there is no endothelial lining, although some of the connective tissue corpuscles may be found on the free border of the membranes. The outermost fibres of the connective tissue blend with the neighboring tissue. When the neighboring tissue is cartilage the fibres penetrate a portion of its matrix and form fibro-cartilage. The membrane may be thrown into folds, the *Haversian fringes,* or into small elevations, the *villi.* The capillary blood-vessels are numerous in the synovial membranes. The synovial secretion is a glairy, viscid fluid, somewhat similar in appearance to the white portion of an uncooked egg.

MUCOUS MEMBRANES occur on those surfaces which communicate with the exterior of the body, consequently they are lined by epithelium. The mucous membranes are not continuous with serous membranes, except in one instance, *which is at the beginning portion of the oviduct.* A mucous membrane consists of two portions, an *epithelial* and a connective tissue portion termed the *tunica*

*The collections of lymphoid tissue will be considered in Chapter X.

propria. The epithelial portion varies according to the location of the membrane; it is stratified squamous in the mouth, in the pharynx below the posterior nares and in the oesophagus; simple columnar in the stomach and intestines; ciliated in the trachea, upper portion of the pharynx, epididymis and oviduct. The tunica propria may occur as a thin or as a thick layer of connective tissue. The connective tissue of which it is composed consists of white and yellow fibres; in some localities there is a preponderance of the former, in others a preponderance of the latter. The portion of the tunica propria nearest to the epithelium is condensed and is termed the *membrana propria,* or basement membrane. The tunica propria sometimes contains *lymphoid* tissue in some instances loosely arranged, in other instances collected into nodules. Usually the connective tissue of the tunica gradually blends with the underlying connective tissue (submucous membrane), but in some instances it is separated from the submucous connective tissue by one or two layers of involuntary muscle fibres, forming a muscular layer to the mucous membrane, termed the *muscularis mucosae.* A mucous membrane, in order to give a greater surface, may be thrown into folds, as the valvulae conniventes of the small intestine; into elevations, as the papillae of the tongue and the villi of the small intestine; or it may form *depressions,* forming glands. Glands are of different varieties, depending upon the simplicity or complexity of the depressions. If the depression is a single tube, it is termed a *simple tubular gland* (Fig. 74, *a*). If the depression gives off secondary tubular projections, it is termed a *compound tubular gland* (Fig. 74, *b*). If the depression is as a dilatation it is termed a *simple saccular gland* (Fig. 74, *c*). If the depression terminates in more than one saccule it is termed a compound saccular (or *racemose,* from its similarity in appearance to a bunch of grapes) gland (Fig. 74, *d*).

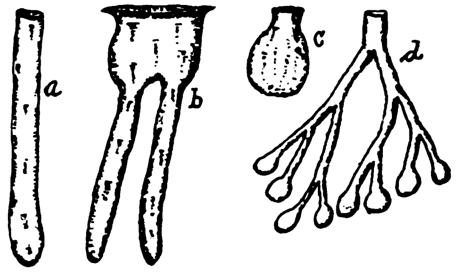


FIG. 74.
Diagrammatic representation of the general shape of the varieties of glands.
(*a*) simple tubular; (*b*) compound tubular; (*c*) simple saccular; (*d*) compound saccular or racemose.

Experiment 83. Stain with silver nitrate a piece of omentum, and transfer it to the slide, being careful that it is not wrinkled, and mount in balsam. Examine and look for the endothelium of lymphatic vessels. Examine the endothelium of the serous membrane, looking especially for stomata and stigmata. Sketch.

Exp. 84. Stain with silver nitrate and mount a piece of the central tendon of an animal's diaphragm. Look for lymphatic vessels. Sketch.

Exp. 85. Stain with haematoxylin and eosin a transverse section of the thoracic duct, mount, and examine. Notice the similarity which exists between it and a transverse section of a vein. Sketch.

Exp. 86. Examine the specimens mounted in Exps. 21 and 23, and study the structure of the mucous membrane. Sketch.

CHAPTER IX.

THE ALIMENTARY CANAL AND ITS APPENDAGES.

Food, before it can be utilized for the maintenance of the body, must be digested and absorbed into the blood. After the food has been taken into the mouth it is divided into small particles, the process being termed *mastication,* which is effected by means of the teeth.

THE TEETH, are firmly retained within their sockets by means of the alveolar periosteum, which is reflected upon the roots of the teeth as a *root membrane.* Each tooth is divided into three parts—a crown, a neck, and a root, according to some authorities; into two parts—a crown and a root, by others, who regard the neck as a portion of the root. The CROWN is the portion of the tooth which projects beyond the gum. The crown of the tooth may exist as one elevation or cusp, two or more. If there be only one cusp the tooth is termed a *cuspid,* if two cusps a *bicuspid,* if three a *tricuspid,* etc., the number of cusps to one tooth usually not exceeding five. The NECK of the tooth, or of the root of the tooth, is the portion which is embedded in the gum. At the junction of the neck with the crown there is a constriction termed the *gingival* line. The enamel above the line forms a ridge termed the basal ridge, or *cingulum.* The ROOT is the portion of the tooth which is embedded in the alveolar process of the maxillary bone, or in the gum and alveolar process, if the neck be considered as a portion of the root. It consists of a body continuous above as the neck, and terminating below in an apex in the lower jaw; vice versa in the upper jaw. In the centre of the tooth, running lengthwise, there is a cavity termed the PULP CAVITY, the portion of which contained in the crown is termed the *pulp chamber,* and the portion in the root the *root canal.* The pulp chamber at its upper portion in the lower teeth, or the lower portion of the upper teeth, terminates as a club-shaped cavity, with two or more projections, termed *cornua,* if the tooth has two or more cusps. The root canal is a continuation of the pulp chamber, and communicates with the subdental tissue by means of an opening in the apex of the fang, termed the apical foramen. If the root should have more than one fang, there is a root canal in each.

THE DENTINE exists as a zone bounded internally by the pulp cavity, externally by the enamel of the crown and the crusta petrosa of the root. It consists of an organic substance in which are mineral salts, and through which pass canals, termed the *dentinal canals.* The dentinal canals extend in a radial manner from the pulp cavity to just beneath the enamel, terminating in irregular-shaped spaces, termed the *interglobular spaces,* the area containing the spaces being termed the *interzonal layer*. Just before reaching the interzonal layer the tubules usually divide into two branches. A dentinal tubule contains a fibrilla, which appears beaded, and is either derived from a nerve or from a cell contained in the pulp. Offshoots from the fibrilla extend into the dentine, permeating it as network. In chemical composition dentine is very similar to bone, but there is more mineral matter in dentine than in bone, the amount of organic matter

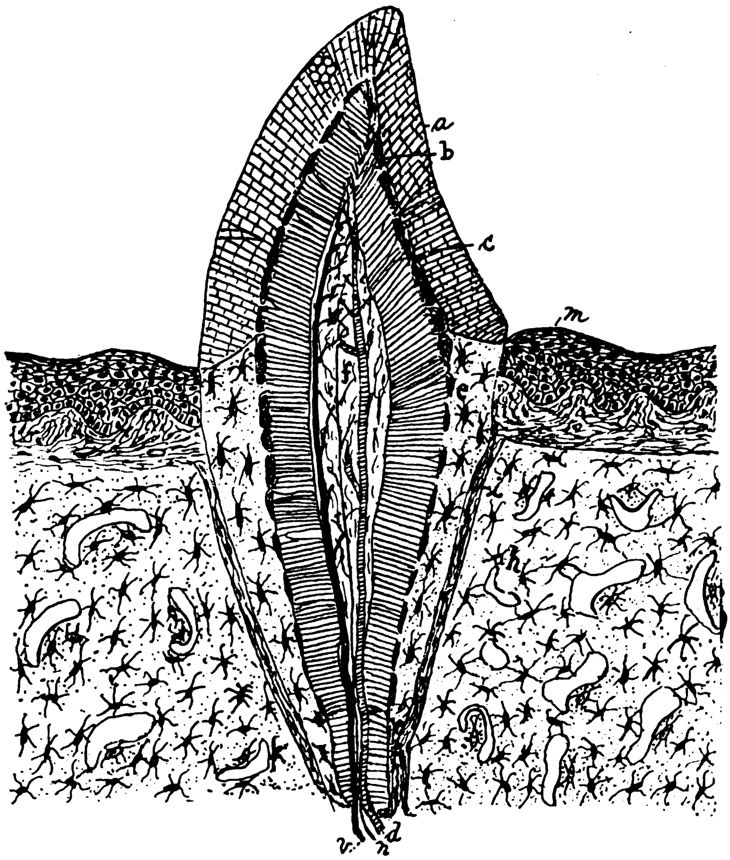


FIG. 75.
Longitudinal section of an incisor tooth (partly diagrammatic).
(*a*) enamel; (*b*) interglobular spaces; (*c*) dentine; (*e*) crusta petrosa; (*f*) pulp cavity; (*d*) artery; (*v*) vein, and (*n*) nerve passing into pulp cavity through apical foramen; (*h*) maxillary bone; (*i*) pericementum; (*m*) stratified squamous epithelium of gum.

in dentine being about 27 or 28 per cent.; of inorganic matter, which contains chiefly calcium phosphate, fluoride, carbonate and magnesium phosphate, about 72 or 73 per cent.

THE ENAMEL is found only on the crown of the tooth as a covering to the dentinal substance, and consists of hexagonal-shaped prisms closely packed together and usually perpendicular to the zone of dentine. The prisms appear to be cross-striated, which is due to the minute canals which pass between the prisms and send branches into the prisms, dividing them up into small cubical-shaped masses. In the deeper portion of the enamel the prisms appear to cross one another. The membrane of Nasmyth is a delicate membrane composed of keratose (horny) epithelial plates which occur on the surface of the enamel in the very young, becoming worn away as the child becomes older. In chemical composition enamel is somewhat similar to bone, but in enamel the amount of mineral matter is about 96 to 98 per cent., the chief salts being calcium phosphate, fluoride and carbonate.

THE CEMENTUM, or *crusta petrosa,* is found only on the root of the tooth as a covering to the dentinal substance. In structure it resembles compact bone, but does not contain canals. The lamellae are disposed longitudinally around the fangs; between the lamellae are lacunae, which possess numerous canaliculi with well-marked branches. In chemical compostion, as well as in structure, the cementum resembles bone more than either the dentine or enamel does. It contains about 30 per cent. organic matter and about 70 per cent. inorganic matter.

THE DENTAL PULP is somewhat similar to the marrow of bone. It consists of a reticulum of areolar and lymphoid tissue, in which are blood-vessels, nerves, lymphatics, and cells. The cells include lymphoid and "medullary" cells. The *medullary* cells, somewhat similar to the myeloplaxes of marrow, are large protoplasmic masses, which contain usually four or five nuclei, and are generally arranged as a layer on the outer surface of the pulp, being the remains of the odontoblasts of young teeth. Into the dentinal canals the dentinal fibrillae extend from the pulp passing between the medullary cells. These fibrillae, giving off branches, reach the interglobular spaces, where they probably communicate with the contents of the spaces, from which fibrillae extend into the enamel and into the canaliculi of the lacunae of the cementum. Whether the fibrillae are protoplasmic projections from cells contained in the pulp, or nerve fibrils, is as yet an unsettled question. From the manner in which they stain when treated with chloride of gold, and their beaded appearance, they seem to be nerve fibrillae.

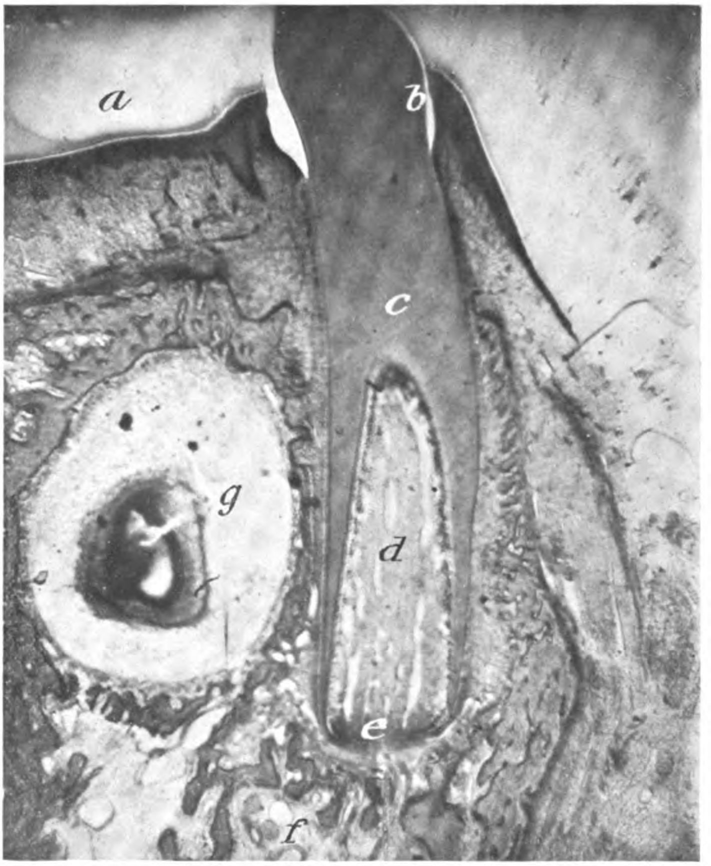
The *blood supply* to the tooth is large. One or more arterioles enter the pulp cavity through the opening in the fang of the tooth, divide into capillaries in the pulp, then form one or more veins, which pass out in the same way as the arteries enter.

The *lymphatics* arise in the clefts of the pulp, and pass out into the neighboring tissue, communicating with the lymph channels of the tissue.

The *nerves* which go to and enter the pulp cavity are of the medullated variety. They lose their medullary sheaths and their axis-cylinders, divide into fibrillae, which are beaded in appearance. The ultimate distribution of the fibrillae is an unsettled question, but probably they extend into the dentinal canals as the dentinal fibrillae to the various portions of the tooth.

Experiment 87. Prepare a longitudinal and a transverse section of a tooth in the same manner as you prepared the specimen of bone. After having mounted

M 35—Microphotograph of a vertical section of a human lip x 45.
a, skin surface; *b*, hair follicles and sebaceous glands in the subcutaneous tissue; *c*, mucous membrane of oral surface; *e*, sections of orbicularis oris muscle.



M 36—Microphotograph of a portion of the jaw of a child x 6.
a, surface of the gum; *b*, enamel at apex of a deciduous or temporary tooth; *c*, dentine; *d*, pulp showing layer of odontoblasts between pulp and dentine; *e*, apical foramen; *f*, maxilla; *g*, the permanent tooth in early stage of its development.

them, examine. Notice the pulp cavity, dentine, enamel, and cementum. Sketch under the low power the outlines of the tooth; under the high power portions of its structure.

Exp. 88. Prepare a thin section of a tooth recently extracted, as in Exp. 87, and put it into a dilute solution of chromic acid (.5 per cent.) for forty-eight hours. Wash with distilled water and stain with haematoxylin. Examine and look especially for the dentinal fibrillae. Sketch.

Exp. 89. Stain with haematoxylin a fresh specimen of dentinal pulp. This may be done by putting the pulp in normal saline solution on a slide and adding the haematoxylin. Cover and examine. Look for the fibrous reticulum, lymphoid cells, nerves, and medullary cells. Sketch.

THE TONGUE.

THE TONGUE is a muscular organ, covered by mucous membrane except at its point of attachment. The organ is divided into two lateral halves by a septum, or raphé, composed of connective tissue. The muscular tissue of which it is composed is of the voluntary variety, the fibres being arranged in bundles which run longitudinally, vertically, transversely and obliquely, some of the muscle fibres branching. Between the bundles of muscle fibres there is a loose network of areolar connective tissue, in which are blood-vessels, nerves, lymphatic vessels and glands.

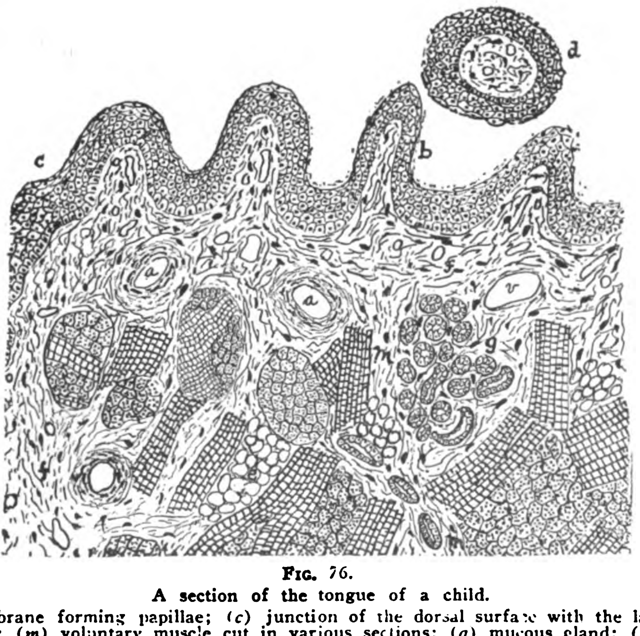


FIG. 76.

A section of the tongue of a child.

(*b*) mucous membrane forming papillae; (*c*) junction of the dorsal surface with the lateral border; (*a*) artery (*v*) vein; (*m*) voluntary muscle cut in various sections; (*g*) mucous gland; (*e*) adipose tissue; (*f*) fibrous tissue; (*d*) a transverse section of a papilla.

THL GLANDS of the tongue are of two kinds, mucous and serous. The mucous glands are of the compound racemose type, are found in the submucous tissue, and are composed of mucous alveoli. The serous glands are found in the submucous tissue and between the bundles of muscle fibres. They are of the com-

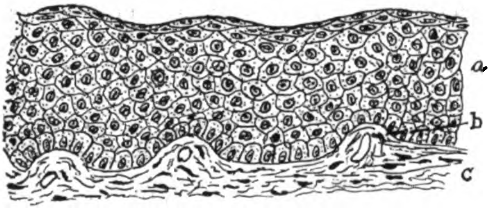


Fig. 77.
The mucous membrane of the under surface of the tongue of a child.
(*a*) stratified squamous epithelium; (*c*) tunica propria; (*b*) microscopic papilla.

pound racemose type, and exist only in the posterior portion of the tongue, especially in the region covered by the circumvallate papillae, their ducts opening in the fossae which surround the papillae.

The mucous membrane of the tongue is divided into two layers, epithelial and fibrous. The epithelial portion consists of stratified squamous epithelium, the lower border of which is thrown into depressions which fit over the papillae of the fibrous layer. The papillae of the tongue are of two kinds, the microscopic and macroscopic. The microscopic papillae are elevations of the outer portion of the fibrous tissue of the tunica propria. The macroscopic are elevations of the mucous membrane. The former variety occurs in all portions of the mucous membrane, while the latter occurs only on the dorsum of the tongue.

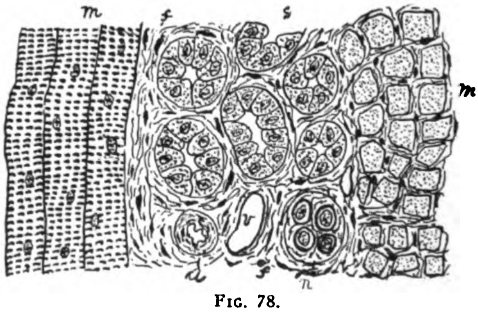


Fig. 78.
A portion of a section of the tongue of a rabbit (posterior region.)
(*m*) voluntary muscle cut longitudinally; (*m'*) voluntary muscle cut transversely; (*s*) serous acini held together by fibrous tissue septa (*f*); (*v*) vein; (*a*) artery; (*n*) nerve.

The macroscopic papillae are of three varieties:

1. Conical, or filiform.
2. Fungiform.
3. Circumvallate.

The conical papillae are the most numerous of the papillae. They are conical in shape, the epithelium of which they are composed becomes keratose at the apex of each cone and projects as filaments of a horny appearance.

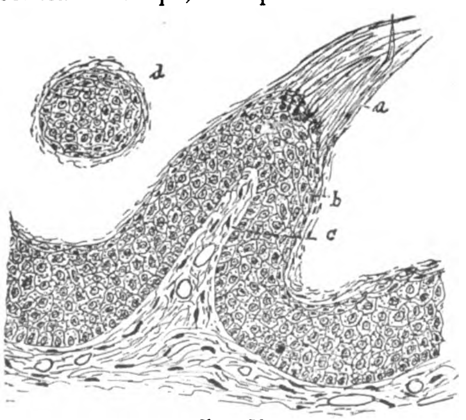
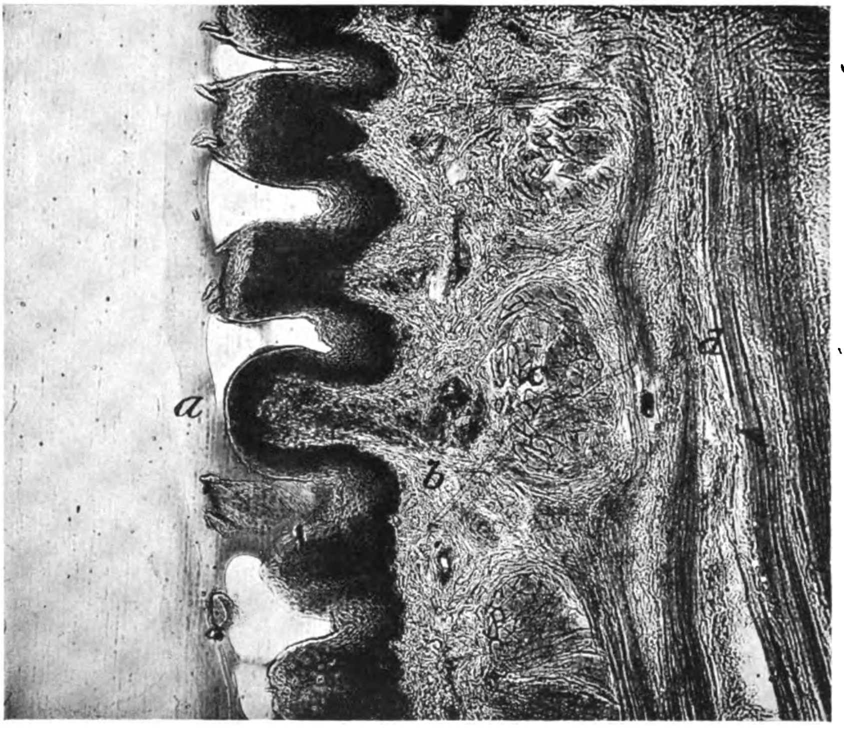


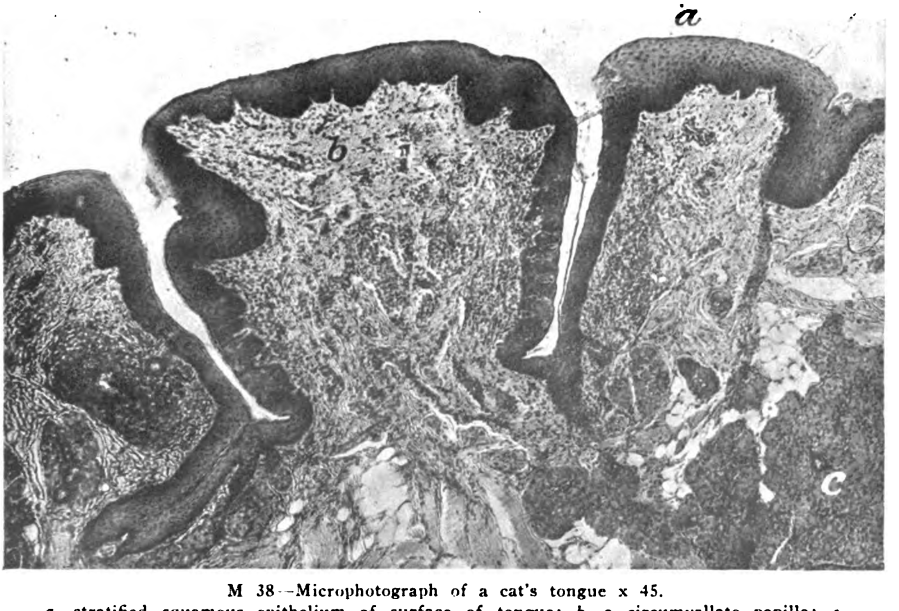
Fig. 79.
Filiform, or conical papilla, of the cat's tongue. (*a*) horny threads due to the keratinization of the upper layers of cells of the mucous membrane (*b*); (*c*) fibrous core derived from the tunica propria; (*d*) a transverse section of one of the papillae.

The Fungiform papillae are bulbous-looking projections of the mucous membrane, consisting of a peripheral portion composed of epithelium, and a central portion composed of fibrous tissue, an extension of the tunica propria. At the base of the fungiform papilla there is a slight depression of the mucous membrane, termed a *fossa*.

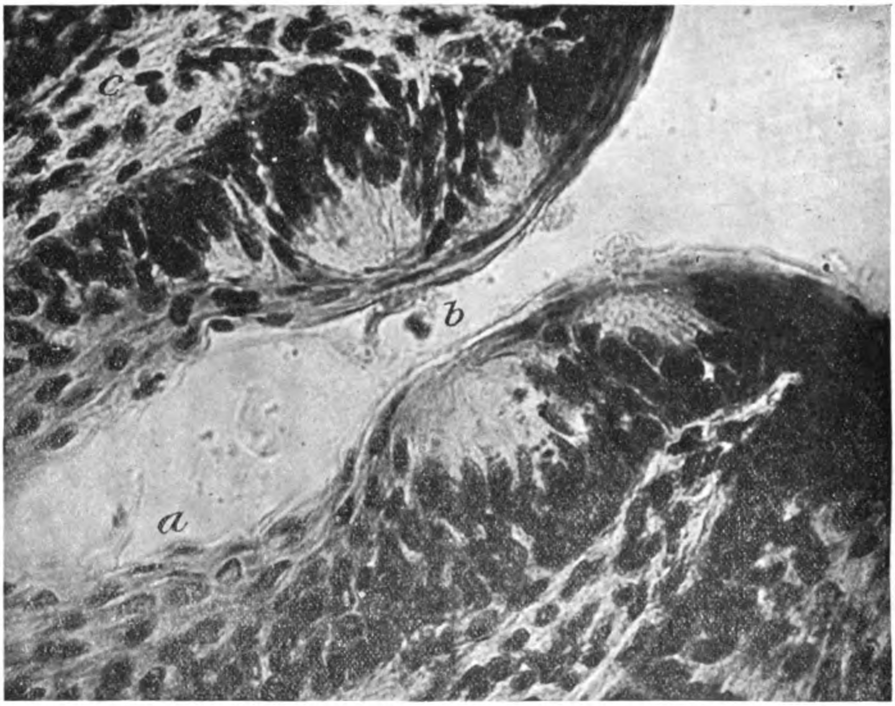
The circumvallate papillae are somewhat similar to the fungiform type. They are about ten in number,



M 37—Microphotograph of a section of the tongue of a cat x 45.
a, fungiform papilla; *b*, submucous connective tissue; *c*, muscle cut transversely; *d*, muscle cut longitudinally.



M 38—Microphotograph of a cat's tongue x 45.
a, stratified squamous epithelium of surface of tongue; *b*, a circumvallate papilla; *c*, mucous gland.



M 39—Microphotograph of a portion of the tongue of a rabbit x 450, illustrating taste bulbs (*b*) in the stratified squamous epithelium (*a*) of the mucous membrane.

and are arranged in two rows, which converge and meet at the foramen caecum of the tongue, forming a V-shaped arrangement, the divergence being toward the apex of the tongue. Each papillae is about $\frac{1}{20}$ inch transversely. Separating the rows of papillae from the vallum there is a depression in the mucous membrane, termed a fossa. The under surface of the epithelium appears corrugated, in order to fit over the papillae of the fibrous tissue which composes the central portion of each circumvallate papilla. The epithelial portion of the lateral boundaries of the papilla contains nerve endings for the appreciation of the sensation of taste, termed *taste-buds*. The taste-buds are not limited to the circumvallate papillae, as they may also be found in the epithelium scattered throughout the mucous membrane of the tongue, and in the mucous membrane of the soft palate and epiglottis. A taste bud is an ovoid or pear-shaped body, which communicates with the exterior by means of a small

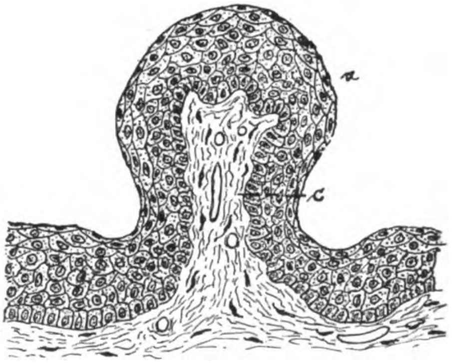


FIG. 80.
A fungiform papilla from the tongue of a rabbit. (*a*) stratified squamous epithelium; (*c*) connective tissue of the unica propria.

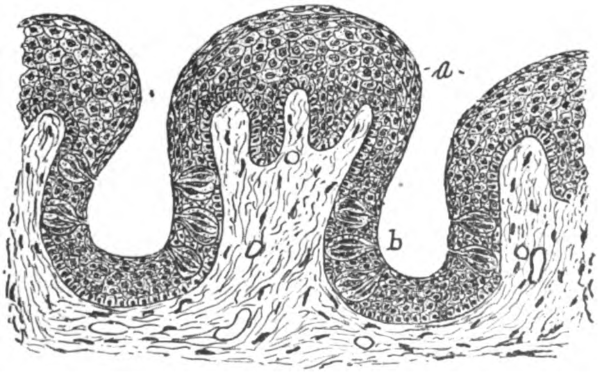


FIG. 81.
Circumvallate papillae of a rabbit's tongue (*a*) stratified squamous epithelium; (*b*) taste-buds.

opening, the *gustatory pore,* on the surface of the tongue. It is composed of cells, *neuro epithelial cells,* which evidently are cells of stratified squamous epithelium, which have been modified for their special function. The cells are of two kinds, *gustatory* and *sustentacular.* The gustatory cells are spindle-shaped, consisting of a body in which there is a large oval nucleus, and tapering ends, the distal of which extends into the gustatory pore. The proximal end is supposed to be continuous with a nerve fibrilla. The sustentacular cells are also spindle-shaped, but are broader than the cells of the other variety, and probably become gustatory cells.

The fibrous portion of the mucous membrane, the tunica propria, consists of white and yellow fibrous tissue, among which, especially at the posterior portion of the tongue, is lymphoid tissue collected into nodules, or follicles. Beneath the tunica propria there is some fibrous tissue continuous with that of the tunica and with that which separates the bundles of muscle fibres from one another, termed the *submucous* layer. To the fibrous tissue of the submucous layer the muscle fibres of the tongue are inserted.

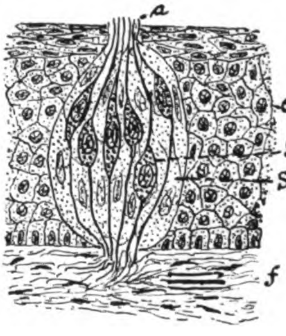


FIG. 32.
A taste bud highly magnified.
(*a*) gustatory pore; (*g*) gustatory cell; (*s*) sustentacular cell; (*f*) tunica propria containing medullated nerve fibres; (*e*) stratified squamous epithelium.

Blood-vessels enter the tongue, and branch, the branches supplying the muscles and the fibrous tissue of the tunica propria.

Lymphatic vessels arise in the clefts of the fibrous tissue, join, and form large channels which pass from the tongue with the blood-vessels.

The *nerves* to the tongue are of the medullated variety, some of the fibres terminating in the muscle fibres as motor end-plates, others in the gustatory cells of the taste-buds.

Experiment 90. Stain and mount a section of a rabbit's tongue, the section having been preferably obtained from the posterior portion. Examine and notice the papillae on the surface, the muscle fibres cut transversely, longitudinally and obliquely, the areolar tissue, blood-vessels, and nerves. Find a taste bud, and examine with the low and high powers. Sketch.

Exp. 91. Prepare a section of the anterior portion of the tongue of a dog or rat, and notice the conical papillae. Sketch.

THE MUCOUS MEMBRANE of the mouth is continuous anteriorly at the outer border of the lips with the skin, posteriorly with the mucous membrane lining the fauces. It consists of two portions, an epithelial and a fibrous. The epithelial portion consists of stratified squamous epithelium. The fibrous portion or tunica propria consists of white and yellow fibrous tissue, densely arranged in the gums, not so densely in the lips, and least dense in the buccal mucous membrane. In the tunica propria there are small mucous glands of the compound racemose variety, which communicate with the free surface by means of ducts which are lined near their orifices by stratified squamous epithelium. The tunica propria possesses

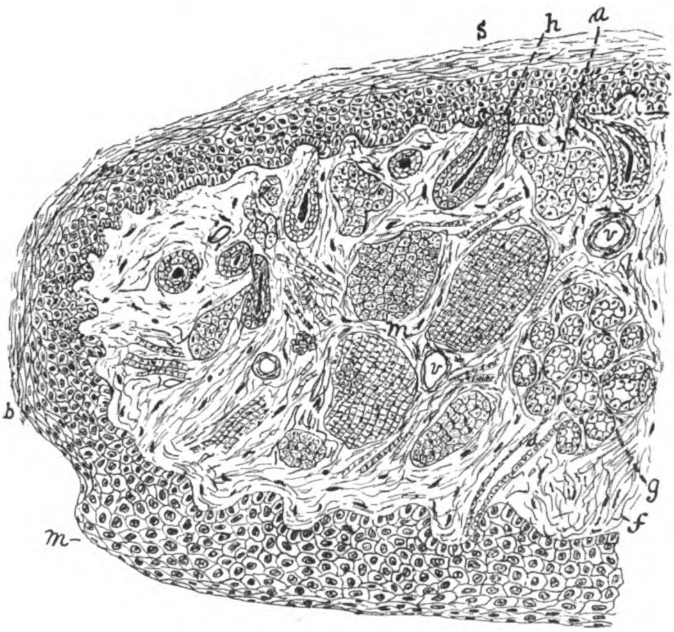


FIG. 83.

A longitudinal section of the upper lip (human).

(*s*) surface of skin; (*h*) hair follicle containing a portion of a hair in the center; (*a*) sebaceous gland; (*m'*) voluntary muscle cut in various sections; (*b*) anterior border showing continuity of the epithelium of the skin with that of the mouth (*m*); (*g*) mucous gland with duct (*d*); (*v*) blood vessels; (*f*) fibrous connective tissue.

papillae, which cause depressions in the lower border of the epithelial covering. The fibrous tissue of the tunica is intimately connected to the periosteum of the palate and maxiliary bones.

The mucous membrane lining the fauces is similar to the buccal mucous membrane, except that it contains a large amount of lymphoid tissue, which is collected into masses or nodules; on each side of the fauces there is an accumulation of lymphoid tissue, so great as to cause a protuberance of the mucous membrane, which is termed the tonsil.

THE PHARYNX.

The pharynx is a musculo-membranous tube extending from the posterior nares and fauces to the oesophagus. It consists of three coats, mucous, fibrous, and muscular.

THE MUCOUS COAT is continuous above with that of the nares and fauces, below with that of the Eustachian tubes, larnyx, and oesophagus. The epithelial portion of the mucous membrane is composed of two varieties of epithelium, that lining the upper portion down to the palate, and extending into the Eustachian tubes, is ciliated stratified columnar; that lining the portion of the pharynx below the hard palate is stratified squamous. The tunica propria of the mucous membrane is composed of white and yellow fibrous tissue, in which there are mucous glands of the compound racemose type termed the *pharyngeal* glands. There is in the tunica a considerable quantity of lymphoid tissue, collected into nodules in the upper portion of the pharnyx, one of which is especially large, and situated between the orifices of the Eustachian tubes, termed the *pharyngeal tonsil.* Beneath the mucous membrane there is a loosely-arranged area of fibrous tissue, which may be regarded as a submucous coat, although there is no line of demarcation between it and the tunica propria.

THE FIBROUS COAT consists of densely-arranged fibrous tissue, termed the *pharyngeal aponeurosis.* Posteriorly it is much thicker than elsewhere, forming the raphé to which the constrictor muscles are attached.

THE MUSCULAR COAT consists of the voluntary variety of muscle. External to the muscular coat there is a sheath composed of areolar connective tissue, which connects the pharynx to the neighboring organs. The *blood-vessels* pierce the outer coats of the pharynx, giving off branches to the muscle fibres, reach the submucous tissue, and form a network from which branches supply the glands and the tunica propria. The *lymphatics* arise in the interfascicular clefts of the fibrous tissue in the various coats. The *nerves* are of both varieties, and besides supplying the muscle fibres they form a subepithelial plexus.

Experiment 92, Stain and mount a transverse section of the pharynx. Examine and notice the muscular tissue, the fibrous coat, and the mucous membrane. Look for lymphoid tissue and pharyngeal glands. Sketch.

THE OESOPHAGUS.

Extending from the lower end of the pharynx to the cardiac end of the stomach there is a musculo-membranous tube, termed the gullet, or oesophagus, which consists of a central opening surrounded by four tunics, or coats.

Mucous coat, or tunica mucosa.
Submucous coat, or tunica submucosa.
Muscular coat.
Fibrous coat.

THE MUCOSA, the innermost of the coats, is continuous with the corresponding coat of the pharynx. It is thrown into folds termed rugae, which disappear when the oesophagus is distended. It consists of three distinct layers:

Epithelial, or inner layer.
Tunica propria, or middle layer.
Muscularis mucosae, or outer layer.

The *epithelial layer* is composed of stratified squamous epithelium. The tunica propria consists of areolar and adenoid tissue. In the lower part of the oesophagus the ***muscularis mucosae*** consists of two layers of involuntary muscle, an inner layer composed of circularly disposed fibres, and an outer layer composed of longitudinally disposed fibres. In the upper part of the oesophagus the muscularis mucosae is not present, but gradually makes its appearance in about the middle portion, and is quite distinct in the lower portion near the cardiac end of the stomach.

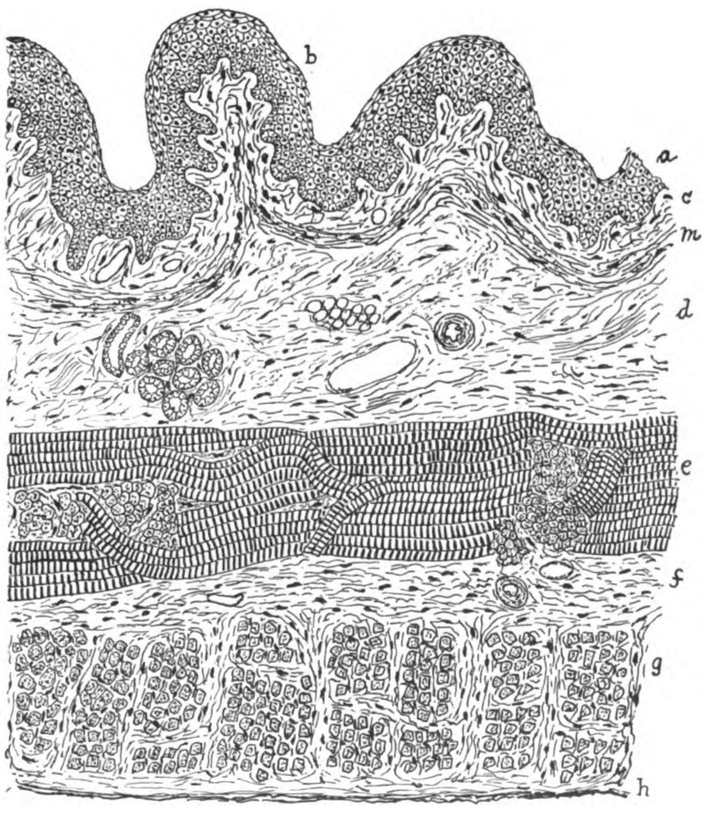


FIG. 84.
A portion of a transverse section of the oesophagus of a child (upper third.)
(*a*) stratified squamous epithelium; (*c*) tunica propria; (*m*) rudimentary muscularis mucosae; (*b*) a ruga; (*d*) submucosa containing blood-vessels, adipose tissue and oesophageal gland; (*e*) inner layer and (*g*) outer layer of muscular coat; (*f*) connective tissue; (*h*) fibrous coat.

In the mucous membrane of the oesophagus, near its junction with that of the cariac end of the stomach, there are a few tubular glands, termed the oesophageal-cardiac glands.

THE SUBMUCOSA, sometimes termed the areolar or vascular coat, consists of an areolar connective tissue network in which ramify blood vessels, lymphatics, and nerves. Mucous glands of the compound racemose variety, termed the

oesophageal glands, occur in the submucosa. The acini of these glands are lined by modified columnar-shaped cells, the nuclei of which are near the basement membrane; the ducts are lined by cuboidal cells, except near the surface of the mucous membrane, where they are lined by an extension of the stratified squamous epithelium of the surface.

THE MUSCULAR COAT consists of two layers of muscular tissue, an inner layer, composed of bundles of circularly-disposed fibres, and an outer layer, composed of bundles of longitudinally-disposed fibres. Between the two layers there is a

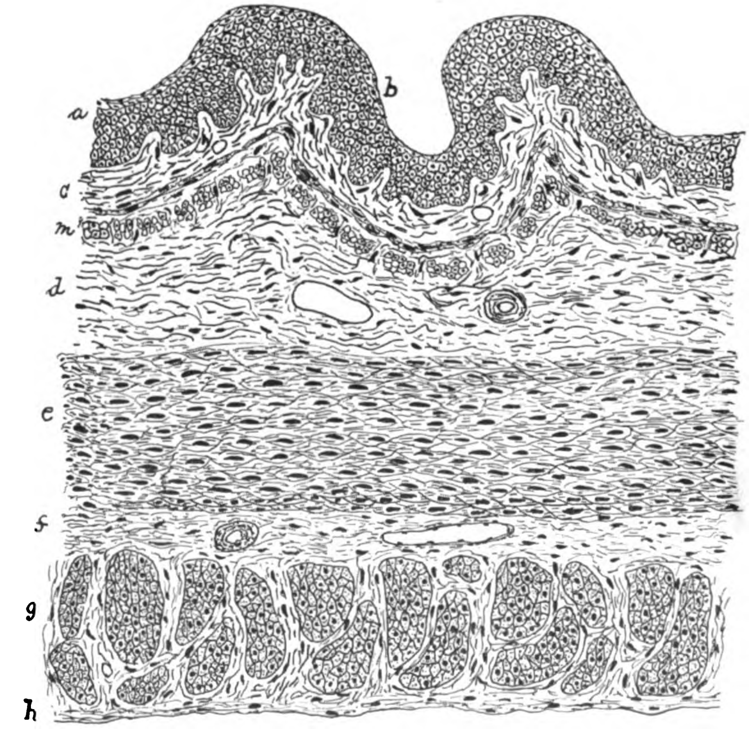
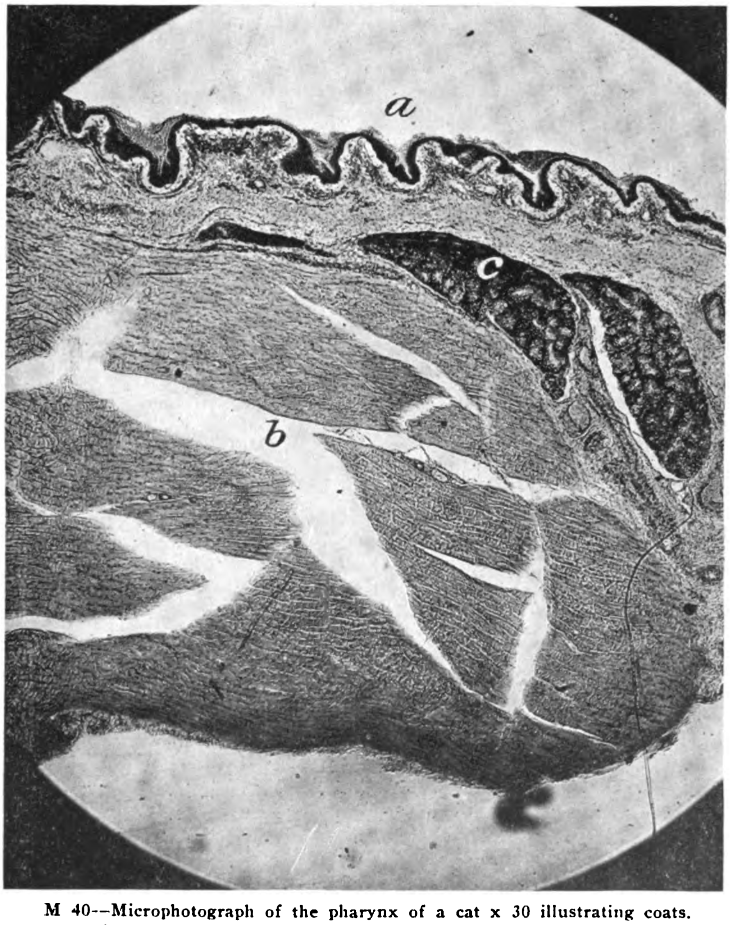


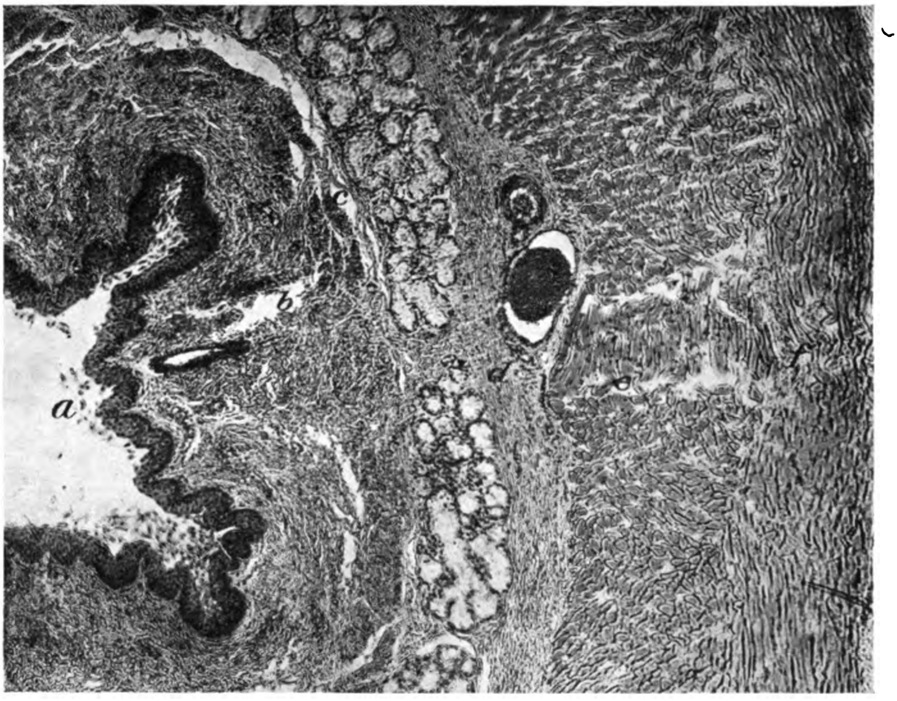
FIG. 85

A portion of a transverse section of the oesphagus of a dog (lower third).
(*a*) stratified squamous epithelium; (*c*) tunica propria; (*m*) muscularis mucosae (longitudinal and transverse sections of involuntary muscle); (*b*) ruga; (*d*) submucosa; (*e*) inner layer, and (*g*) outer layer of muscular coat; (*f*) fibrous connective tissue; (*h*) fibrous coat.

layer of areolar connective tissue continuous with the areolar tissue of the muscular layers, which in turn is continuous with the submucous and fibrous coats. In the upper third of the oesophagus the muscle fibres are of the voluntary variety, in the lower third they are of the involuntary variety, and those of the middle third are of both varieties, there being a gradual diminution and disappearance of the voluntary

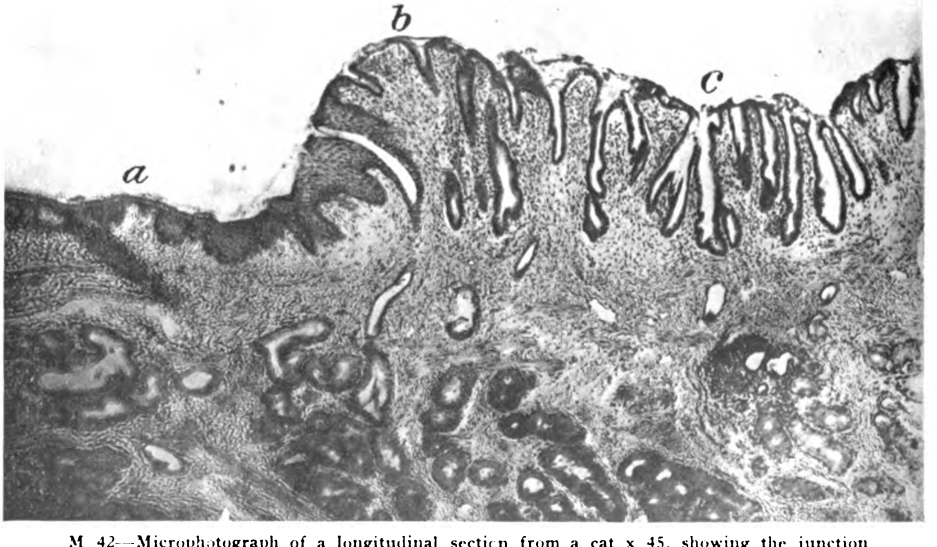


M 40--Microphotograph of the pharynx of a cat x 30 illustrating coats. *a*, mucous membrane; *b*, striated muscle; *c*, mucous glands in submucosa.



M 41--Microphotograph of a longitudinal section of the upper third of the oesophagus of a cat x 50.

a, stratified squamous epithelium of mucosa; *b*, tunica propria of mucosa; *c*, rudimentary muscularis mucosae; *d*, submucosa, submucosa containing oesophageal glands; *e*, inner layer of muscular coat; *f*, outer layer of muscular coat on the outer edge of which is shown a small portion of the fibrous coat.



M 42--Microphotograph of a longitudinal section from a cat x 45, showing the junction of the oesophagus and cardiac end of the stomach.

a, oesophageal portion showing stratified squamous epithelium and oesophageal glands; *b*, the junction showing the cessation of the stratified squamous epithelium, and the beginning of the simple columnar type, and the cardiac oesophageal glands; *c*, cardiac end of the stomach showing compound tubular type of glands.

variety, and a gradual appearance and increase of the involuntary variety from the upper to the lower third.

THE FIBROUS COAT consists of yellow fibrous tissue mixed with a small amount of the white fibrous variety. The fibres are arranged circularly around the oesophagus, some of which are continuous with the areolar tissue of the muscular coat. External to the fibrous coat there is areolar connective tissue, which holds the oesophagus to the neighboring organs.

The *blood-vessels* pierce the fibrous coat, and extend to the submucosa, giving off branches to the fibrous and muscular coats. in the submucous coat the vessels form an anastomosing network, branches from which supply nourishment to the tunica propria. The *lymphatics* arise in the fibrous tissue of the oesophageal coats and accompany the veins from the oesophagus. The *nerves* are of both varieties, and after supplying the other coats form a subepithelial plexus in the mucosa.

Experiment 93. Stain and mount a transverse section of the oesophagus. Examine and notice to which variety the muscular tissue belongs. Look for oesophageal glands and ducts. Notice the mucous membrane thrown into folds or rugae. Sketch.

THE STOMACH.

The stomach is a dilated portion of the alimentary canal, and has four coats, *mucous*,

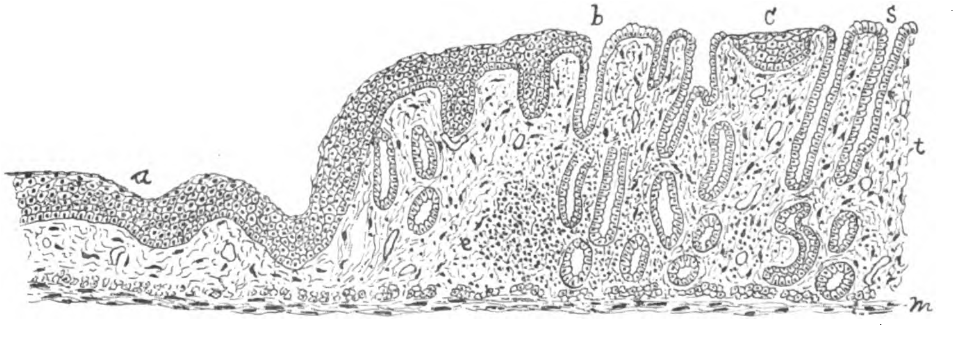


FIG. 80.
A longitudinal section at the junction of the oesophagus and stomach of a cat, showing continuity of mucous membrane.
(*a*) epithelium of oesophagus; (*b*) point of junction; (*c*) small patch of stratified squamous epithelium; (*t*) tunica propria; (*e*) collection of lymphoid tissue (lenticular gland); (*m*) muscularis mucosae; (*s*) oesophageal-cardiac glands.

submucous, muscular and *serous*. The first three are continuous with the corre-

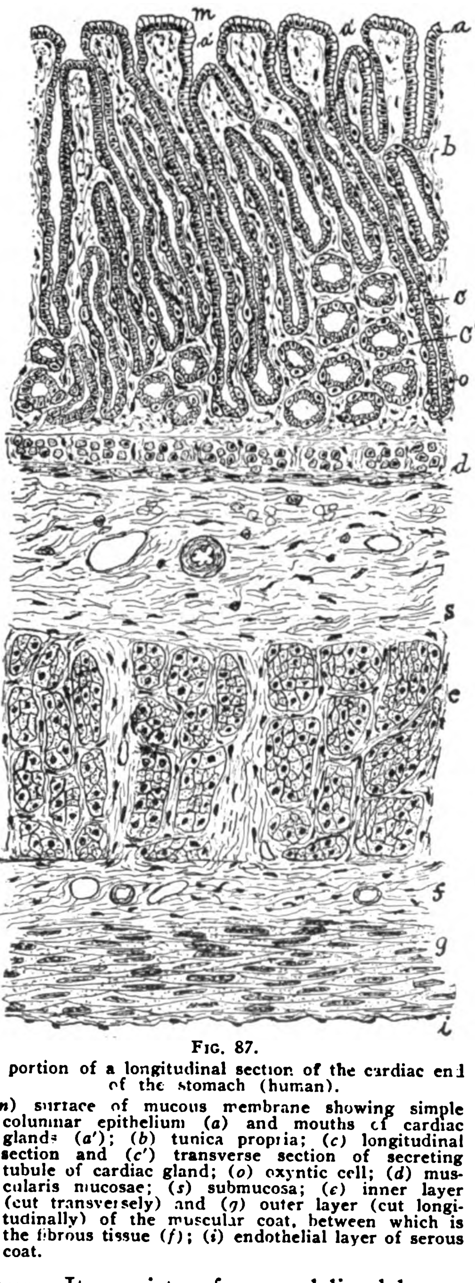
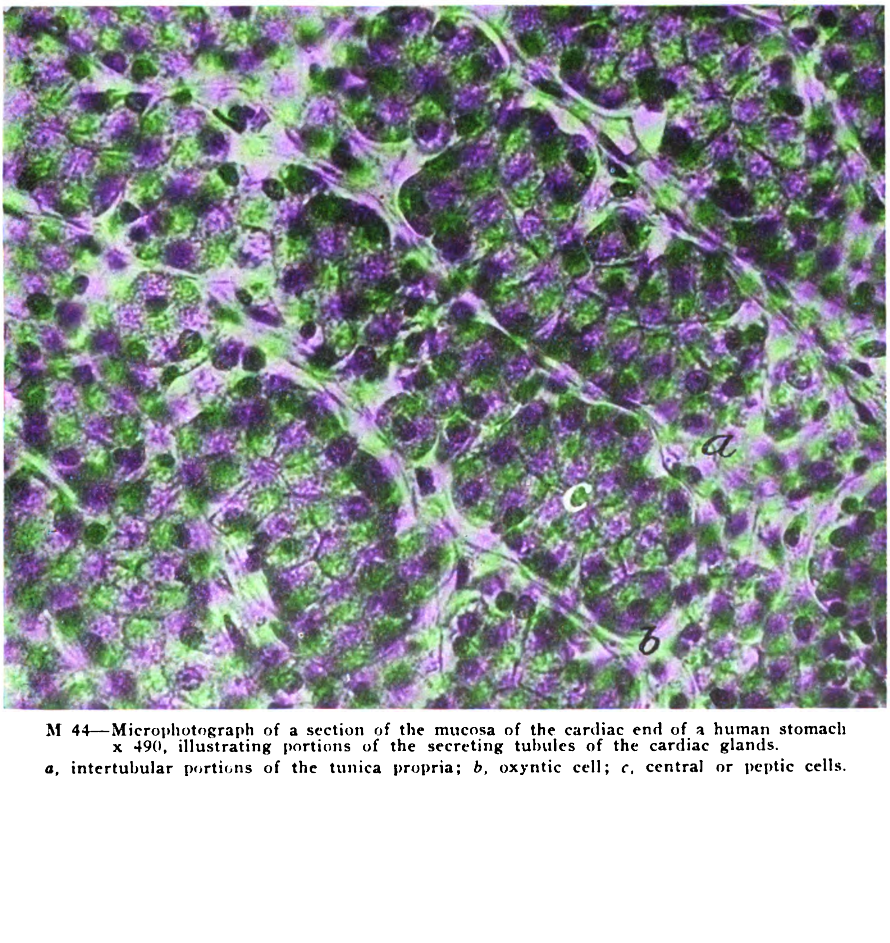


FIG. 87.
A portion of a longitudinal section of the cardiac end of the stomach (human).
(*m*) surface of mucous membrane showing simple columnar epithelium (*a*) and mouths of cardiac glands (*a'*); (*b*) tunica propria; (*c*) longitudinal section and (*c'*) transverse section of secreting tubule of cardiac gland; (*o*) oxyntic cell; (*d*) muscularis mucosae; (*s*) submucosa; (*e*) inner layer (cut transversely) and (*g*) outer layer (cut longitudinally) of the muscular coat, between which is the fibrous tissue (*f*); (*i*) endothelial layer of serous coat.

sponding coats of the oesophagus, while the serous coat is analogous to the fibrous tunic of the oesophagus. The MUCOUS MEMBRANE, the most important of the gastric coats, consists of three portions, the epithelial, the tunica propria, and the muscular. The *epithelial portion* consists of simple columnar epithelium, the cells of which have not a striated border, resting upon a basement membrane, which dips into, or nearly to, the muscularis mucosae, forming the gastric glands. The gastric glands are of two kinds, named according to their principal locations, cardiac and pyloric glands.

THE CARDIAC GLANDS are most numerous at the cardiac end of the stomach, although they may be found in all regions of the gastric mucous membrane except near the pylorus. They are compound tubular glands, arranged perpendicularly to the surface of the mucous membrane. Each gland, resembling in appearance a pair of trousers, consists of a mouth and two secreting tubules. The epithelium lining the mouth of the gland is of the simple columnar type, which becomes cuboidal at the beginning of the tubules. The tubule is long, reaching to, or nearly to the muscularis mucosae, and has an irregular contour. It consists of a canal lined by secreting cells. The canal runs the length of the tubule, terminating below in a blind extremity, above in the mouth of the gland, the portion of the tubule at its junction with the mouth being termed the neck. Lining the canal there is a layer of cells of an irregular quadrilateral shape, each cell containing a nucleus and granular protoplasm. These cells are termed *central* according to their location, *chief* or *peptic* cells on account of

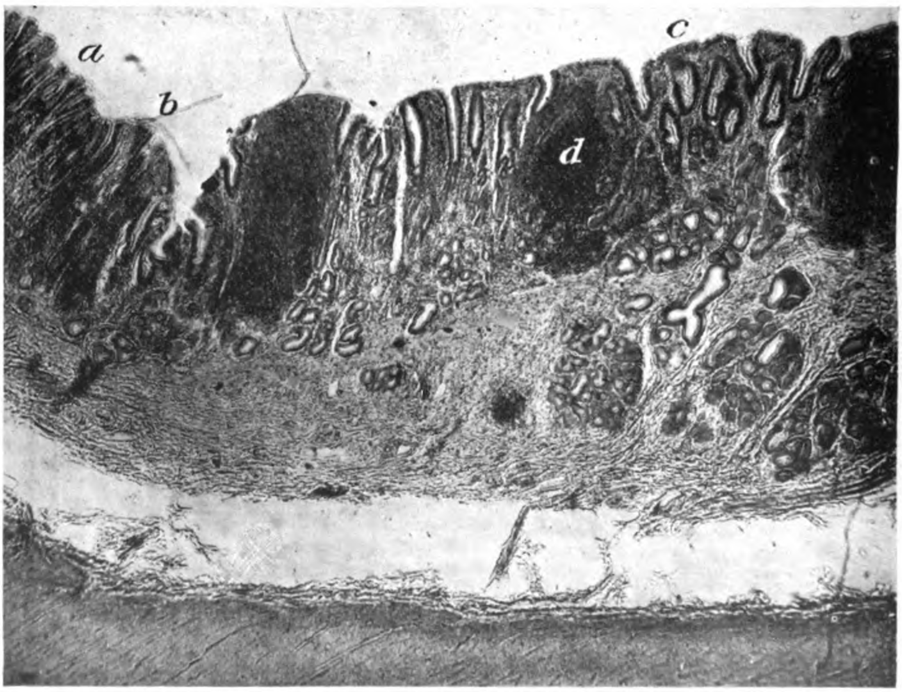
M 43—Microphotograph of cardiac end of human stomach x 40 illustrating the arrangement of the coats of stomach.



M 44—Microphotograph of a section of the mucosa of the cardiac end of a human stomach x 490, illustrating portions of the secreting tubules of the cardiac glands.

a, intertubular portions of the tunica propria; *b*, oxyntic cell; *c*, central or peptic cells.

M 45—Microphotograph of pyloric end of stomach of a cat x 45 illustrating pyloric glands, lenticular glands, and muscularis mucosae.



M 46—Microphotograph of a portion of a longitudinal section of a cat illustrating the junction of pyloric end of the stomach and the duodenum x 18.

a, pyloric end of stomach; *b*, junction, indicated by the sections of ducts in and below the muscularis mucosae; *c*, duodenum with ducts passing through the muscularis mucosae to the Brünner glands in the submucosa.

giving the ferment pepsin. Situated external to the central cells is the other variety, which consists of cells arranged, not in a continuous row, but at irregular intervals, thus causing the irregular contour of the tubules. These cells are ovoid in shape, each containing a nucleus and granular protoplasm, and are termed *parietal* according to their location, *ovoid* on account of their shape, and *oxyntic* (Gr. ὀξύς, acid) because they secrete the hydrochloric acid of the gastric juice. Leading from the canal between two neighboring chief cells to an oxyntic cell, there may in some instances be a clear-looking area, which is probably a means of communication between the oxyntic cell and the lumen of the tubule.

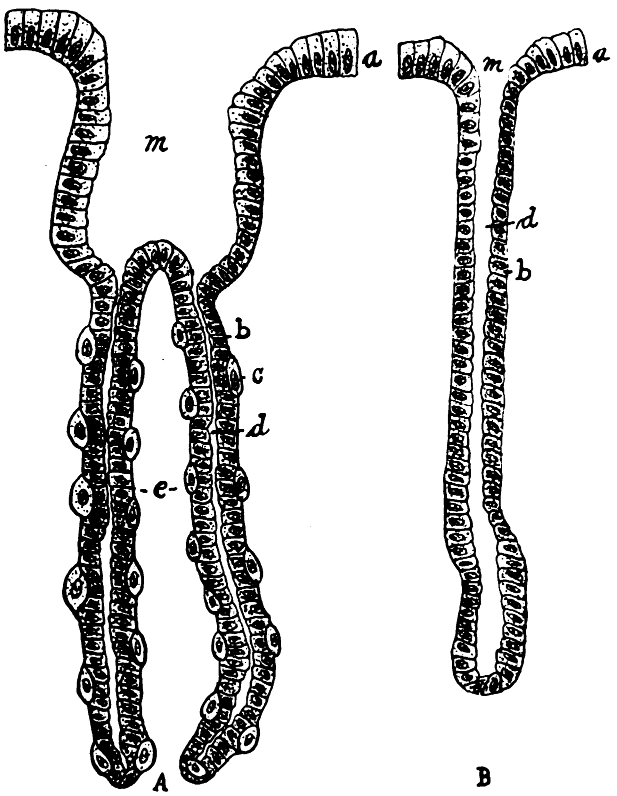


FIG. 88.
Glands of the stomach.
(*A*) cardiac gland; (*B*) pyloric gland; (*a*) epithelial surface of the gastric mucous membrane; (*m*) mouth; (*e*) secreting tubules; (*b*) chief or peptic cells; (*c*) oxyntic cell; (*d*) lumen or canal.

THE PYLORIC GLANDS are simple tubular glands, located principally at the pyloric end of the stomach, and lined by a layer of quadrilateral-shaped cells very similar in appearance to the central cells of the cardiac glands. The cells, owing to their similarity in appearance, and when treated with reagents, to the central cells of the cardiac glands, probably secrete pepsin. The pyloric glands do not contain oxyntic cells. Although usually the cardiac glands are compound tubular, and the pyloric simple tubular, some of the cardiac glands may be simple tubular, and some of the pyloric compound tubular.

THE TUNICA PROPRIA of the mucosa consists of a network of areolar and lymphoid tissue between and around the gastric glands. Scattered about in the tunica propria, but most numerous at the pyloric end of the stomach, are collections or nodules of lymphoid tissue termed *lenticular glands*.

THE MUSCULARIS MUCOSAE consists of two layers of involuntary muscle, the inner of which is composed of fibres disposed circularly; the outer of fibres disposed longitudinally.

THE SUBMUCOSA consists of a network of areolar connective tissue, in which ramify blood-vessels, lymphatics and nerves. The nerves form a sympathetic plexus, the *plexus of Meissner*.

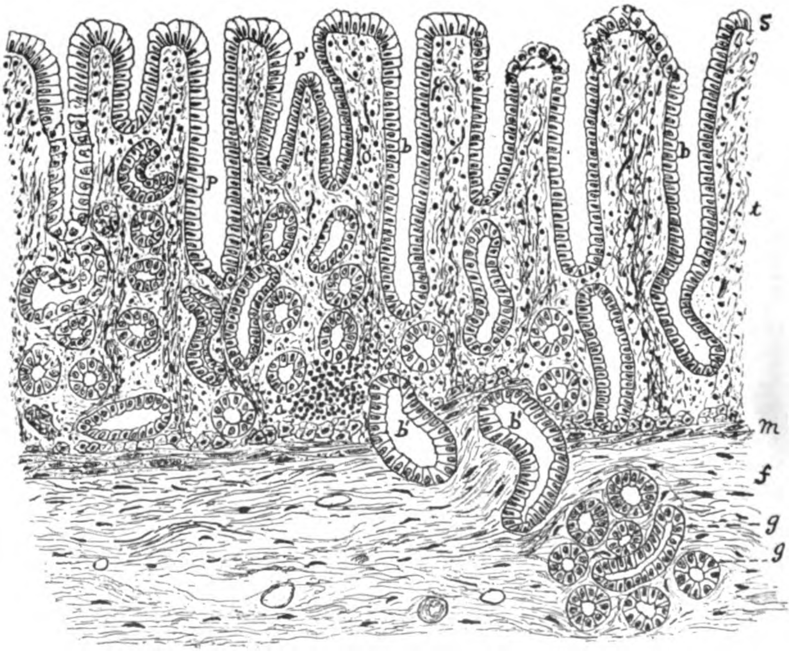


FIG. 89.
Portion of a longitudinal section at the junction of the pyloric end of the stomach with the duodenum, showing the mucous and submucous coats.
(*p*) pyloric gland; (*p'*) pyloric gland of the compound tubular type; (*b*) duodenal glands; (*b'*) sections of ducts of the duodenal glands passing through the muscularis mucosae (*m*) to reach the submucous coat (*f*) to form the glands (*g*); (*s*) surface of mucous membrane; (*t*) tunica propria; (*a*) aggregation of lymphoid tissue, (lenticular gland).

THE MUSCULAR COAT consists of involuntary muscle disposed in two layers, an inner circular and an outer longitudinal; at the fundus there is a third layer consisting of a few oblique fibres internal to the circular layer. Of the two layers the circular is much thicker than the longitudinal, and between them there is a layer of areolar tissue which contains, besides vessels, a sympathetic nerve plexus, the *plexus* of *Auerbach*. At the pylorus the circular fibres become more numerous and form a sphincter, termed the *sphincter pylori*.

THE SEROUS COAT, the most external tunic, is a reflection from the peritoneum, and covers nearly the entire surface of the organ.

In the empty condition of the stomach its mucous membrane is thrown into longitudinal folds, termed *rugae*.

The *blood-vessels* pass to the stomach between the layers of the mesentery, penetrate the muscular coat, giving off branches to the bundles of muscle fibres and the areolar connective tissue between the layers of the muscular coat, and reach the submucosa, where they form a network termed the plexus of Heller, which supplies the tunica propria, glands, and muscularis mucosae.

The *lymphatics* arise in the connective tissue of the gastric coats, and form larger channels which pass out with the blood-vessels.

The *nerves* are of both varieties, the medullated nerves being derived from the pneumogastrics, the non-medullated from the solar plexus. The nerves form a plexus of non-medullated fibres between the layers of circular and longitudinal fibres of muscular coat, termed the *plexus* of *Auerbach*, from which fibres pass to the submucosa and form a secondary plexus, termed the *plexus* of *Meissner*, the fibres of which are smaller than those of the former plexus. From the latter plexus branches pass between the bundles of fibres of the muscularis mucosae, to supply the glands and to form a subepithelial plexus.

Experiment 94. Stain and mount a longitudinal section of the junction of the oesophagus with the stomach. Notice the cessation of stratified squamous epithelium and the appearance of simple columnar epithelium, and tubular glands. Sketch, showing the oesophageal-cardiac, and the gastric cardiac glands.

Exp. 95. Stain and mount a transverse section of the cardiac end of the stomach. Examine and sketch, under the low power, the coats. Under the high power study the structure of the cardiac glands, the muscularis mucosae, and the layers of the muscular coat.

Exp. 96. Stain with Haematoxylin and eosin or with orange G. a longitudinal section of the cardiac end of stomach. Mount and look for under high power, oxyntic cells. Sketch.

Exp. 97. Stain and mount a longitudinal section of the pyloric end of the stomach. Study and sketch the pyloric and the lenticular glands. Compare the appearance of the coats with the appearance of the corresponding coats of the specimen used in the foregoing experiment.

THE SMALL INTESTINE.

The small intestine has four coats, which are similar in nomenclature and disposition to those of the stomach.

THE MUCOUS COAT is the most important of the coats of the small intestine, and consists of an epithelial portion, a tunica propria, and a muscularis mucosae.

The *epithelial portion* consists of simple columnar epithelium, the outer border of the constituent cells being striated. The striated border, or cubicular seam, has not been demonstrated to consist of small canals leading from the free surface for a short distance into the cell-protoplasm, but owing to the fact that the striae occur on an absorbing surface it seems probable that they aid absorption, and are little canals appearing as dark lines when viewed under a microscope.

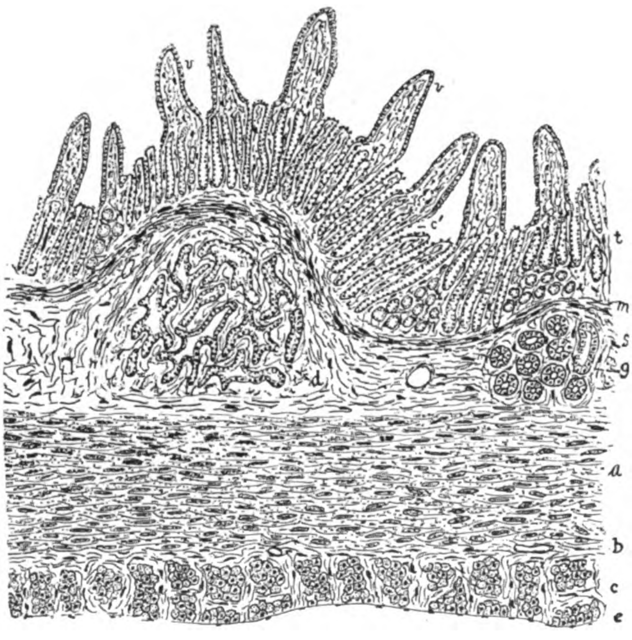


FIG. 90.
A portion of a transverse section of the duodenum of a cat.
(*v*) villi; (*c'*) duct of duodenal gland; (*t*) tunica propria; (*m*) muscularis mucosae; (*s*) submucosa, containing a section of the ductus communis choledochus (*d*) as it is passing through the coats of the duodenum to open on the surface of the mucous membrane along with the pancreatic duct, and a portion of a duodenal gland (*g*); (*a*) inner layer and (*c*), outer layer of the muscular coat; (*b*) connective tissue; (*e*) endothelial layer of serous coat.

The *tunica propria* consists of a network composed of areolar and lymphoid tissue. The *muscularis mucosae* consists of two layers of involuntary muscle, the inner of which is composed of fibres disposed circularly around the intestine, the outer of longitudinally-disposed fibres.

The mucous membrane contains the following important structures:

Villi.
Crypts of Lieberkühn.
Brunner's glands.
Solitary follicles.
Peyer's patches.
Valvulae conniventes.

THE VILLI are finger-like projections of the mucous membrane, which are very numerous (about four million, according to Krause), and give to the mucous membrane a velvety-like surface. They are most numerous and largest in the upper portion of the intestine, and become fewer and smaller in size the nearer they are to the lower end of the small intestine, their average length being about ½ mm.; their diameter about $\frac{1}{20}$ mm.

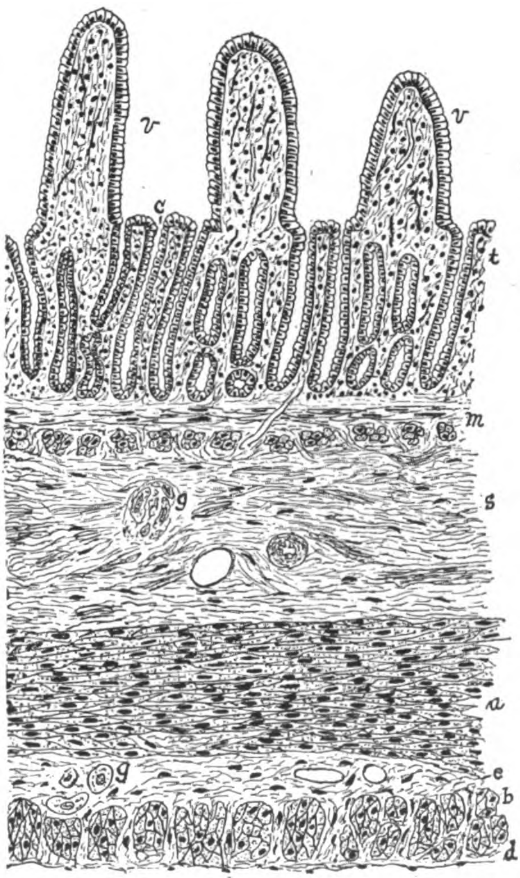


FIG. 91.
Portion of a transverse section of small intestine of a cat.
(*v*) villi; (*c*) crypt of Lieberkühn; (*t*) tunica propria; (*m*) muscularis mucosae; (*s*) submucous coat containing areolar connective tissue, blood-vessels, lymphatics and plexus of Meissner; (*a*) inner layer of muscular coat, the fibres of which are cut longitudinally; (*b*) outer layer of muscular coat; (*e*) areolar connective tissue, between the two layers of the muscular coat and extending between the bundles of muscle fibres of the two layers, containing areolar connective tissue, blood-vessels, lymphatics and plexus of Auerbach; (*g*) ganglion cells; (*d*) serous coat.

A VILLUS consists of an epithelial covering of simple columnar-shaped cells with a striated border, among which are goblet cells; a club-shaped lymph radicle, termed a *lacteal* or *chyliferous* vessel, which is in its central portion; a capillary network, formed by afferent arterioles and forming the efferent veins; involuntary muscle fibres derived from the muscularis mucosae, which run lengthwise of the villus and are connected to the fibres of the network of connective tissue; a connective tissue network composed of areolar and lymphoid tissue.

THE CRYPTS of Lieberkühn, or simple follicles, are simple tubular glands extending perdendicularly from the surface of the mucous membrane to the muscularis mucosae. They occur in the mucous membrane between the villi, and are lined by simple columnar epithelium and goblet cells. Their function is to secrete the intestinal juice, the *succus entericus*.

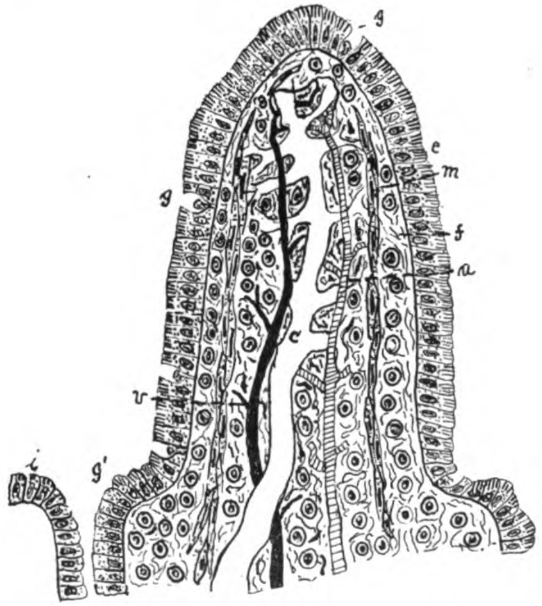
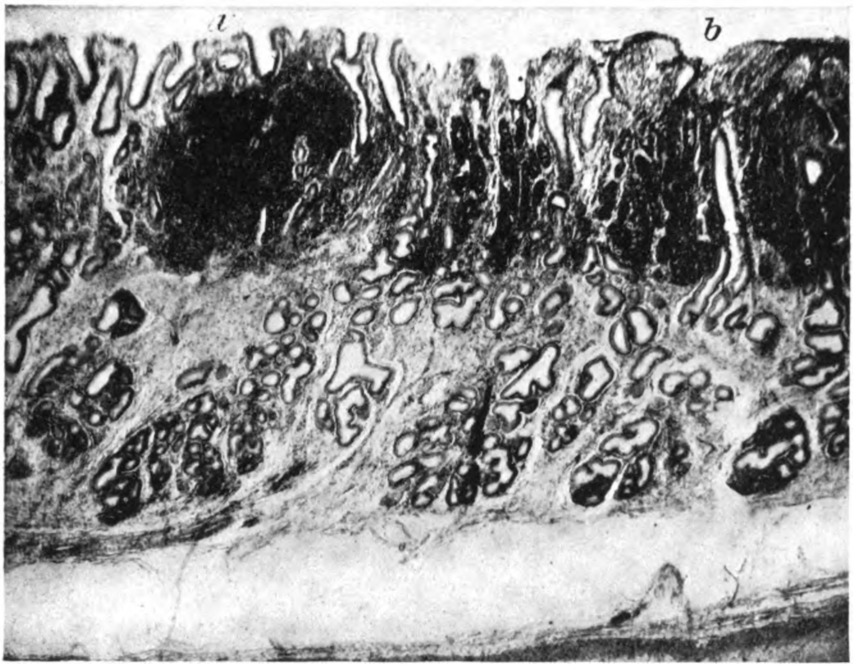


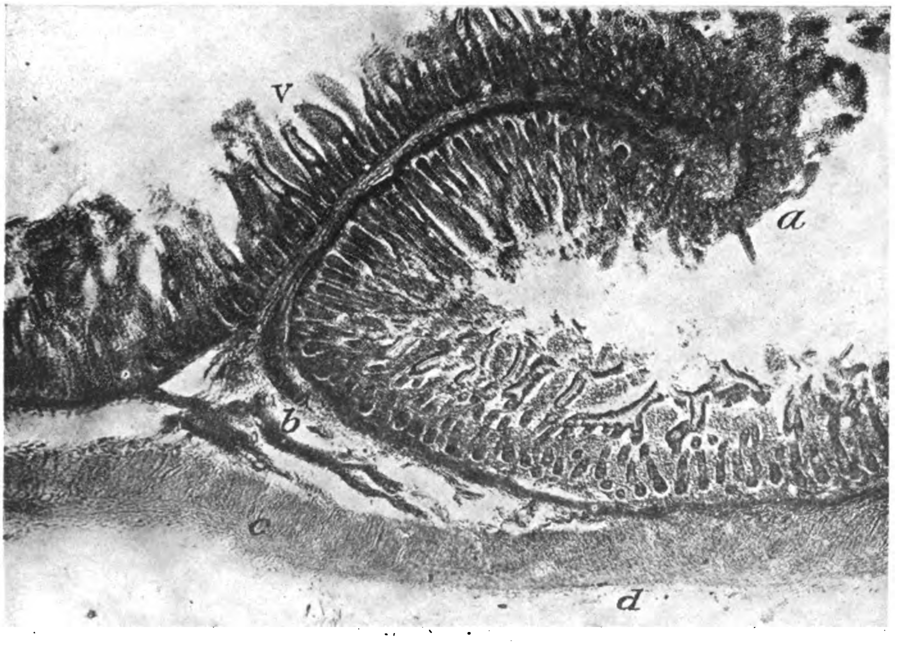
FIG. 92.
A villus of specimen used for Fig. 91, highly magnified and partly diagrammatic.
(*e*) epithelial covering containing simple columnar cells with striated border and goblet cells (*g*); (*f*) tunica propria; (*m*) muscular fibres derived from the muscularis mucosae; (*a*) artery; (*v*) vein; (*c*) lacteal or chyliferous vessel; (*g'*) crypt of Lieberkühn; (*i*) epithelium of the general surface of mucous membrane of the intestine.

THE VALVULAE CONNIVENTES are folds of the mucous membrane and part of the submucosa, and may be as much as two inches in length. The mucous membrane contains villi and crypts. They are not present in the beginning of the duodenum, appearing about two inches from the pyloric end of the stomach, becoming long and numerous in the lower portion of the duodenum and upper portion of the jejunum. At about the middle of the jejunum they begin to decrease in number and size, disappearing in the lower portion of the ileum. Their functions are to retard the onward movement of the intestinal contents and to give a greater surface for absorption.

THE DUODENAL, or Brunner's glands, are limited to the duodenum. They make their appearance as the duodenum begins at the pyloric end of the stomach, becoming numerous in the upper portion, but are entirely absent in the lower portion. They are tubular glands which begin at the surface of the mucous membrane and extend through the muscularis mucosae into the submucosa, where the tubules become coiled upon themselves. They are lined by glandular epithelium of the modified simple columnar variety.

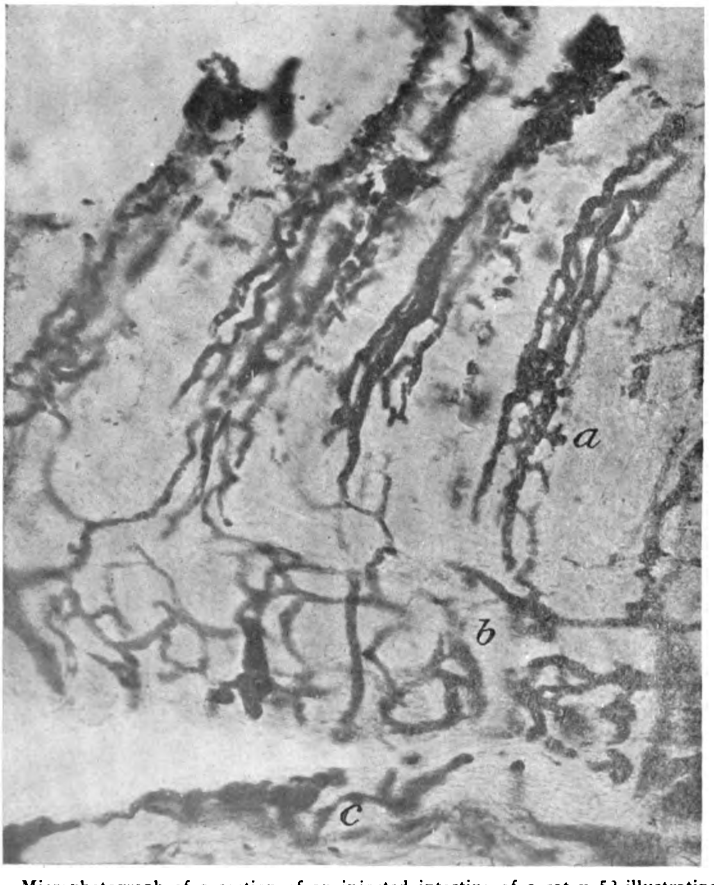


M 47—Microphotograph of the duodenum of a cat x 20.
a, solitary follicle; *b*, duct leading down through the muscularis mucosae to the Brünner's glands in the submucous coat.



M 48—Microphotograph of a longitudinal section of the jejunum of a cat x 20, illustrating a valvula conniventis.
a, mucosa at the tip of valve showing villi and cryps; *b*, submucosa; *c*, muscular coat; *d*, serous coat.

M 49—Microphotograph of a portion of a section of ileum of a cat x 50, illustrating a Peyer's patch.
a, mucosa; *b*, a follicle of the Peyer's patch; *c* submucosa.



M 50—Microphotograph of a section of an injected intestine of a cat x 52 illustrating the distribution of the capillaries.
a, capillary network in a villus; *b*, network in the tunica propria of the mucosa; *c*, network or plexus of Heller in the submucosa.

THE SOLITARY GLANDS are collections of lymphoid tissue, round or oval in shape, occurring in the tunica propria of the intestines. They are most numerous in the ileum, sometimes causing a bulging of the free surface of the mucous

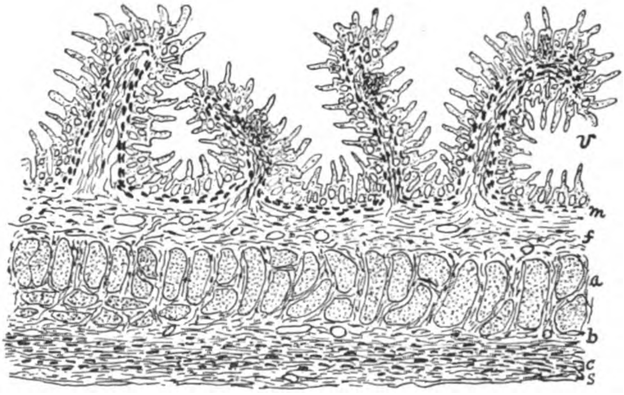


FIG. 93.
A portion of a longitudinal section of the jejunum of a cat, showing valvulae conniventes.
(v) valvulae conniventes possessing villi, crypts and lymphoid aggregations (solitary follicles); (m) muscularis mucosae; (f) submucosa, part of which extends into valvulae conniventes; (a) inner layer (cut transversely) and (c) outer layer, (cut longitudinally) of the muscular coat; (b) fibrous tissue between the two layers of muscle; (s) serous coat.

membrane and encroaching upon the submucosa. They consist of an adenoid tissue network, in the meshes of which are lymphoid cells and capillaries.

THE AGMINATED GLANDS, commonly termed *Peyer's patches,* are collections or aggregations of solitary glands, one patch containing, in some instances, as many as thirty solitary glands. They are from one to four inches long, and are

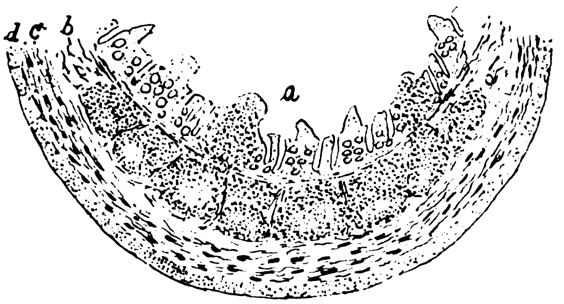


FIG. 94.
A portion of a transverse section of the ileum of a cat (low power).
(a) surface of mucous membrane possessing villi and crypts; (b) submucosa containing agminated gland, or Peyer's patch; (c) inner layer, and (d) outer layer of muscular coat.

most numerous in the ileum. They are located in the mucous and submucous membranes of the *small intestine,* opposite to the amesenteric border.

THE SUBMUCOSA consists of a loose network of areolar connective tissue containing blood-vessels, lymphatics, and a plexus of nerves termed the *plexus of Meissner.*

THE MUSCULAR COAT consists of involuntary muscle disposed in two layers, an inner circular and an outer longitudinal. The muscular coat is thicker in the upper portion of the small intestine than in the lower portion and is comparatively thin in the jejunum. Of the two layers, the inner is the thicker. Between the two layers there is a small amount of areolar tissue, which contains, besides vessels, a nerve plexus, the *plexus* of *Auerbach*.

THE SEROUS COAT is a reflection from the peritoneum, and envelopes the small intestine, excepting portions of the duodenum and the amesenteric border.

The *blood-supply* to the small intestine is abundant. The arteries enter between the layers of the mesentery, penetrate the muscular coat, and form an intermuscular plexus in the connective tissue between the two layers of the muscular coat. Branches from the intermuscular plexus pass through the inner layer of the muscular coat to the submucous coat, wherein they form another plexus, termed the *plexus* of *Heller,* from which branches arise to supply the muscularis mucosae, tunica propria, crypts, duodenal glands, solitary follicles, Peyer's patches, and villi.

Veins arise from the capillary networks, and pass out in the same manner as the arteries enter.

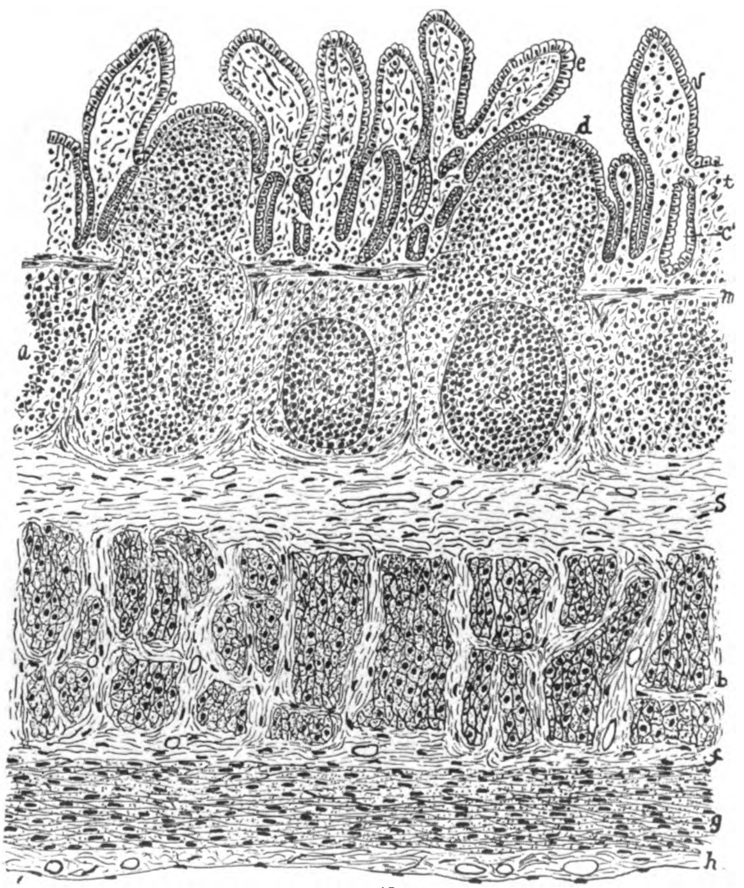


FIG. 95.

Portion of a longitudinal section of the ileum of a cat (high power).

(*e*) epithelial lining of mucous membrane; (*c*) crypt; (*v*) villus; (*t*) tunica propria: (*c'*) section of a crypt; (*m*) muscularis mucosae; (*s*) submucosa containing part of a Peyer's patch (*a*), portions of which extend through the muscularis mucosae and cause a bulging of the free surface (at *d*) of the mucous membrane; (*b*) inner layer (cut transversely) and (*g*), outer layer (cut longitudinally) of the muscular coat; (*f*) areolar connective tissue between the two layers of muscular coat; (*h*) serous coat.

The *lymphatics* arise in the connective tissue of the intestine. The most important origin is in the lymphoid tissue of the tunica propria, in the solitary and agminated glands, and villi. The clefts in the lymphoid tissue of a villus are continuous or communicate with the club-shaped lacteal in its centre.

The *nerves* which pass to the small intestine are of the non-medullated variety, and are derived from the solar plexus of the sympathetic system. The fibres form a plexus between the two layers of the muscular coat, termed the *plexus myentericus* of *Auerbach,* from which fibres pass to the submucosa and form a secondary plexus, the *plexus* of *Meissner,* in which the fibres are smaller and the ganglia less numerous than in the former plexus.

Experiment 98. Stain and mount a longitudinal section showing the junction of the pyloric end of stomach with the beginning portion of the duodenum. Notice the appearance of the Brunner's glands in the submucous coat.

Exp. 99. Stain and mount a transverse section of the lower portion of the duodenum. Examine and sketch the arrangement of the coats. Examine a villus and a crypt, measuring the length of each. Look for Brunner's glands in the submucous coat. Sketch.

Exp. 100. Stain and mount a longitudinal section of the jejunum. Notice the thickness of the coats as compared with the corresponding coats of specimen used in Exp. 99. Notice the valvulae conniventes; the villi and crypts on their surface, and the fibrous core derived from the submucous coat. Look for solitary follicles. Sketch.

Exp. 101. Stain and mount a longitudinal section of the lower portion of the ileum. Examine and study a Peyer's patch. Notice the difference between the villi and crypts when compared with those of the preceding specimen. Sketch.

Exp. 102. Mount an injected section of the small intestines. Examine and study the disposition of the blood-vessels.

Exp. 103. Examine a prepared specimen of the small intestine, showing one of the plexuses of nerves, and sketch.

Exp. 104. Compare the specimens used in experiments 99 and 101. Notice the points of difference, especially the layers of the muscular coat.

THE LARGE INTESTINE.

The large intestine has four coats similar, in nomenclature and disposition, to those of the small intestine. The mucous membrane is covered by simple columnar epithelium, and possesses a well-marked muscularis mucosae divided into two layers, an inner circular and an outer longitudinal. The mucous membrane differs from that of the small intestine in containing only the crypts of Lieberkühn and the solitary glands. The crypts are very numerous and larger than those of the small intestine, and are lined by simple columnar-shaped cells, among which there are numerous goblet cells. The solitary glands occur in the upper portion of the large intestine, being present in the submucous and mucous coats.

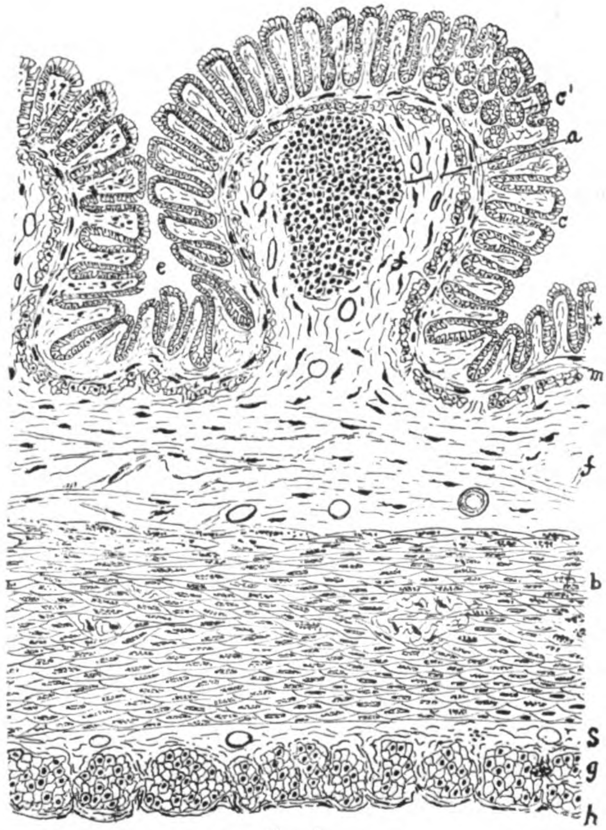
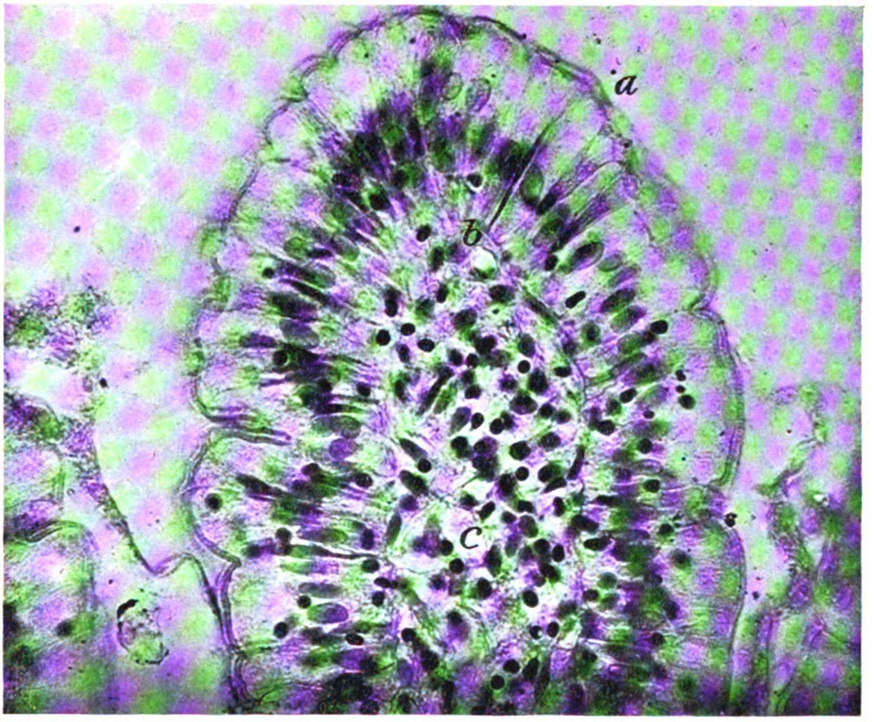


FIG. 96.
A portion of a transverse section of the large intestine.
(*c*) crypt of Lieberkühn cut lengthwise; (*c'*) crypt cut transversely; (*t*) tunica propria; (*m*) muscularis mucosae; (*f*) submucosa; (*a*) solitary follicle; (*b*) inner layer, and (*g*), outer layer of muscular coat; (*s*) areolar tissue between the two layers of the muscular coat, (*h*) serous coat; (*e*) depression between the rugae.

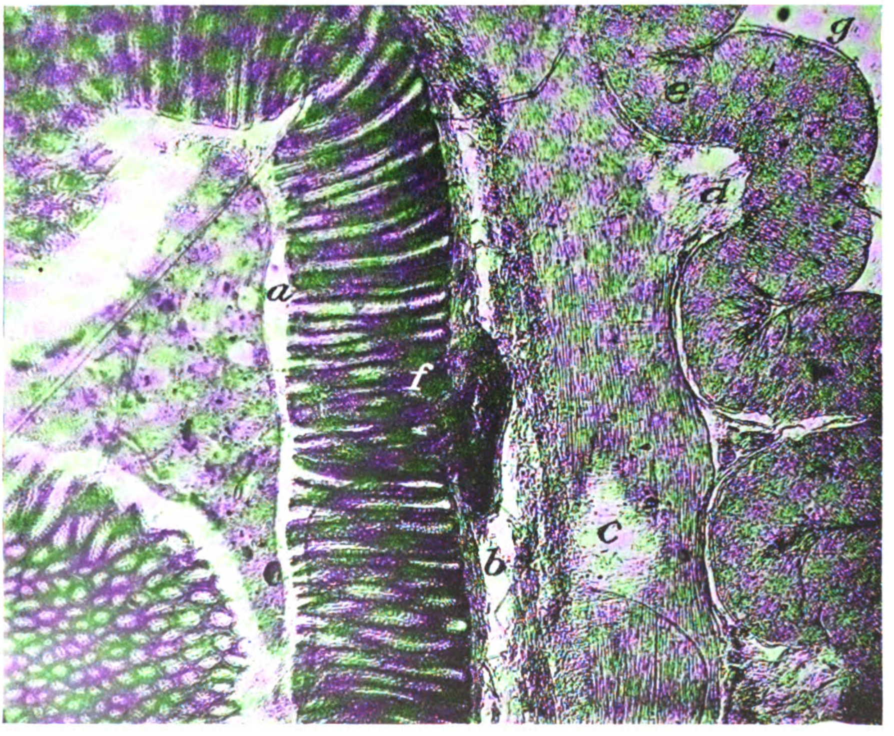
The submucosa is similar to that of the small intestine.

The muscular coat is composed of involuntary muscle disposed in two layers, an inner circular and an outer longitudinal, the fibres of the former layer increasing in number at the lower portion of the rectum to form the internal sphincter ani. The outer layer is composed of longitudinal fibres, which are arranged in bands; the fibres in the caecum and colon being about one-half as long as the remaining coats, cause the sacculated appearance so characteristic of the caecum



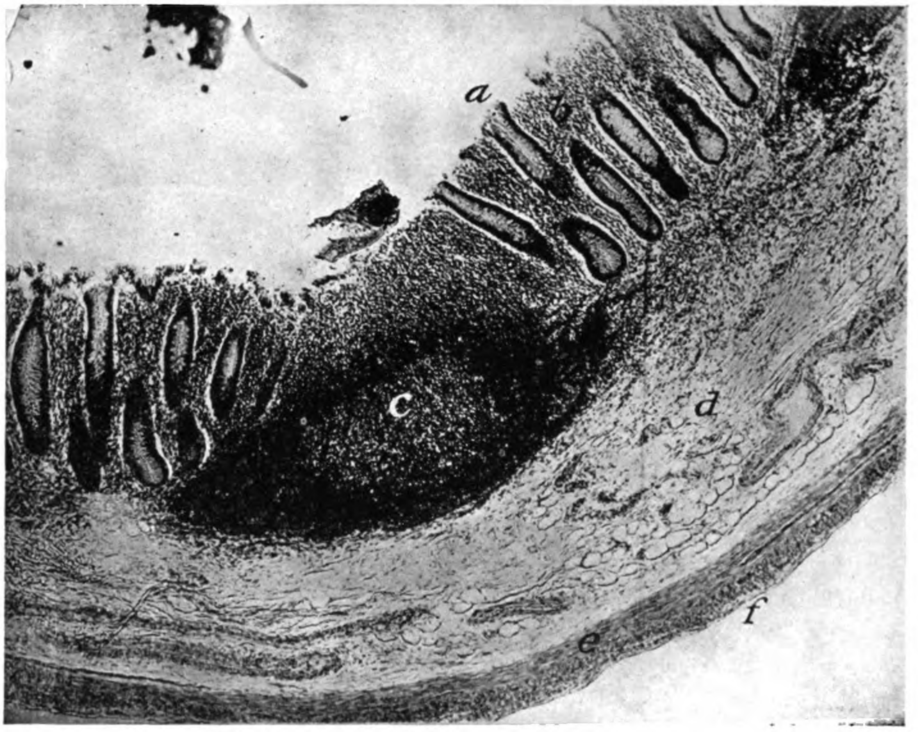
M 51—Microphotograph of an intestinal villus x 390.

a, epithelial portion of the mucosa, illustrating the simple columnar epithelial cells and their striated border and goblet cells, one of which is especially distinct at the lower part of the left border of the villus; *b*, transverse section of a capillary blood vessel near the membrana propria; *c*, tunica propria showing connective tissue, lymphoid cells, and vessels.



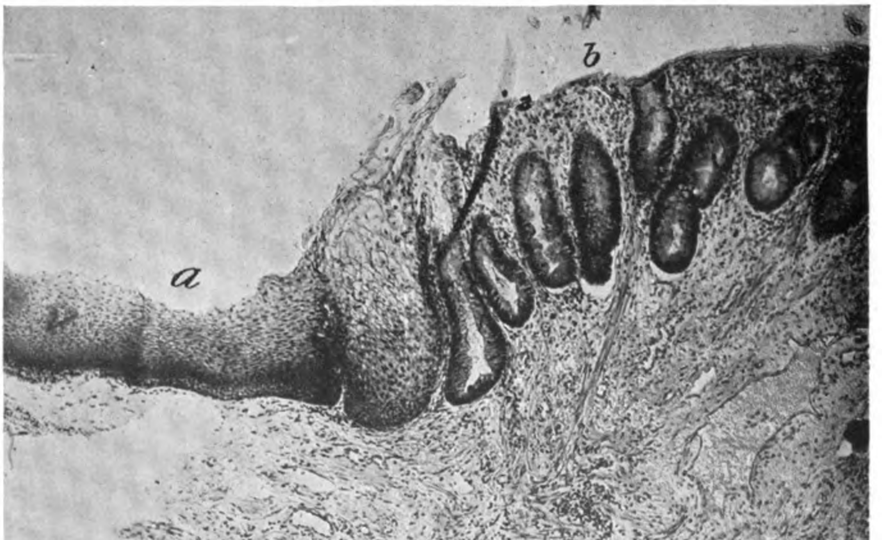
M 52—Microphotograph of a portion of a transverse section of the large intestine of a cat x 35, illustrating the arrangement of the coats.

a, mucosa with crypts of Lieberkühn; *b*, submucosa in which is a solitary follicle (*f*); *c*, inner layer, and *e*, outer layer of the muscular coat, separated by layer of connective tissue (*d*); *g*, serous coat.



M 53—Microphotograph of a portion of a transverse section of a child's appendix vermiformis x 35.

a, crypt of Lieberkühn; *b*, tunica propria of the mucosa; *c*, solitary follicle; *d*, submucosa; *e*, muscular coat; f, serous coat.



M 54—Microphotograph illustrating the junction of the rectum and anus of a cat x 55.

a, stratified squamous epithelium of mucous membrane of the anus; *b*, lower end of the rectum showing crypts.

and colon. The puckering of the muscular coat causes a puckering of the serous coat; the pouches thus formed are filled with fat, forming the ***appendices epiploicae***.

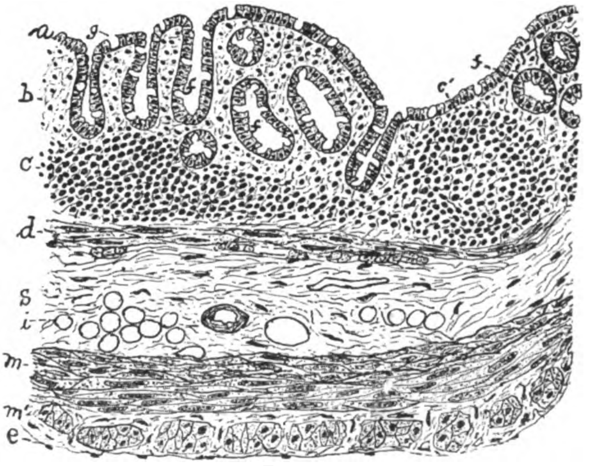


FIG. 97.
Portion of a transverse section of the vermiform appendix of a child.
(*a*) epithelial portion of the mucous membrane consisting of simple columnar cells and goblet (*g*) cells; (*b*) tunica propria; (*f*) crypts of Lieberkühn cut longitudinally, obliquely, and transversely; (*c*) lymphoid tissue, (*c'*) solitary follicle; (*d*) muscularis mucosae; (*s*) submucous coat; (*i*) adipose tissue; (*m*) inner layer, and (*m'*) outer layer of muscular coat; (*e*) serous coat.

The lymphatic, blood and nerve supplies are similar to those of the small intestine.

The VERMIFORM APPENDIX being a portion of the large intestine is made up in the same manner with a large amount of lymphoid tissue in the mucous coat; the lymphoid tissue in some cases being so great as to simulate in appearance an agminated gland. The muscular coat is very thin due to lack of use.

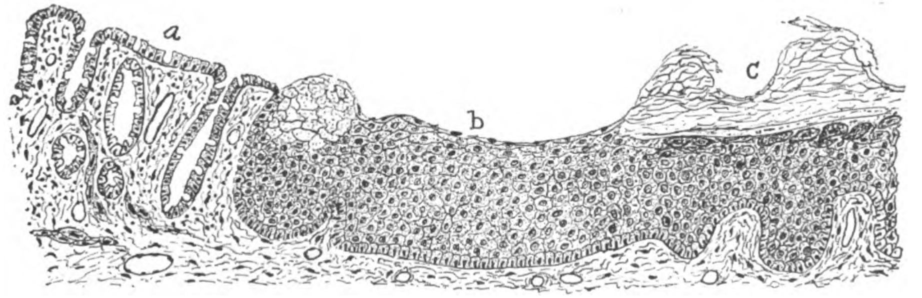


FIG. 98.
Portion of a longitudinal section of the lower portion of the rectum (human) showing continuity of the mucous membrane of rectum with that of anus, and that of the anus with the skin just beyond.
(*a*) rectal mucous membrane; (*b*) anal mucous membrane; (*c*) skin.

Experiment 105. Stain and mount a section (transverse) of the upper portion of the large intestine. Examine and notice the rugae of the mucous membrane, the crypts of Lieberkühn, the goblet cells, and the outer layer of the muscular coat. Sketch.

Exp. 106. Stain and mount a longitudinal section of the large intestine. Examine and look for a solitary gland. Sketch.

Exp. 107. Stain and mount a transverse section of the vermiform appendix. Notice the large amount of lymphoid tissue present in the mucous and submucous coats, and the thin muscular coat. Sketch.

Exp. 108. Stain and mount a longitudinal section of rectum in the region of the anus. Notice the crypts in the rectum, the stratified squamous epithelium of the anus, and the layers of the skin beyond the anus.

THE LIVER.

The liver is a compound tubular gland, the excretory duct of which is the hepatic duct. The tubular arrangement, although not well shown by the human liver, is shown by the gland of some of the lower forms of animal life, especially the frog. It has two coats, the outer of which is a reflection from the peritoneum termed the serous coat, the inner a fibrous coat. The *serous* coat forms a complete covering to the organ, being absent at the attachments of the ligaments and at the bottom of the fissures. The *fibrous* coat is composed of densely-arranged white and yellow fibrous tissue, the former variety predominating, and forms a complete covering beneath the serous coat. The fibrous coat sends projections,

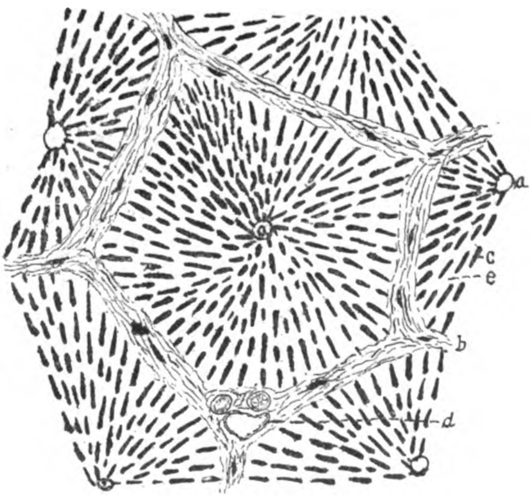


FIG. 99.
Portion of the liver of the pig to show the lobular arrangement, consisting of one lobule surrounded by portions of five others.
(*a*) intralobular vein; (*c*) cords of liver cells radiating toward centre of lobule; (*e*) intralobular capillaries; (*b*) fibrous tissue of the interlobular spaces in which is a section of a portal canal (*d*).

termed *trabeculae,* into the substance of the liver, and accompanies the vessels entering the liver at the transverse fissure as a reticular capsule termed the *capsule of Glisson.* The capsule divides and subdivides, the divisions accompanying the branches of the vessel; ultimately the capsular fibrous tissue blends with that of the trabeculae sent in from the periphery of the liver. In this manner the liver is divided up into smaller portions, termed *lobules.* The lobules are not well

FIG. 100.

Diagrammatic representation of the liver.

a, interlobular artery; *v*, interlobular vein; *b*, interlobular bile duct; *c*, intralobular capillaries; *d*, bile capillaries; *e*, group of liver cells; *i*, intralobular vein.

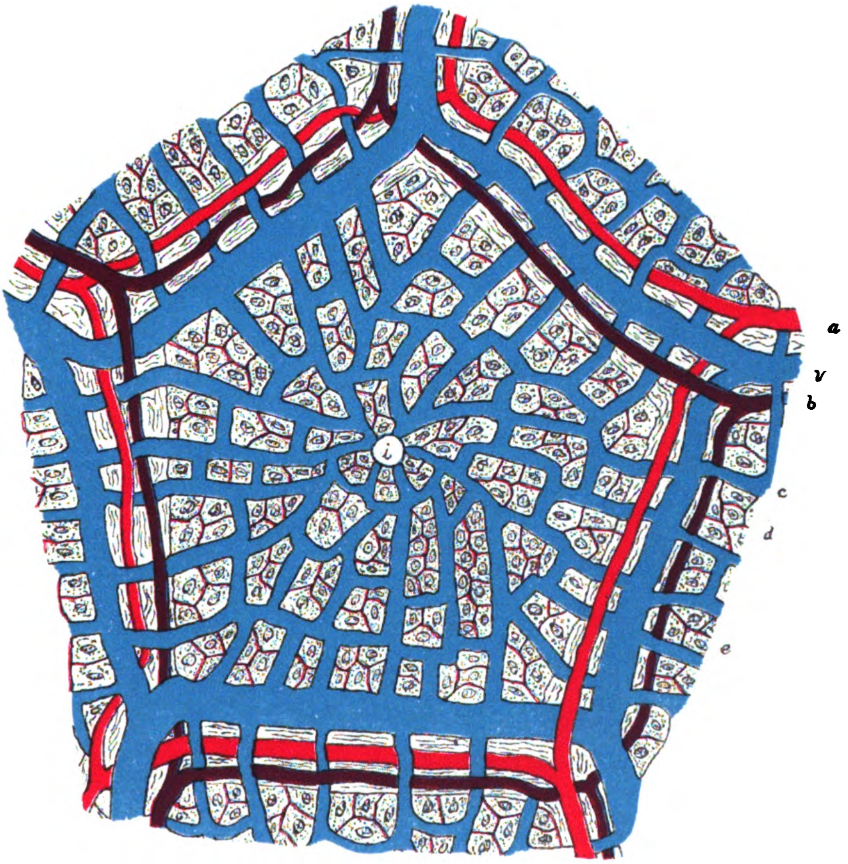


FIG. 100

shown by the human liver, except in the very young child, but are well shown by the pig's liver. They vary from $\frac{1}{20}$ to $\frac{1}{10}$ inch in diameter, and appear polygonal (usually pentagonal or hexagonal) in transverse section and quadrilateral in vertical section. In shape they resemble somewhat inverted truncated pyramids. The spaces between the lobules, the *interlobular spaces,* contain four sets of vessels, enclosed and held together by extensions of Glisson's capsule, which are:

The branches of the portal vein, termed the interlobular veins.

The branches of the hepatic artery, termed the interlobular arteries.

The branches of the hepatic duct, termed the interlobular ducts.

The branches of the lymphatic vessels, termed the interlobular lymphatics.

A lobule contains hepatic cells, blood capillaries, bile capillaries and a central vein. The hepatic cells vary in size, from $\frac{1}{2000}$ to $\frac{1}{1000}$ inch in diameter, are polygonal in shape, and each one is composed of a mass of protoplasm in which is one and sometimes two nuclei, each nucleus containing one or more nucleoli. The cells are enclosed by a thin cell wall, and are arranged in groups radiating from the center of the lobule toward the periphery. The protoplasm of the liver cells contains some fat and glycogen. The bile capillaries arise between the liver cells, the walls of the capillaries being formed by depressions in adjoining cells, join one another, and empty into the interlobular bile ducts. In the center of the lobule there is a vein, termed the *intralobular or central vein,* toward which the blood capillaries, the *intralobular capillaries,* derived from the *interlobular vein,* converge. The intralobular vein runs in the centre of the lobule from the base towards its apex, receiving the intralobular capillaries, and empties into a vein at the apex termed a *sublobular vein.*

FIG. 101.
Portion of a section of the human liver.
(*a*) liver cells; (*b*) bile capillaries; (*c*) intralobular (blood) capillaries containing colored corpuscles and leucocytes; (*d*) group of liver cells enclosing a capillary.

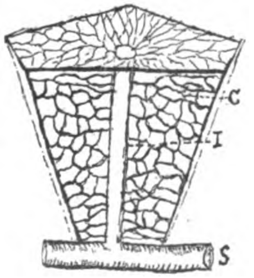


FIG. 102.
Diagrammatic representation of a vertical section of a lobule of the liver.
(*c*) intralobular capillaries; (*i*) intralobular vein; (*s*) sublobular vein.

THE BLOOD VESSELS OF THE LIVER.—The *portal vein* enters the liver at the transverse fissure and gives off branches, termed the *interlobular veins,* which pass between the lobules. From the interlobular veins capillaries, termed the *intralobular capillaries,* pass into the lobules, forming an anastomosing network; the vessels, converging toward the centre of each lobule, enclose the cords of liver cells and empty into the central vein, termed an *intralobular vein,* which empties into a *sublobular vein.* The sublobular vein join to form the hepatic veins. The hepatic veins occur as channels in the substance of the liver, and not with the interlobular vessels, their walls, on account of being in close union with the liver-cells, remain open after death.

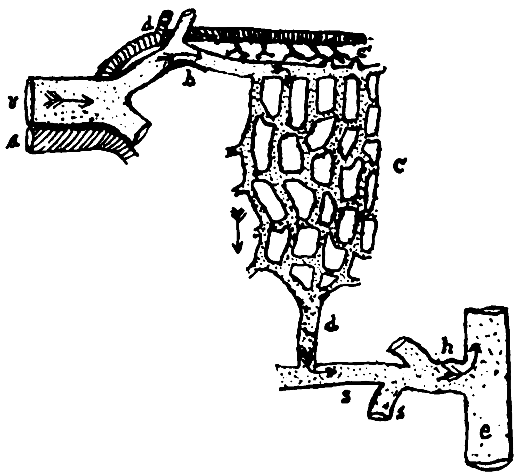
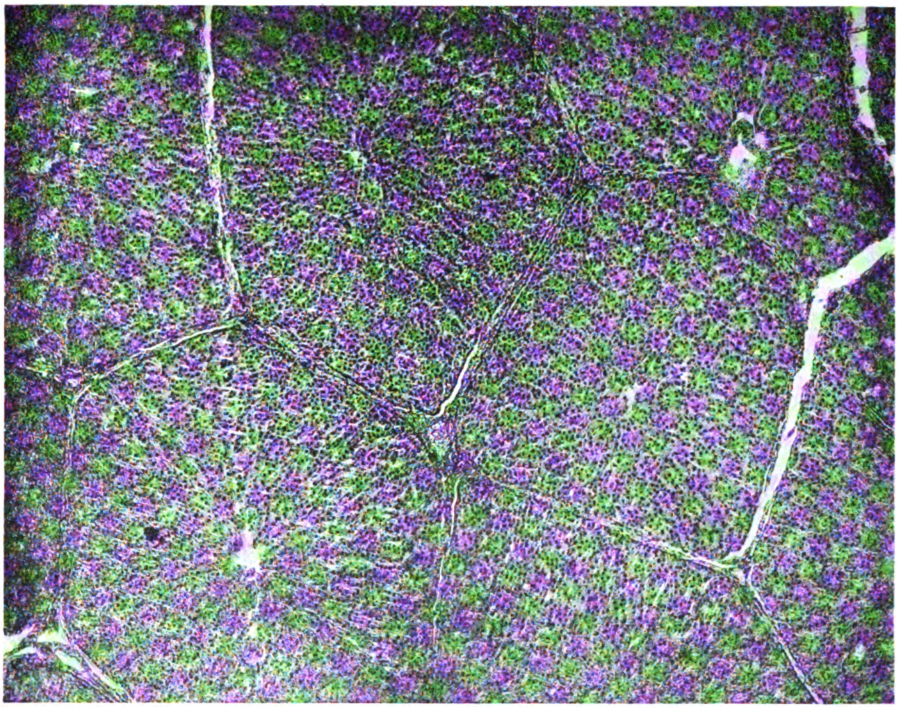


FIG. 103.
Schematic representation of the circulation through the liver.
(*a*) hepatic artery; (*v*) portal vein; (*b*) interlobular vein; (*d*) interlobular artery; (*c*) intralobular capillaries; (*c'*) interlobular capillaries; (*d*) intralobular vein; (*s*) sublobular vein; (*h*) hepatic vein; (*e*) ascending vena cava.

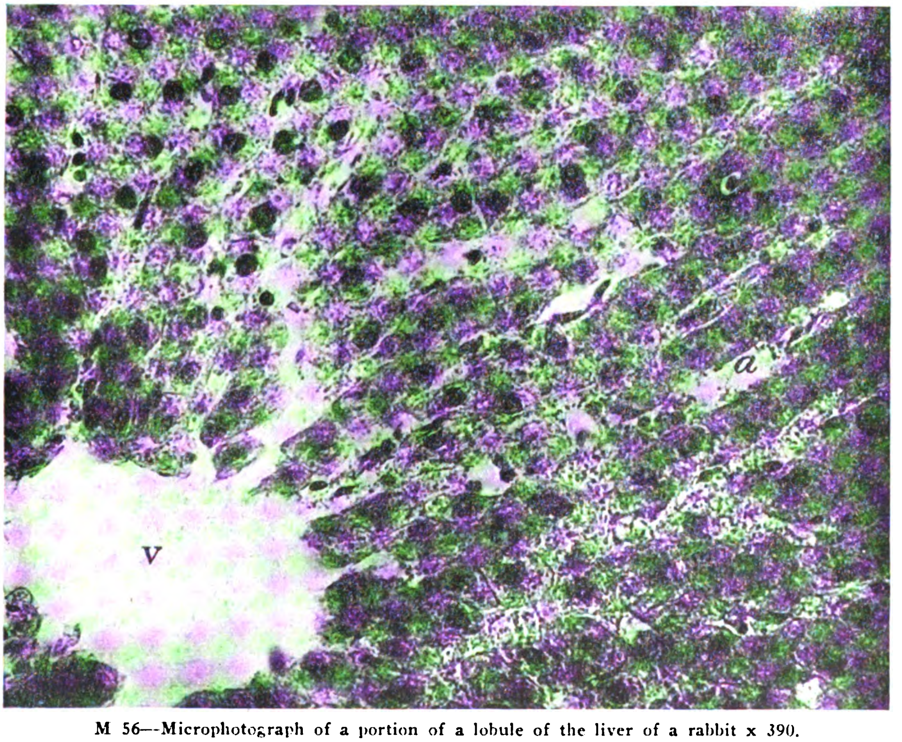
The hepatic veins occur as three main channels, in addition to numerous small ones, all of which empty into the inferior vena cava.

The *hepatic artery* enters the liver at the transverse fissure, and divides into branches, some of which supply nourishment to the capsule of Glisson, and are termed vaginal branches; some supply the capsule of the liver, termed capsular branches; the others become *interlobular arteries,* which give off capillaries, the *interlobular capillaries,* which supply nourishment to the interlobular spaces and anastomose with the intralobular capillaries. Thus the intralobular capillaries contain blood brought to the liver by the portal vein and by the hepatic artery. The blood derived from the hepatic artery, after it reaches the intralobular capillaries, passes from the liver by means of the same channels which convey the blood derived from the portal vein.

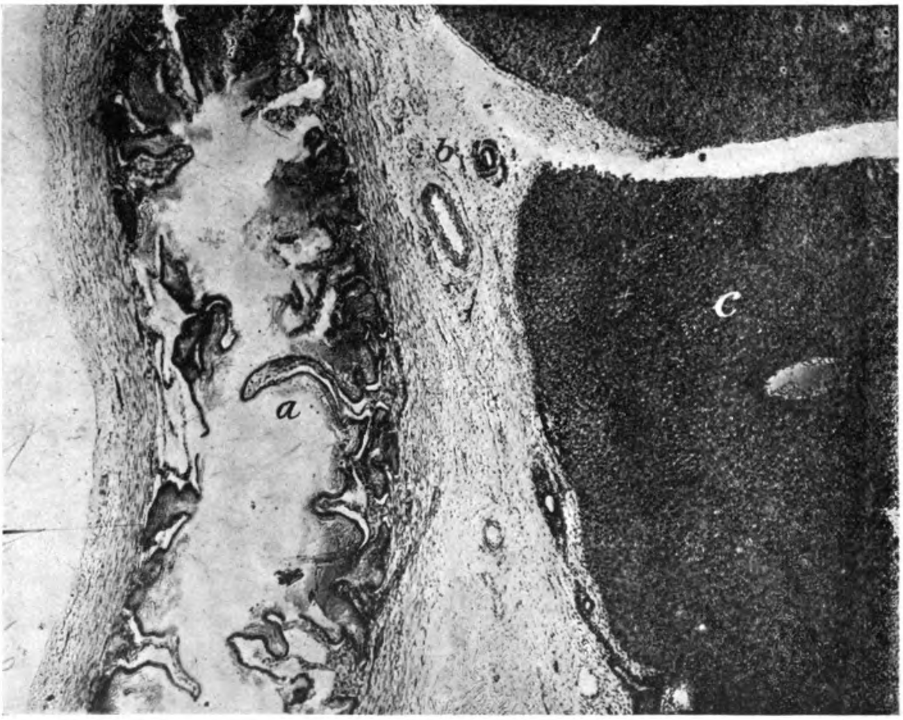
THE HEPATIC DUCT.—The bille capillaries are formed by depressions in neighboring liver-cells, the wall of the capillaries being portions of the cell walls of the liver-cells. The capillaries join and empty into an interlobular bile duct, which joins the other interlobular bile ducts to form the hepatic duct. The hepatic duct is formed by the union of two channels, one from the right lobe, the other from the left lobe of the liver, each being formed by the junction of the interlobular bile ducts of their respective lobes. It consists of three coats—an inner mucous, a middle muscular, and an outer fibrous. The mucous coat consists of a layer of columnar-shaped cells resting upon a basement membrane, beneath which there is a tunica propria. The middle coat consists of involuntary



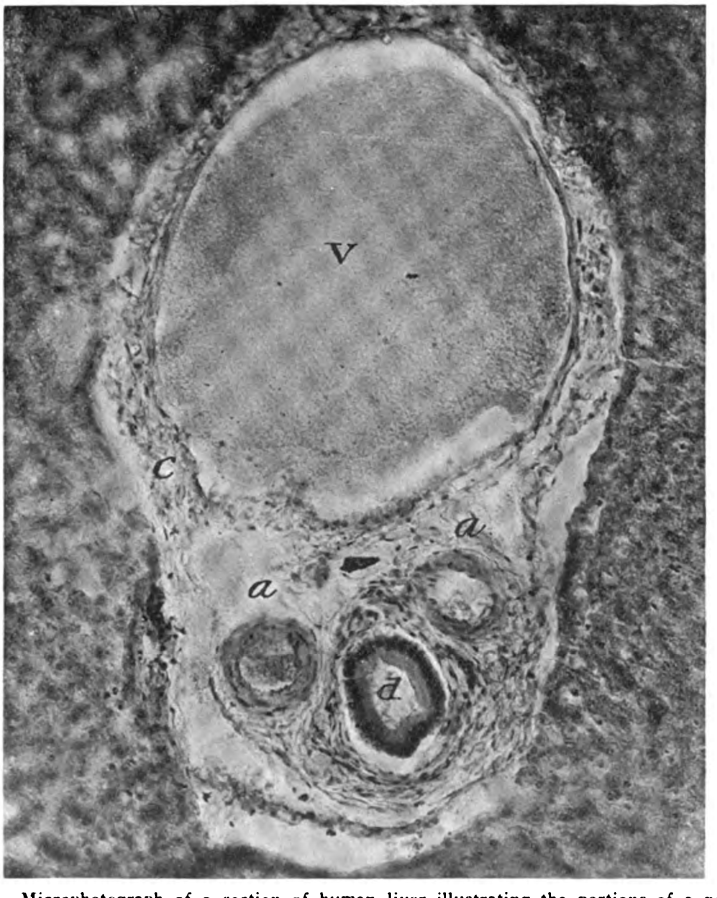
M 55—Microphotog aph of a secti n of a pig's liver showing lobulation besides regular liver structures x 45.



M 56—Microphotograph of a portion of a lobule of the liver of a rabbit x 390.
v, intralobular vein; *a*, intralobular blood-capillaries; *c*, cords of liver cells; *b*, liver cells showing cell walis and shape of the cells.

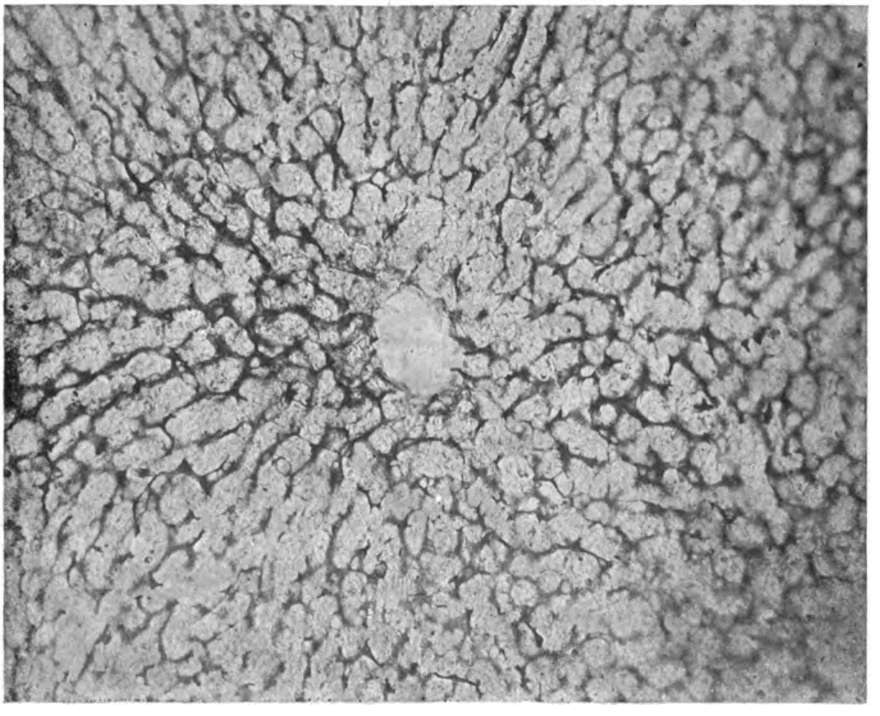


M 57.—Microphotograph of a section of the liver of a dog x 57, showing the gall bladder. *a*, villus of the mucosa; *b*, capsule of Glisson; *c*, portion of a lobule of the liver.



M 58—Microphotograph of a section of human liver illustrating the portions of a portal canal x 152.

a, artery; *d*, duct; *v*, vein; *c*, connective tissue.



M 59—Microphotograph of a portion of an injected liver of a cat x 152, illustrating the intralobular network of blood capillaries.

muscle fibres circularly disposed, among which there is some fibrous connective tissue. The outer coat consists of areolar connective tissue. The hepatic duct and its interlobular branches have numerous diverticula.

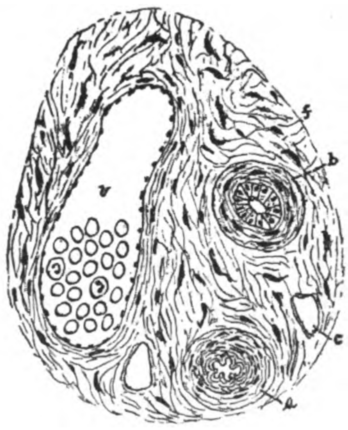


FIG. 104.
A transverse section of the portal canal of the human liver.
(a) interlobular artery; (b) interlobular bile duct; (v) interlobular vein: (c) lymph channel; (f) fibrous tissue of the capsule of Glisson.

The contents of an interlobular space are spoken of collectively as a *portal canal*. A portal canal consists of an interlobular artery, an interlobular vein, an interlobular bile duct, and lymphatic vessels, all of which are surrounded by an extension of Glisson's capsule and held together by projections from the capsule of each canal. It is common to find more than one of each in one canal. The nerves to the liver are of both varieties, the medullated being derived from the pneumogastrics and the right phrenic; the non-medullated from the hepatic plexus of the sympathetic system. The nerves accompany the vessels into the liver and between the lobules, their termination being unknown at the present time.

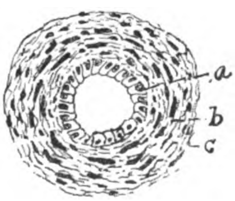


FIG. 105.
Transverse section of a bile duct.
(a) simple columnar epithelium; (b) involuntary muscle (c) connective tissue.

The *lymphatics* of the liver are arranged in two sets, superficial, and deep. The superficial set arises in the capsule of the liver. The deep set arises in the connective tissue of the interlobular spaces, and probably around the intralobular capillaries as perivascular channels.

THE GALL BLADDER consists of three coats similar to those of the hepatic duct. The inner or mucous coat is thrown into folds or rugae, which disappear when the bladder is distended. The middle coat contains beside dense fibrous tissue, involuntary muscle fibres, some of which run longitudinally, others circularly.

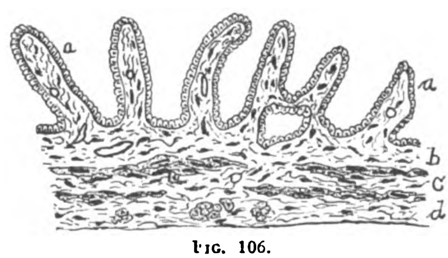


FIG. 106.
A portion of a section of the gall bladder of a cat.
(a) rugae covered by simple columnar epithelium; (b) tunica propria; (c) few fibres of involuntary muscle cut longitudinally; (d) connective tissue containing a few transverse sections of involuntary muscle fibres.

Experiment 109. Stain with Van Giesen stain and mount a section of a pig's liver. Examine and notice the lobules, the interlobular and intralobular veins. Measure two lobules. Sketch.

Exp. 110. Stain and mount a section of human or rabbit's liver. Examine and notice the lobular arrangement under the low power. Examine under the high power the liver cells and the constituents of a portal canal. Measure three liver-cells. Sketch.

Exp. 111. Mount a section of a liver the blood-vessels of which have been injected. Examine and sketch.

Exp. 112. Mount and examine a section of a liver the bile capillaries of which have been previously injected. Sketch.

THE SALIVARY GLANDS.

The principal salivary glands are the submaxilliary, parotid, and sublingual. The salivary glands are of the compound racemose variety, each being formed by a duct leading from the mucous membrane of the mouth. The duct branches dichotomously, the branches subdividing in the same manner, their ultimate branches terminating in dilated blind pouches to form the *lobules*. Each lobule is formed by a number of small pouches termed *acini*, or alveoli.

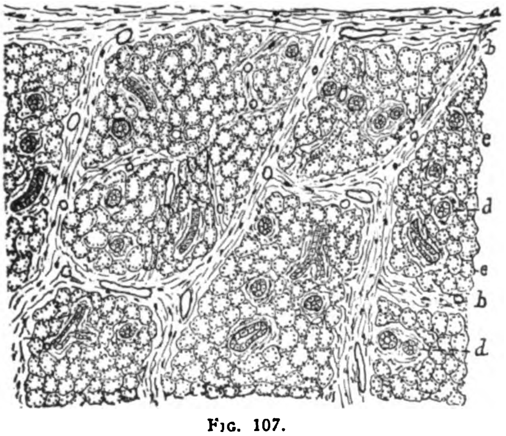


FIG. 107.
A section of submaxillary gland of a child (under low power).
(*a*) fibrous capsule; (*b*) trabeculae, dividing the gland into lobules; (*e*) acini; (*d*) ducts.

Areolar tissue forms a capsule to the gland, and sends inshoots termed *trabeculae*, into the gland, which subdivide it into lobes and separate the lobules from each other. The alveoli are oval in shape, and are of two kinds, *mucous* and *serous*, depending upon the kind of secretion which they give.

THE MUCOUS ALVEOLI are so termed because they give a mucous secretion, which is of a ropy consistency and contains mucin. Each alveolus consists of a basement membrane upon which rests a layer of secreting cells. Each cell is conical in shape arranged with its base on the basement membrane and its apex toward the center of the alveolus, and contains a clear-looking protoplasm. In the protoplasm near the basement membrane is the nucleus surrounded by a few granules. Between the cells there is a small amount of cement substance, of a hyaline appearance. In the peripheral portion of the alveolus, sometimes causing a bulging of the basement membrane, there is a crescent-shaped collection of dark granular-looking cells termed *crescent* of *Gianuzzi*, or *demilune* of Heidenhain, the constituent cells of which are termed the *marginal* cells.

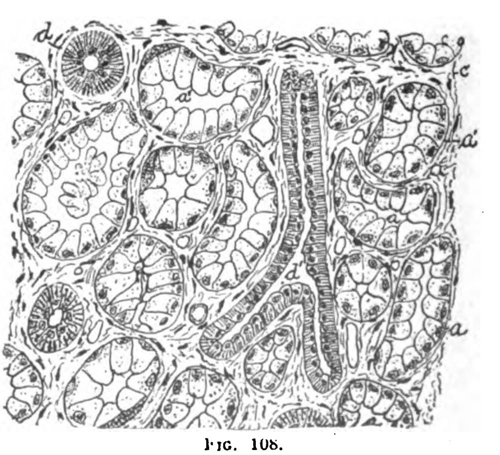


FIG. 108.
A section of a salivary gland of an infant showing mucous aveoli.
(*a*) acinus; (*a'*) acini possessing crescents or demilunes; (*c*) areolar connective tissue; (*d*) transverse section of a duct; (*d'*) longitudinal section of a duct.

THE SEROUS ALVEOLI, so termed because they give a serous secretion which contains serum albumin, are smaller than the mucous alveoli. The cells of this type of alveolus possess a

M 60—Microphotograph of salivary gland of a dog x 152 illustrating sections of the acini and ducts (*d*).

granular-looking protoplasm, the nucleus of which is in the centre of the cell. The cells nearly fill the aveoli, leaving a very small lumen perceptible.

THE DUCTS begin at the alveoli, the membrana propria of the aveoli being continuous with that of the ducts. The duct, as it begins at the lobule, is lined by simple squamous epithelium, which, as the duct increases in size, is replaced by a modified form of columnar epithelium termed rod epithelium. The rod epithelium occurs as a single layer of columnar shaped cells, each cell appearing to consist of two zones, the inner of which is granular and contains the nucleus; the outer zone appears striated. The striae or rods, so arranged that an imaginary line continued in their long axis would pass through the centre of the duct, are probably little canals.

FIG. 109.
A section of the parotid gland showing serous alveoli.
(*a*) acinus; (*d*) duct; (*c*) connective tissue.

Of the human being, the parotid gland is composed of serous alveoli, the sublingual of mucous alveoli, and the submaxillary of both varieties.

The *blood* passes into the gland by means of arteries, which pierce the areolar tissue capsule and send branches along the trabeculae, which terminate in a capillary network around the alveoli. Veins arise from the capillary network, and convey the blood from the gland.

The *lymphatic* vessels arise in the fibrous tissue between the lobules and lobes, and communicate with those of the capsule, and finally join the lymphatics of the neighboring tissues.

The *nerves* of the salivary glands are composed of both varieties, medullated and non-medullated. The nerves follow the division of the ducts, and form a network around the alveoli. It is possible that the ultimate fibrillae pass through the basement membrane and terminate between or within the cells.

Experiment 113. Stain with haematoxylin and eosin and mount a section of the human submaxillary or parotid gland and one of the sublingual. Examine and look for mucous and serous alveoli, crescents of Gianuzzi, and ducts. Sketch.

Exp. 114. Stain a section of a salivary gland with Van Giesen stain, and examine under both powers. Notice the connective tissue. Sketch.

THE PANCREAS.

THE PANCREAS (Gr. Πᾶν, all; Κρέας, flesh) is a racemose gland, resembling in structure a salivary gland, and is appropriately termed by the Germans "the abdominal salivary gland." It has a connective tissue coat composed of loosely arranged areolar tissue, in which there is some involuntary muscle fibres. The capsule sends trabeculae into the gland, which divide it into lobes and lobules, from which projections extend between the acini. The pancreatic duct, the duct of Wirsung, consisting of a fibrous tube lined by simple columnar cells, divides and subdivides the ultimate branches terminating in dilated blind extremities which form the lobules. The dilated extremities have secondary dilatations termed acini. The columnar-shaped cells lining the pancreatic duct gradually become cuboidal in the branches, then squamous near the dilatations. The acini are more tubular than those of the salivary glands, and are lined by simple columnar epithelium which has become modified for the purpose of secreting the pancreatic juice. The protoplasm of the cells is divided into two zones, an outer homogeneous or faintly-striated zone which stains readily with carmine and contains the nucleus; an inner granular zone which does not stain readily with carmine. During the secretion of the pancreatic juice the granules, which are claimed to be zymogen, gradually disappear, as a consequence of which the inner zone becomes narrow and the outer zone broader. During the periods of rest the granules accumulate in the inner zone which becomes broader, while the outer zone becomes narrow. In the ducts, rod epithelium does *not* occur. Scattered among the acini are round or oval bodies which are termed the *"bodies or Islands of Langerhans."* These bodies have been regarded as immature acini, but are more likely nerve terminations.

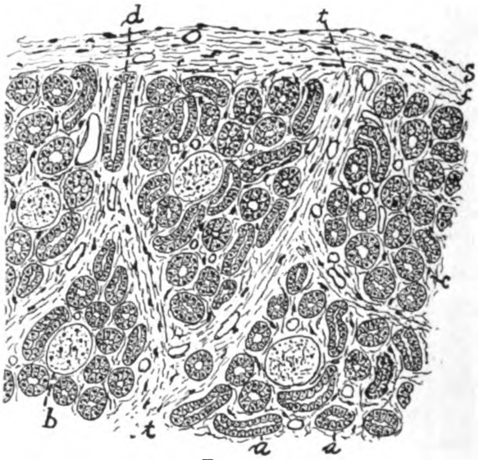


FIG. 110.
A portion of the pancreas of a cat (low power).
(*s*) serous coat; (*f*) fibrous coat from which extend trabeculae (*t*) which divide the gland into lobules; (*a*) acini; (*b*) body of Langerhans; (*d*) interlobular duct; (*c*) interacinal connective tissue.

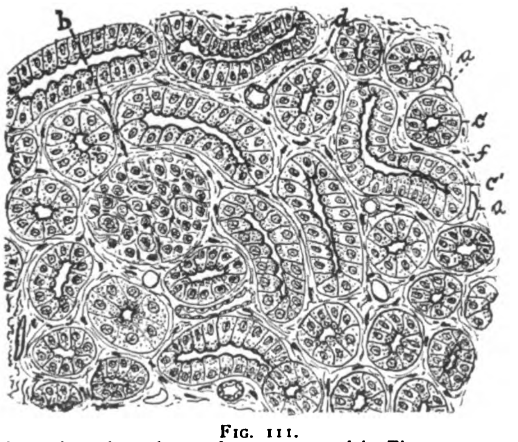
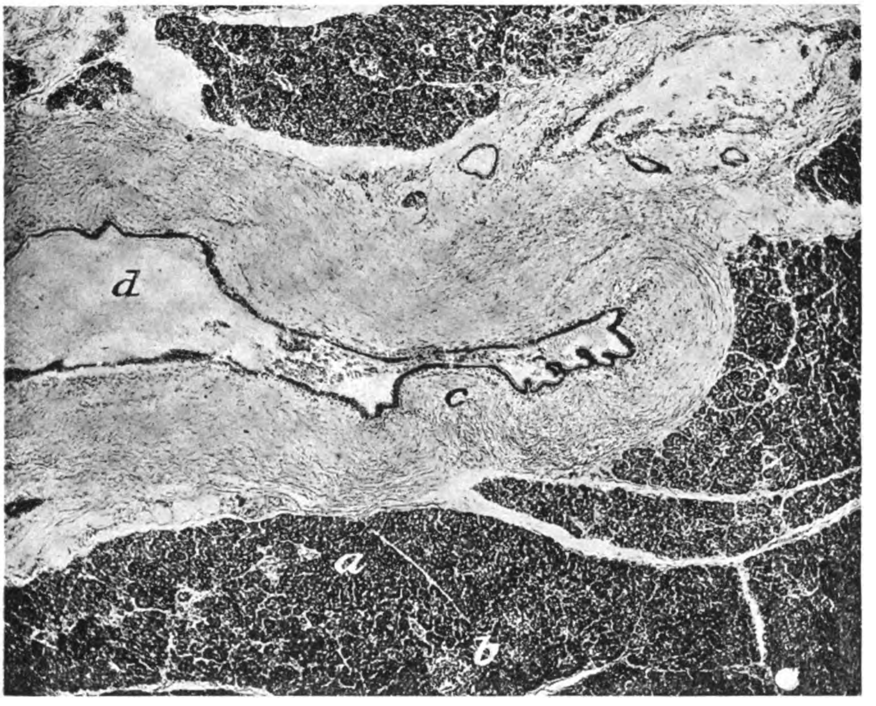


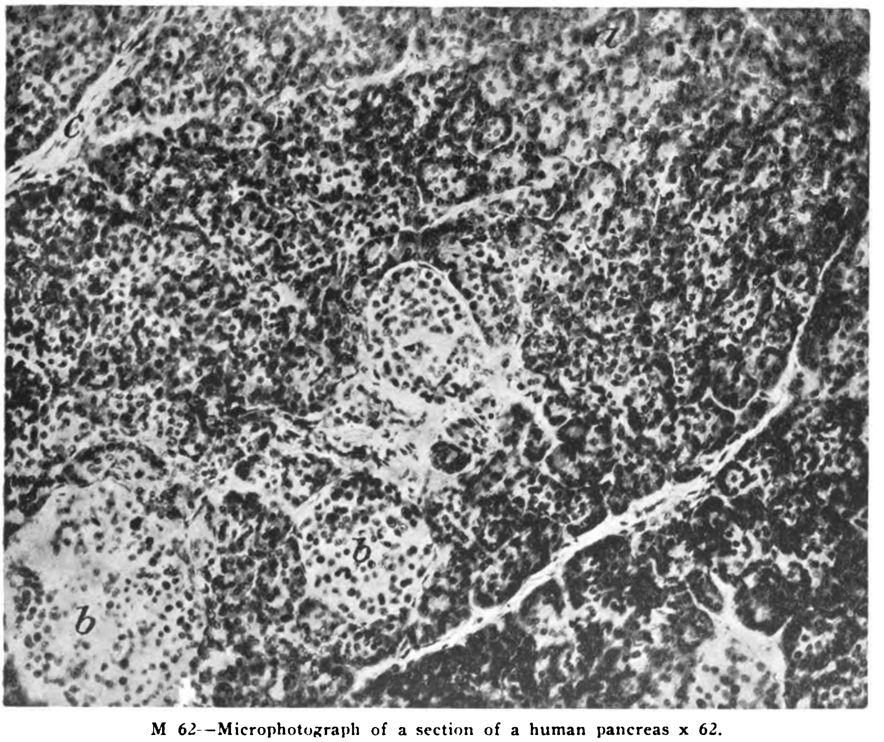
FIG. 111.
A portion of specimen of pancreas used in Fig. 110, more highly magnified.
(*a*) capillary blood vessel in the interacinal connective tissue (*f*); (*c*) transverse section of an acinus; (*c'*) longitudinal section of an acinus; (*d*) interacinal duct; (*b*) body of Langerhans.

The *arteries* are derived from the splenic, hepatic, and superior mesenteric arteries, and ramify in the areolar connective tissue capsule, sending branches between the lobules and the acini. The veins arise from the capillary network around the acini, and pass out in the same manner as the arteries enter, emptying into the splenic and superior mesenteric veins.

The *lymphatics* arise between the acini, and pass through the interlobular



M 61—Microphotograph of pancreas of a cat x 45.
a, acini; *b*, body of Langerhans; *c*, connective tissue; *d*, duct.



M 62—Microphotograph of a section of a human pancreas x 62.
a, acini; *b*, body of Langerhans; *c*, fibrous trabecula.

and interlobar connective tissue to the capsule, whence they pass to the lumbar glands.

The *nerves* are of the non-medullated variety, and are derived from the splenic plexus of the sympathetic system. They pass between the lobes and lobules, and probably terminate as the bodies of Langerhans and as a plexus around the acini.

Experiment 115. Stain and mount a section of the human pancreas. Examine and compare it with a section of the parotid gland. Notice the loose arrangement, the more tubular acini, and the absence of rod epithelium. Look for the bodies of Langerhans and ducts. Sketch.

Exp. 116. Examine a specimen of pancreas stained with carmine. Notice the two zones of the cells composing the acini. Sketch.

CHAPTER X.

THE AGGREGATIONS OF LYMPHOID TISSUE.

Lymphoid tissue may be arranged as a loose network; or as aggregations. simple or complex. When loosely arranged it is termed *diffuse lymphoid tissue,* as is found in the tunica propria of the mucous membrane of the alimentary canal. The simplest type of the aggregations of lymphoid tissue occur as the *lenticular glands* of the stomach. The *solitary glands* of the intestine are aggregations of lymphoid tissue, usually oval in shape, the peripheral portion of each gland being more dense than the central portion. The glands are surrounded by a thin capsule of areolar tissue, and are permeated by blood capillaries and lymphatic vessels as clefts in the tissue. When a varying number of these solitary glands are collected together an *agminated gland,* or Peyer's patch, is formed. When the solitary follicles are collected together with loosely-arranged lymphoid tissue a compound lymph follicle is formed.

THE LYMPH GLANDS.

The lymph glands are compound lymph follicles somewhat oval in shape. One portion of the surface of each gland is usually less convex than the remainder, in which portion, especially of the large glands, there is a depression, termed the *hilum,* for the transmission of blood-vessels and the efferent lymph channels. The gland has a distinct capsule, composed of white and yellow fibrous tissue among which are involuntary muscle fibres, connected externally with the areolar connective tissue which serves to connect the gland to the neighboring tissues. In the largest glands the yellow fibrous tissue of the capsule is arranged in alternating layers of longitudinally and circularly-disposed fibres. The capsule sends inshoots into the gland, which terminate in a loosely-arranged network. Some of the inshoots are collected into bands termed *trabeculae.* The substance of the gland is composed of a network of areolar and adenoid tissue, in which there are lymphoid cells and vessels. By the arrangement of the lymphoid tissue the gland is divided into a cortical and a medullary or central portion. The CORTICAL PORTION encircles the gland, except at the hilum, and consists chiefly of dense collections of lymphoid tissue which are situated between the trabeculae. The collections of lymphoid tissue are round or oval in shape, similar in appearance and structure to the solitary gland of the intestines. Between the nodules and the capsule of the gland and the trabeculae there is a narrow area in which is loosely arranged fibrous tissue containing lymphoid cells, termed a *lymph sinus*.

THE MEDULLARY PORTION consists of loosely-arranged lymphoid tissue, among which are dense collections of the tissue, of irregular shapes, termed *medullary* cords, and ramifying trabeculae and vessels.

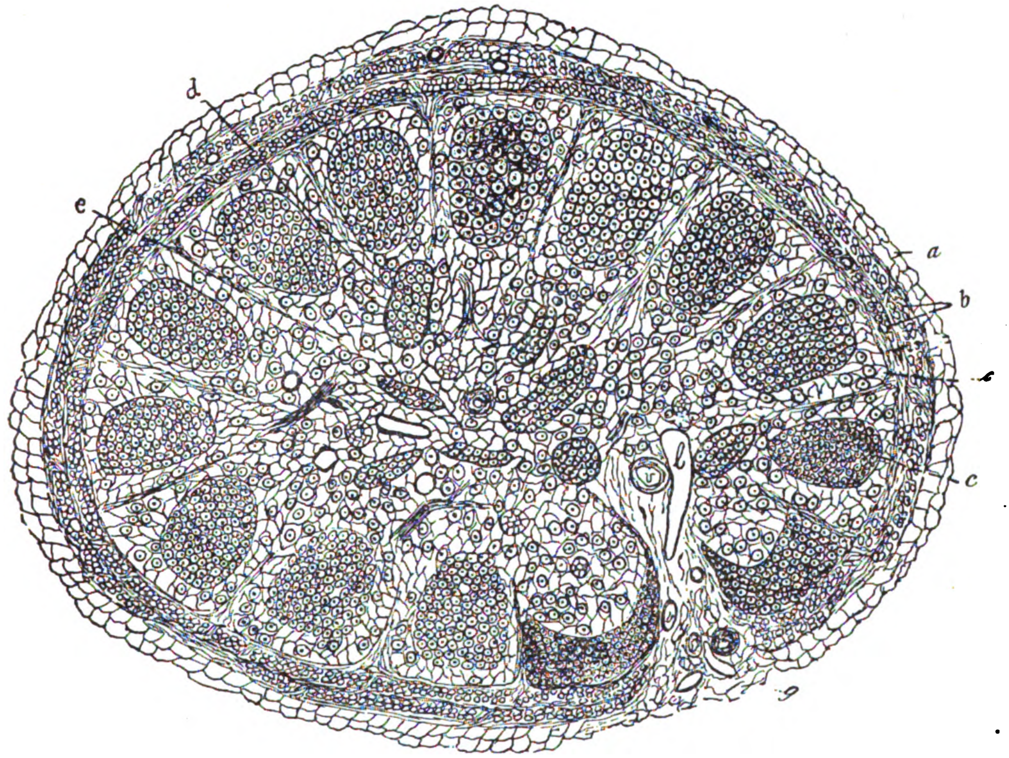


FIG. 112.
A longitudinal section of a lymph gland of a sheep.
(*a*) network of areolar and adipose tissue; (*b*) capsule containing circular and longitudinal fibres of connective tissue; (*e*) trabecula; (*c*) lymphoid nodule; (*i*) lymph sinus; (*d*) medullary cord; (*v*) vein; (*l*) lymph channel; (*g*) hilum.

The areolar connective tissue surrounding the capsule of the gland is loosely arranged, containing distinct irregular shaped spaces. The lymph passes through the spaces of the areolar tissue, through the capsule of the gland into the lymph sinuses, whence it passes through the lymphoid tissue of the gland. The lymph in this manner filters through the lymphoid tissue and is drawn toward the hilum to the efferent lymph channels by means of the negative pressure at the hilum caused by the efferent vessels. Its onward course is aided by the contraction of the involuntary muscle fibres contained in the capsule and in the trabeculae of the gland.

The *blood-vessels* enter the gland at its periphery, including the hilum, some of which pass into the substance of the gland, enclosed by trabeculae; others pass directly into the lymphoid tissue. The blood passes by means of arterioles into the sinuses of the cortical and medullary portions, and is carried from the gland by veins which arise in the medullary portion and pass out through the hilum.

The *nerves* to the glands are medullated and non-medullated, the ultimate distribution of which is not known.

Experiment 117. Stain, mount, and examine a section of a lymph gland, preferably of a sheep. Sketch, under both powers, portions of the capsule, trabeculae, cortical and medullary regions.

THE SPLEEN.

The spleen is a compound lymph follicle, and is very similar in structure to the lymph glands. It has two coats, the outer of which, the *serous* coat, is a reflection from the peritoneum; the inner is a *fibrous* coat, composed of white and yellow fibrous tissue containing involuntary muscle fibres. The fibrous coat sends in *trabeculae,* which by their ultimate ramifications form a network. The

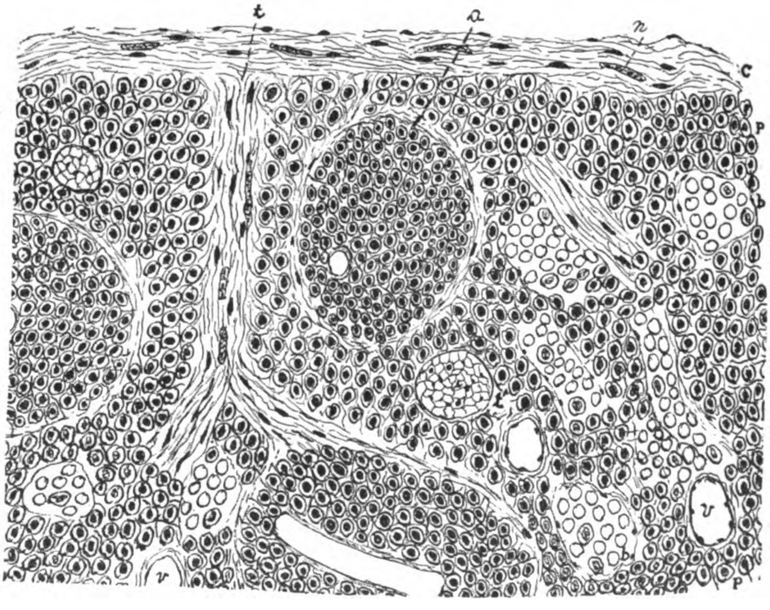
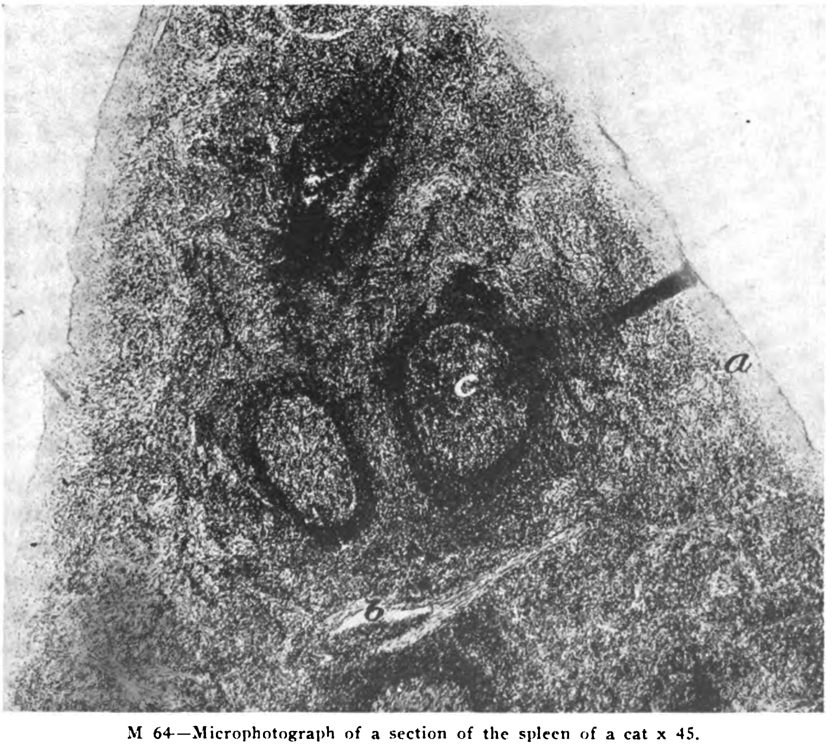


FIG. 113.
Portion of a section of the human spleen.
(*c*) fibrous capsule; (*t*) trabecula; (*n*) nucleus of involuntary muscle fibre; (*a*) Malpighian corpuscle; (*p*) splenic pulp; (*v*) blood-vessels; (*b*) blood corpuscles; (*t'*) transverse section of a trabecula.

splenic substance is composed of lymphoid tissue arranged as a loose network termed the *splenic pulp,* and as dense aggregations termed the *Malpighian corpuscles.*

THE SPLENIC PULP consists of a network formed by the ramifications of the trabeculae and adenoid tissue. The junctions of the fibres of the adenoid

M 63—Microphotograph of a lymph gland of a dog x 152.
a, fibrous capsule; *b*, lymph nodule; *c*, medullary cords.



M 64—Microphotograph of a section of the spleen of a cat x 45.
a, fibrous capsule; *b*, trabecula; *c*, Malpighian corpuscle.

tissue appear large, sometimes nucleated, and have been termed *sustentacular* cells. In the network there are numerous blood-vessels, lymphoid cells, leucocytes, and colored corpuscles of the blood. Some of the leucocytes and lymphoid cells contain pigment which has been derived from the disintegrated colored corpuscles of the blood.

THE MALPIGHIAN CORPUSCLES of the spleen are dense collections of lymphoid tissue, very similar to the corresponding collections in the lymph glands, which may be found throughout the spleen, but are most numerous in its peripheral portion. They ensheath one or more arterioles, are most dense at their periphery, and are surrounded by delicate capsules.

The *blood-vessels* of the spleen are of great importance. The splenic artery enters the spleen at its hilum and divides into numerous branches, some of which are enclosed by trabeculae, while others pass directly into the splenic substance. The arterioles become continuous with spaces in the splenic pulp formed by the connective tissue, some of them having previously passed through the Malpighian corpuscles. The walls of the arterioles blend with the fibrous tissue of the network; as a consequence of which the blood flows into the spaces termed sinuses, of the splenic pulp, thus facilitating the disintegration of the enfeebled colored corpuscles of the blood and the addition of lymph corpuscles, to become lymphocytes, to the blood. The blood, after slowly filtering through the lymphoid tissue, is carried away by veins, which begin in the same manner as the arteries terminate, join, and pass through the hilum as the splenic vein.

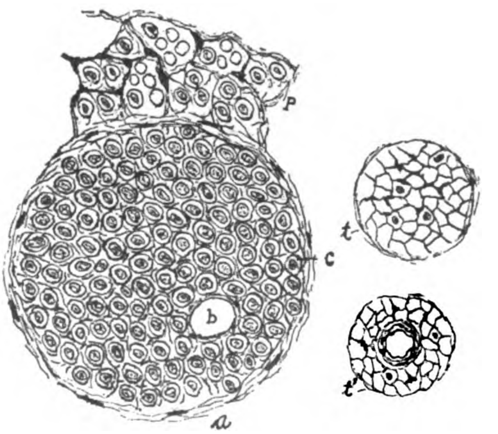


FIG. 114.
Portion of specimen used for fig. 113—more highly magnified.
(*a*) Malpighian corpuscle; (*c*) lymphoid cells; (*b*) arteriole; (*p*) splenic pulp; (*t*) transverse section of a trabecula containing sections of elastic and involuntary muscle fibres; (*t'*) a trabecula with an artery contained within it.

The *lymphatics* occur as a plexus in the capsule of the spleen, which is continuous with clefts in the trabeculae, sheaths of the arteries, and the spaces of the lymphoid tissue. The clefts join and pass as lymphatic vessels from the spleen through the hilum. The flow of the lymph from the periphery of the spleen to the hilum is brought about by the contraction of the involuntary muscle fibres contained in the capsule and the trabeculae, and by the negative pressure at the hilum caused by the efferent vessels.

The *nerves* of the spleen are of both varieties, the medullated fibres being derived from the right pneumogastric nerve, the non-medullated from the semilunar ganglion of the sympathetic system.

Experiment 119. Stain with haematoxylin and eosin and mount a section of the spleen. Examine and notice the trabeculae cut longitudinally, obliquely, and transversely; the Malpighian corpuscles; splenic pulp; and blood-vessels. Sketch the general arrangement under the low power, and the individual portions under the high power. Measure a Malpighian corpuscle.

Exp. 120. Stain with Van Gieson stain a section of the spleen. Notice the connective tissue network.

THE THYMUS BODY.

The thymus body or gland, during its early stages of development, is epithelial in structure, while in its later stages it is lymphoid. It reaches its highest development about the second year of extra-uterine life, then it undergoes retrograde metamorphosis, and disappears at the age of puberty (eighteen to twenty-one years). It consists of two lateral lobes, each of which is composed of lobules. The lobes are enclosed by a capsule, composed of connective tissue containing some involuntary muscle fibres, which sends trabeculae into the gland to divide it into lobules. The trabeculae enclosing the lobules send projections into the lobules, dividing them into small irregular-shaped spaces. The irregular-shaped spaces thus formed contain lymphoid tissue, and some of the remains of the embryonal-epithelial structure. The lymphoid tissue is more densely arranged at the periphery of the lobule than at the centre, thus forming a densely arranged cortical zone enclosing a loosely arranged medullary portion. As the gland degenerates the central portion appears to be the first part affected, consequently the contrast between the medullary and cortical substance becomes

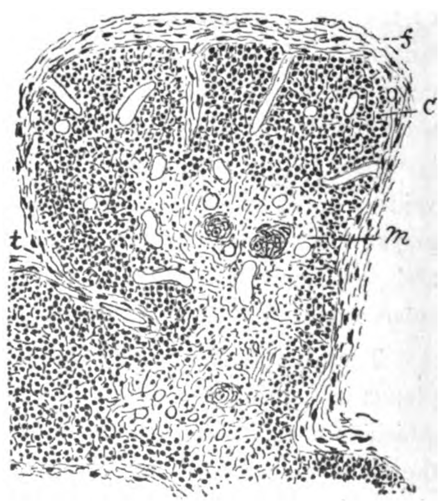
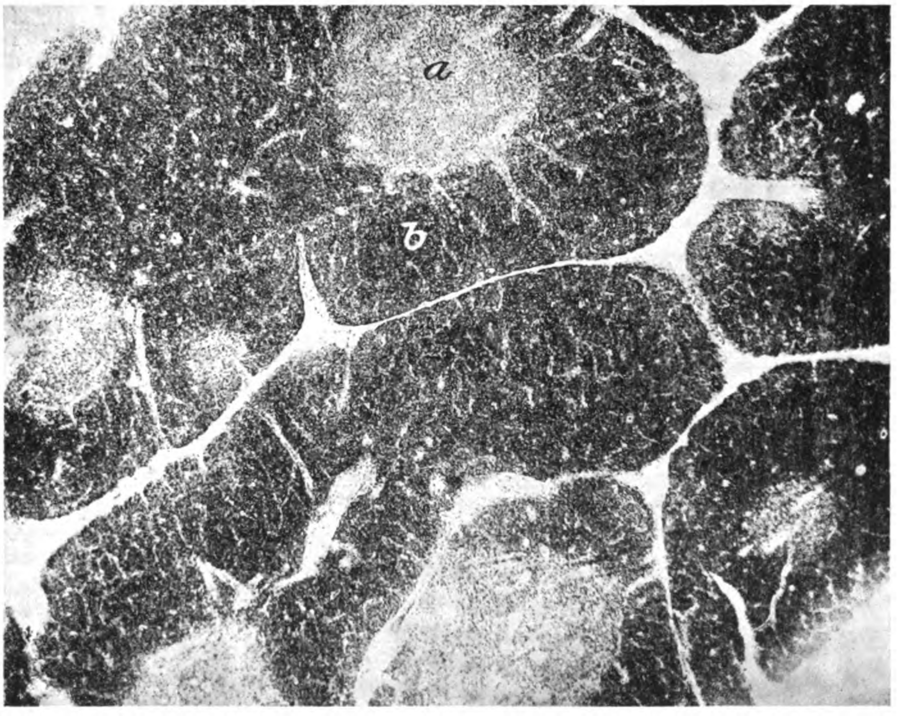
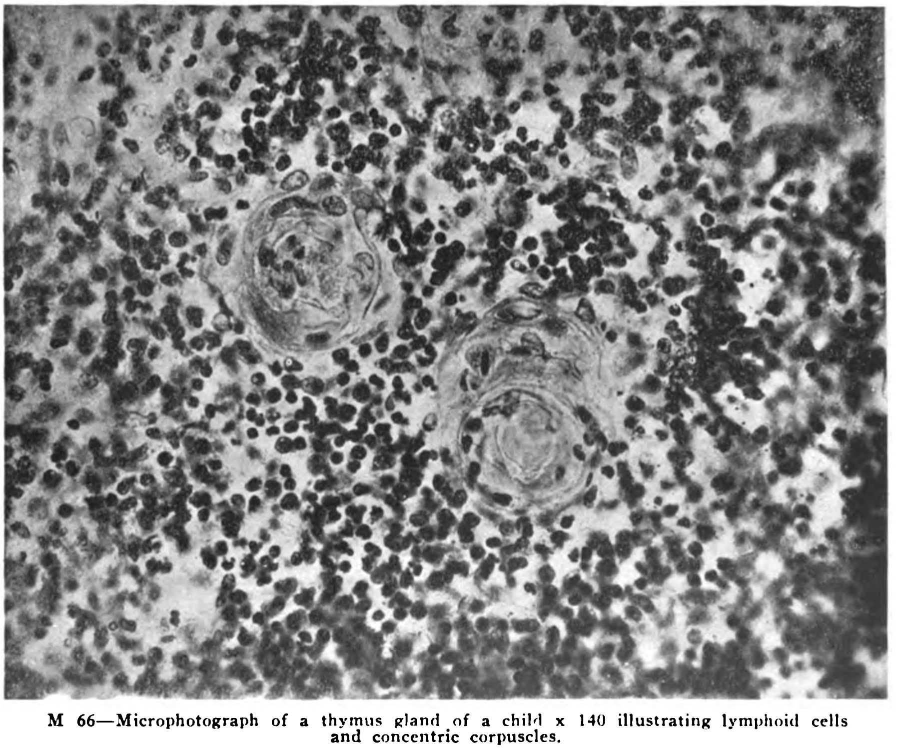


FIG. 115.
A portion of the thymus gland of a child.
(*f*) fibrous capsule; (*t*) trabecula; (*c*) cortical portion, and (*m*) medullary portion of a lobule. In the medullary portion there are three concentric corpuscles, and blood-vessels.



M 65—Microphotograph of a human thymus gland x 50 showing lobulation. *a*, central or medullary portion of a lobule; *b*, cortical portion of a lobule.



M 66—Microphotograph of a thymus gland of a child x 140 illustrating lymphoid cells and concentric corpuscles.

M 67— Microphotograph of a portion of a section of a human tonsil x 45.
a, stratified squamous epithelium on the mucous surface; *b*, lymph node; *c*, tonsillar crypt.

more marked as degeneration progresses. The epithelial structures which occur in the lymphoid tissue are termed the concentric corpuscles or the *corpuscles of Hassel,* are round or oval in shape, and consist of an outer zone concentrically striated, arranged around one or more centrally disposed structures resembling somewhat in appearance epithelial cells.

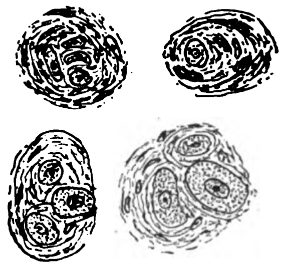


FIG. 116.
Concentric corpuscles of Hassel highly magnified.

The *arteries* enter the lobes, and divide into branches, which accompany the trabeculae into the lobules and divisions of the lobules. The arterioles pass into the lymphoid tissue and form sinuses, from which veins arise and pass from the gland in the same manner as the arteries enter. The *lymphatics* are numerous in the lymphoid tissue, whence they pass to join those in the trabeculae.

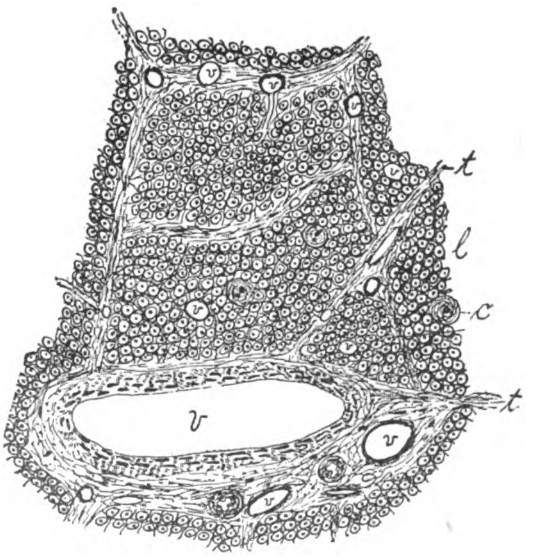


FIG 117
Thymus gland cut tangental to the surface
(*t*) trabeculae; (*l*) lymphoid cells; (*c*) concentric corpuscles: (*v*) blood-vessels.

FIG. 118.
Concentric corpuscles under high power.

From the trabeculae they pass to the capsule, and become connected with those of the surrounding tissues. The *nerves* are derived from the pneumogastric nerves and the sympathetic system.

Experiment 121. Stain with haematoxylin and eosin and mount a section of the thymus gland. Examine and notice the lobules, trabeculae, blood-vessels, lymphoid tissue, and the corpuscles of Hassel. Sketch.

THE TONSIL.

THE TONSIL primitively regarded, is a protuberance of the mucous membrane of the fauces, the tunica propria of which consists of lmphoid tissue loosely and densely arranged. It consists of three portions, *epithelial, lymphoid* and *fibrous.*

The EPITHELIAL portion consists of stratified squamous epithelium, covering the free surface of the tonsil, continuous with that lining the fauces. The epithelial covering forms depressions into the gland, which are termed the *crypts* of the tonsil, and are lined by stratified squamous epithelium. In some instances there may be as many as twelve crypts in one tonsil. The LYMPHOID PORTION consists of a close-meshed network of adenoid tissue closely packed with lymphoid cells. The lymphoid tissue is collected into nodules, and is also diffused. The nodules are most numerous around the crypts. The FIBROUS PORTION corresponds with the tunica propria of the mucous membrane and the submucosa. It extends into the tonsil at its attached border and contains vessels and nerves. In the portion of the fibrous tissue beneath the epithelium there are many mucous glands. The

FIG. 119.
A portion of a section of a human tonsil.
(*e*) stratified squamous epithelium; (*f*) fibrous tissue; (*n*) lymphoid nodules; (*c*) crypt.

lymphoid cells multiply rapidly, some of which become lymph corpuscles or leucocytes, while others penetrate the epithelial covering and enter the fauces as salivary corpuscles. The distribution of the blood and lymphatic vessels and the nerves is the same as in the mucous membrane elsewhere.

Experiment 122. Stain with haematoxylin and eosin and mount a section of a tonsil. Notice the epithelial, lymphoid, and fibrous portions. Look for salivary corpuscles along the free surface of the section, and notice the similarity betwen them and the leucocytes. Sketch.

Exp. 123. Stain with Van Giesen stain a section of the human tonsil. Notice the crypts lined by stratified squamous epithelium and surrounded by lymphoid nodules. Sketch.

CHAPTER XI.

THE RESPIRATORY ORGANS.

THE LARYNX.

The larynx is a cartilaginous box-shaped organ composed of cartilages, which are held together by ligaments, moved by muscles, and lined by mucous membrane. The CARTILAGES are of the hyaline and yellow fibrous variety, those of the former variety being the *thyroid,* the *cricoid,* and the two *arytenoids;* those of the latter variety being the *epiglottis, the two cuneiform* and the two *corniculae* laryngis. Lining the laryngeal surfaces of the cartilages there is mucous membrane, which is reflected over the vocal cords. The EPITHELIUM of the mucous membrane is of the ciliated stratified columnar variety below the false vocal cords. Above the false vocal chords the epithelial lining of the anterior surface of the larynx is composed of ciliated stratified columnar epithelium, while that lining the posterior surface is of the stratified squamous variety continuous with that of the pharynx. The ciliated epithelium ceases on the under surface of the epiglottis, and the stratified squamous epithelium begins, covering a portion of its under surface and its entire upper surface. In the mucous membrane there are numerous mucous glands. Connecting the mucous membrane to the cartilages there is fibrous tissue arranged as a submucous layer. The fibrous tissue adjoining the cartilage is arranged as a dense layer, and is composed chiefly of the yellow fibrous variety. The LIGAMENTS of the larynx consist of yellow fibrous tissue arranged in bands. The MUSCLES of the larynx are of the voluntary variety.

Experiment 124. Stain and mount a section of the epiglottis. Examine and notice the epithelium, the tunica propria of the mucous membrane, the acini of the mucous glands, and the cartilage. Sketch.

THE TRACHEA.

The trachea (Gr. Τραχεῖα, tumultuous) is a tube continuous with the lower end of the larynx, consisting of cartilage, fibrous tissue, involuntary muscle, and mucous membrane, which are disposed in three coats:

Mucous.

Submucous.

Fibro-cartilaginous.

THE MUCOUS COAT consists of an epithelial portion and a tunica propria. The *epithelium* is of the ciliated stratified columnar variety, among the cells of the outer layer of which are numerous goblet cells. The *tunica propria* consists of white and yellow fibrous tissue containing some lymphoid tissue, and is disposed in two zones, the inner of which is loosely arranged, the outer densely arranged. In the tunica propria ramify blood-vessels, lymphatics and nerves.

THE SUBMUCOUS COAT consists of a loose network of areolar connective tissue, in which blood-vessels, lymphatics, nerves, and glands exist. The glands, termed the tracheal glands, are of the racemose type, being most numerous at the posterior portion of the trachea, and are mucous in variety.

THE FIBRO-CARTILAGINOUS COAT, so termed because it is composed of fibrous tissue and cartilage, consists of incomplete cartilaginous rings enclosed in a fibrous sheath. The *cartilage* of the trachea is disposed in C-shaped rings, the open portion being at the posterior portion of the trachea, and is of the hyaline variety, the outer surface of which, being invaded by yellow fibrous tissue, becomes yellow fibro-cartilage. The *fibrous* portion of the coat consists chiefly of yellow fibrous tissue, forming an enveloping sheath to the cartilage. It forms a thick layer at the posterior portion of the trachea between the ends of the incomplete rings of cartilage, and also extends between the rings. At the posterior portion of the trachea there is some involuntary muscle fibres disposed in two layers, one containing transverse fibres; the other longitudinal fibres. The transverse fibres form a continuous layer between the ends of the incomplete cartilaginous rings. The longitudinal fibres are external to the transverse fibres, and are not so well marked. Areolar tissue serves to connect the trachea with the neighboring structures.

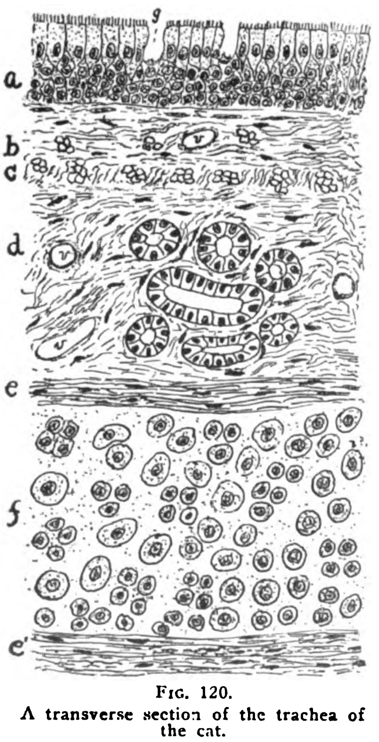
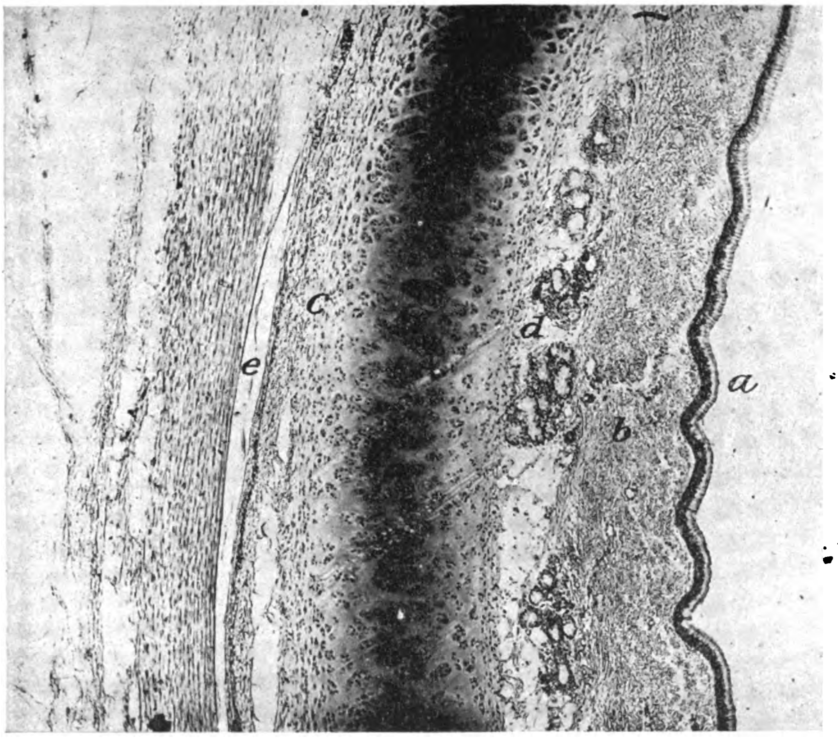


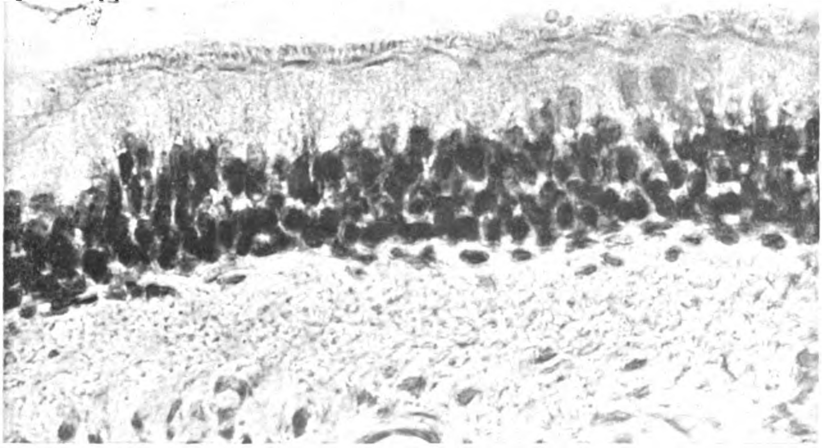
FIG. 120.
A transverse section of the trachea of the cat.
(a) ciliated stratified columnar epithelium; (g) goblet cell; (b) tunica propria; (c) a layer of elastic fibres cut transversely; (d) submucosa containing part of a tracheal gland; (e) inner layer, and (e') outer layer of fibrous tissue ensheathing the hyaline cartilage (f); (v) blood vessels..

The *blood supply* to the trachea is derived from the inferior thyroid arteries. The vessels penetrate the coats to reach the submucosa, where they ramify, the branches surrounding the glands and supplying the tunica propria. The *lymphatics* arise in the clefts of the connective tissue contained in the coats of the trachea. The *nerves* are of both varieties, the medullated fibres being derived from the pneumogastric, the non-medullated from the cavernous plexus of the sympathetic system.

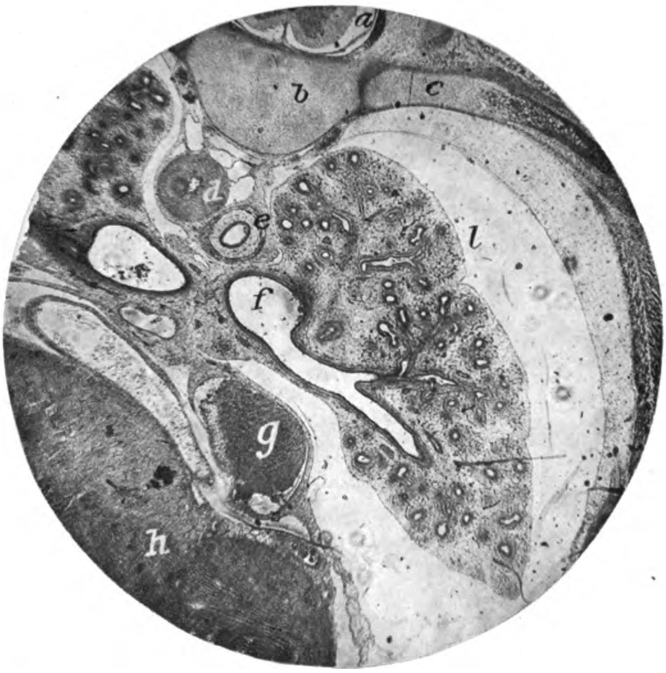
Experiment 125. Stain and mount a section of the trachea. Examine and notice the ciliated epithelium, tunica propria, cartilage, tracheal glands, and fibrous tissue. Sketch.



M 68—Microphotograph of a section of the trachea of a cat x 42.
a, epithelium border; *b*, tunica propria; *d*, submucosa containing tracheal glands; *c*, cartilage; *e*, fibrous coat.



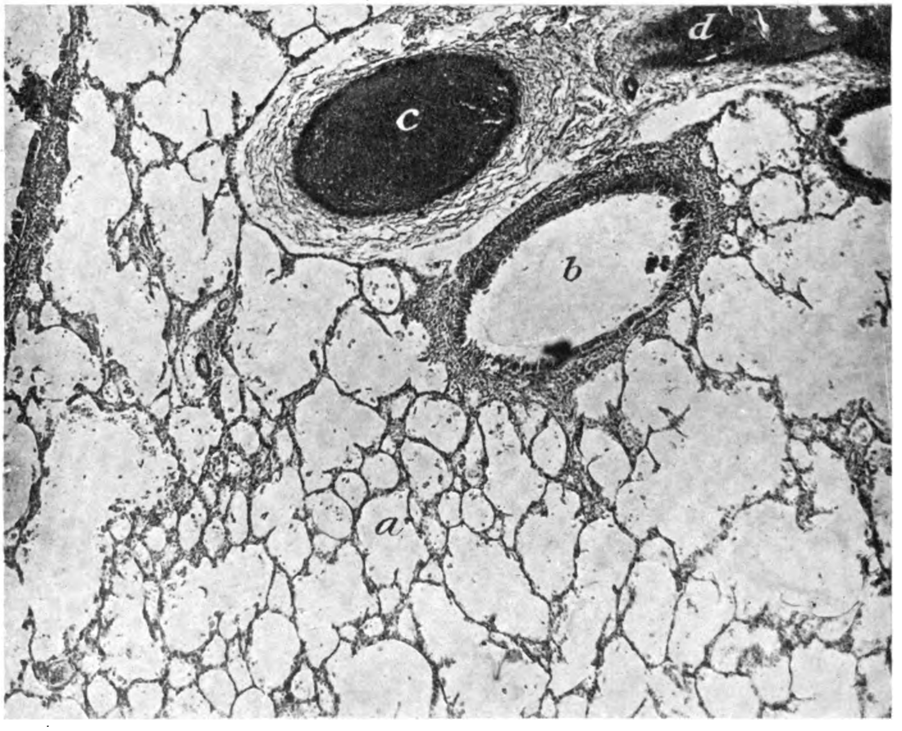
M 69—Microphotograph of a section of a human trachea x 500, illustrating the ciliated stratified columnar epithelium of the mucosa.



M 70—Microphotograph of a portion of a transverse section of a pig-embryo x 6, showing the relation of the lung to neighboring structures, and the branching bronchial tubes.

a, spinal cord; *b*, body of vertebra; *c*, rib; *d*, aorta; *e*, oesophagus; *f*, left bronchus from which a bronchial tube extends and divides and subdivides to terminate as the air sacs of the lung; (*l*); *g*, blood in left auricle; *h*, musculature of ventricles.

M 71—Microphotograph of section of pig-embryo used for M 70 x 20, illustrating the branching of the bronchial tubes to finally terminate as the alveoli of the lung.



M 72—Microphotograph of a section of human lung x 45.
a, alveoli; *b*, bronchial tube; *c*, bronchial artery; *d*, bronchial vein.

THE BRONCHIAL TUBES.

The trachea divides into two tubes, termed *bronchi,* which are similar in structure to the trachea. The bronchi divide, the divisions subdividing, the ultimate divisions, termed *bronchioles,* terminating in dilated extremities termed *infundibula.* There is a gradual change in structure of the bronchial tubes from the bronchi to the infundibula. The *epithelium* gradually changes from the ciliated stratified columnar variety to the ciliated simple columnar, to the non-ciliated simple columnar to the cuboidal and to the squamous, the squamous variety lining the terminal bronchioles and infundibula. The *cartilage* gradually changes from cartilaginous rings in the bronchi to cartilaginous plates in the bronchioles. In the terminal bronchioles there is no cartilage. As the tubes decrease in size involuntary muscle fibres occur in the outer border of the tunica propria, forming a *muscularis mucosae,* becoming more marked as the cartilage diminishes in amount, appearing to take the place of the elastic fibres of the outer zone of the tunica propria. The bronchioles consist of fibrous tissue and involuntary muscle fibres, and are lined by ciliated cuboidal epithelium, which is displaced by simple squamous as the bronchioles near their terminations. The bronchioles continue to divide until the divisions are of a diameter of about $\frac{1}{50}$ to $\frac{1}{80}$ inch, then become dilated, forming the lung substance.

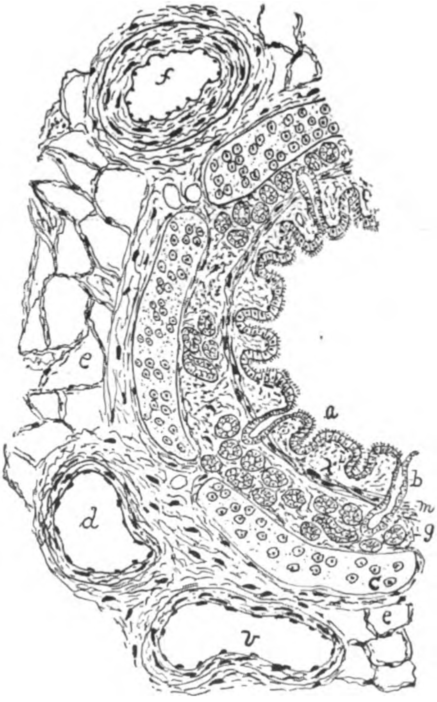


FIG. 121.

Portion of a section of the lung showing bronchial tube.

(*a*) epithelial lining of mucous membrane consisting of ciliated simple columnar epithelium; (*b*) duct of bronchial gland; (*m*) layer of involuntary muscle fibres; (*g*) bronchial gland in submucosa; (*c*) cartilage plate, (*e*) alveoli; (*f*) bronchial artery; (*d*) pulmonary artery; (*v*) pulmonary vein.

THE LUNG.

The substance of the lung consists of the dilated terminations of the bronchioles, and areolar tissue containing blood-vessels, lymphatics and nerves. The terminations of the bronchioles, termed *infundibula,* intercellular passages, or air sacs, are pouch-like dilations, which have secondary dilations termed *air cells* or *alveoli.* The lung, consequently, may be regarded as a racemose gland, the ducts of which are the bronchial tubes which terminate in the main duct, the trachea.

THE ALVEOLI, or *air cells*, are small pouch-like distensions, which normally are filled with air, varying in size from $\frac{1}{200}$ to $\frac{1}{70}$ inch in diameter. They consist of fibro-elastic tissue, lined by simple squamous epithelium. Between the alveoli is connective tissue, composed of white and yellow fibres, in which ramify the blood-vessels. Covering the lung there is a *serous* coat, termed the visceral layer of the pleura.

THE BLOOD SUPPLY OF THE LUNG—The lung has two sets of blood-vessels, the *pulmonary* and the *bronchial*.

FIG. 122.
Portion of a section of human lung.
(*e*) epithelial (cuboidal) lining of a bronchiole; (*m*) involuntary muscular fibres; (*g*) bronchial lymph gland; (*c*) alveoli of lung showng lining epithelium (simple squamous); (*c'*) alveolus in whch are some of the detached epithelial cells; (*f*) fibrous septum, between the alveoli, in which the blood capillaries are located; (*b*) small blood vessel containing corpuscles; (*a*) bronchial artery; (*v*) bronchial vein.

THE PULMONARY ARTERY conveys impure blood from the right ventricle of the heart to the lung. The vessel enters the lung with, but external to, the bronchus, dividing as the bronchus divides and subdivides, and terminates as an anastomosing network of capillaries between and around the infundibula and alveoli. The blood in this manner is brought into close relation to the air contained within the alveoli, and after being aerated returns to the heart by means of the pulmonary veins.

THE BRONCHIAL artery is derived from the thoracic aorta, and conveys pure blood to the lung substance for its nourishment. Its branches form a capillary network to supply the tissue of the bronchioles and of the lung, some of the blood passing from the tissue by the bronchial vein and some by the pulmonary vein. The *lymphatics* of the lung are arranged in two sets, one set arising in the connective tissue of the lung, the other set in the mucous membrane of the bronchioles. Of the first set there are two sources, one just beneath the visceral layer of the pleura, the other in the clefts in the fibrous tissue between the infundibula. The two sets communicate and terminate in the bronchial lymph glands. The *nerves* are derived from the pulmonary plexuses which are formed by the pneumogastric nerves and branches from the sympathetic system. The fibres possess ganglia, and accompany the branching bronchial tubes.

Experiment 126. Stain and mount a section of the lung. Examine and notice the alveoli, the fibrous septa between the alveoli, and sections of bronchioles, and blood-vessels. Look for the lining cells of the alveoli and of the bronchioles. Sketch. If the section includes a bronchial tube, study its structure and sketch it.

Exp, 127. Stain a section of the lung with silver nitrate. Look for the outlines of the lining cells; also stomata and stigmata.

Exp. 128. Mount a section of an injected lung. Examine and notice the capillary network around the alveoli.

Exp. 129. Open the thorax of a curarized or pithed frog, being careful not to injure the lungs. Notice the lungs distended with air; the air sacs and the capillary network of vessels. If necessary use an ordinary hand lens.

CHAPTER XII.

THE SKIN AND ITS APPENDAGES.

The skin is divided into two zones, an outer zone, termed the cuticle or *epidermis;* an inner zone, termed the *dermis*, cutis vera (true skin), or corium. The epidermis is composed of stratified squamous epithelium, modified to withstand the influence of the atmosphere and violence, acting as a covering for the protection of the underlying dermis. On account of the modification of the epithelium, the epidermis is divided into layers or *strata.* The dermis is also divided into strata, the division depending upon the disposition of the component fibrous tissue. The strata of the skin are:

Epidermis—
- Stratum corneum.
- Stratum lucidum.
- Stratum granulosum.
- Stratum Malpighi.

Dermis—
- Stratum papillare.
- Stratum reticulare.

The stratum corneum consists of the superficial layers of the stratified squamous epithelium, the cells of which have lost their nuclei and their protoplasm has been converted into *keratin.* The stratum appears as if it were composed of horny-like fibres.

The stratum lucidum consists of a layer of cells which have lost their nuclei and whose protoplasm has become converted into *eleidin,* a substance closely allied to keratin.

The stratum granulosum consists of irregular-shaped cells the outline and nuclei of which can be readily observed, and whose protoplasm contains numerous dark granules.

The stratum Malpighi or *rete mucosum,* consists of several layers of cells, the lowest layer being composed of irregular cuboidal-shaped cells, the cells of the succeeding layers becoming more flat as they approach the stratum granulosum. In the protoplasm of the cells of this stratum there are pigment granules which give the characteristic hue to the colored races of mankind. Extending between the neighboring cells there are bridge-like projections, which give to the cells a bristling appearance; hence the cells are termed *prickle cells.* The lower border of the stratum Malpighi is thrown into depressions to fit over corresponding elevations of the dermis. The cells of the lower layers of the epidermis reproduce, the cells thus formed pushing those of the other layers nearer to the surface. The cells as they approach the surface become flatter, and their protoplasm gradually changes to eleidin, then to keratin. The outer layers of the stratum corneum are continually being thrown or rubbed off, constituting a physiological desquamation.

THE DERMIS consists of connective tissue, in which are white and yellow fibres, arranged in two strata, the stratum papillare and the stratum reticulare. The STRATUM PAPILLARE consists of dense connective tissue arranged as elevations termed *papillae,* which fit into the depressions in the under surface of the epidermis. The papillae are about $\frac{1}{100}$ inch and long $\frac{1}{250}$ inch in diameter at their base, and contain capillary blood-vessels. In some of the papillae, especially of the portions of the skin destined for the appreciation of the sense of touch, there are *tactile corpuscles.*

THE STRATUM RETICULARE is a loose network of white and yellow fibrous tissue, in which are blood-vessels, lymphatics, and nerves, and in some localities of the body, as the scrotum, penis and the nipple of the mammary gland, involuntary muscle fibres. The fibres of the stratum reticulare blend with those of the subcutaneous tissue. The two zones of the skin vary in thickness in different parts of the body. The *subcutaneous* tissue consists of a loose network of yellow and white fibrous tissue, the former predominating. Fat occurs in the subcutaneous tissue, sometimes as a distinct layer termed the *panniculus adiposus.* In the subcutaneous tissue of some localities, as of the penis, eyelids and labia minora, there is no fat.

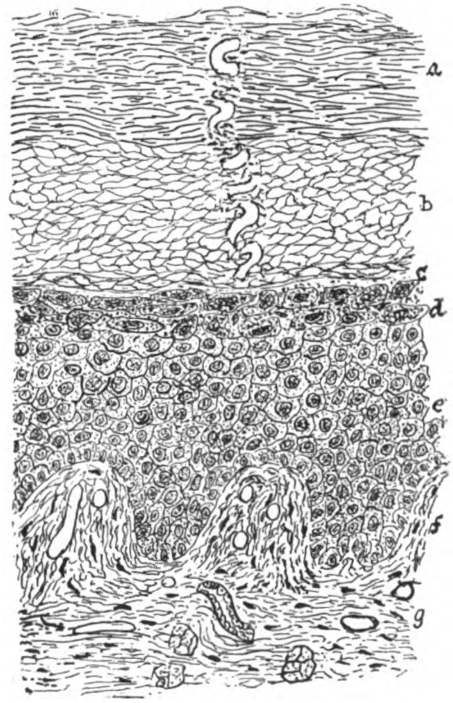


FIG. 123.
A portion of a section of the skin of the heel cut vertical to the free surface.

(*a*) upper portion of stratum corneum showing keratinized fibrous remains of superficial epithelial cells, and portions of duct of sudoriferous gland; (*b*) lower layer of stratum corneum showing outlines of the cells; (*c*) stratum lucidum; (*d*) stratum granulosum; (*e*) stratum Malpighi composed of prickle cells; (*f*) stratum papillare containing blood vessels; (*g*) stratum reticulare showing portion of a duct of sudoriferous gland, and transverse sections of elastic fibres.

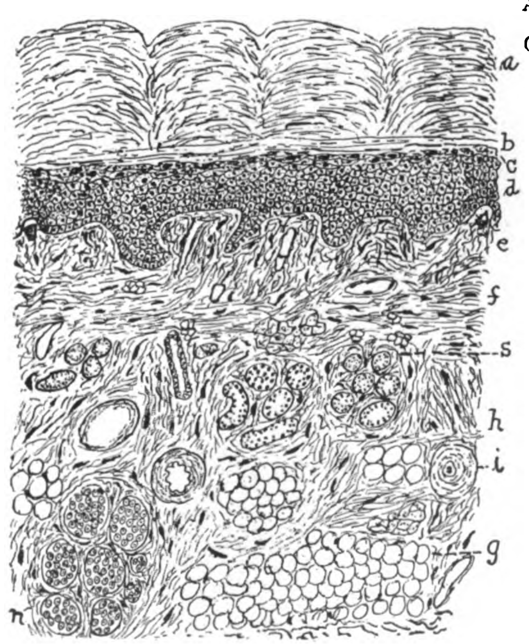


FIG. 124.
Portion of a section of skin of finger cut vertical to the surface.

(*a*) stratum corneum; (*b*) stratum lucidum; (*c*) stratum granulosum; (*d*) stratum Malpighi; (*e*) stratum papillare; (*f*) stratum reticulare; (*S*) portions of sudoriferous gland; (*h*) subcutaneous tissue; (*i*) transverse section of a Pacinian corpuscle; (*g*) adipose tissue; (*n*) transverse section of a medullated nerve.

THE APPENDAGES OF THE SKIN.

The appendages of the skin are the nails, the hairs, and the cutaneous glands.

A NAIL consists of an exposed portion, termed the *body*, which ends anteriorly as a free edge; and of an unexposed portion, termed the *root*, which is covered by an overhanging portion, termed the *nail fold*, of the *nail groove* in the skin. The portion of the skin beneath the nail is termed the *matrix*, or nail bed. The portion of the matrix beneath the body of the nail is arranged in vascular

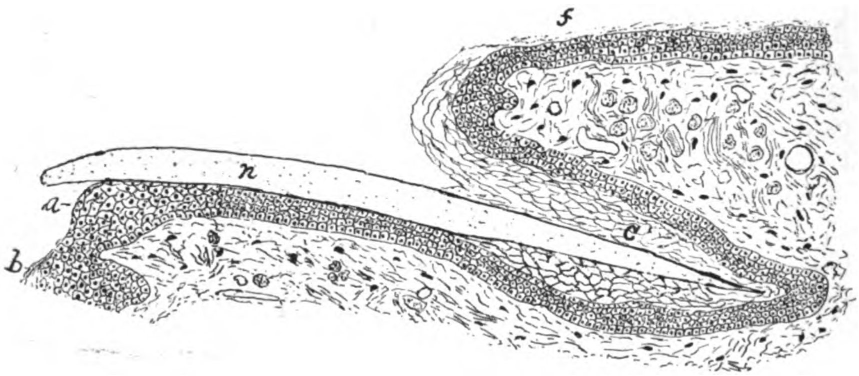
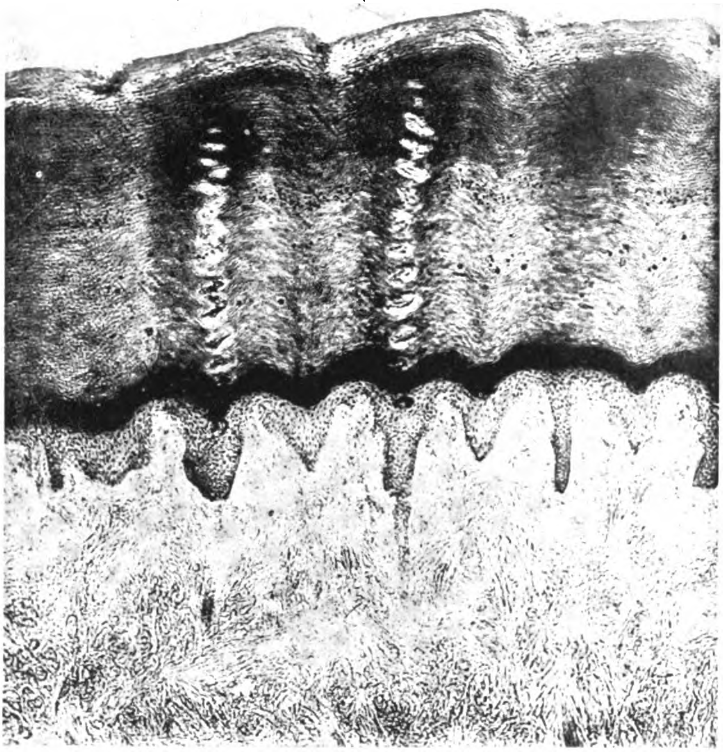


FIG. 125.
A portion of a longitudinal section of a child's finger showing the nail.
(*f*) nail fold; (*c*) nail groove in which is located the root of the nail; (*n*) body of nail; (*a*) body-matrix; (*b*) skin of end of finger.

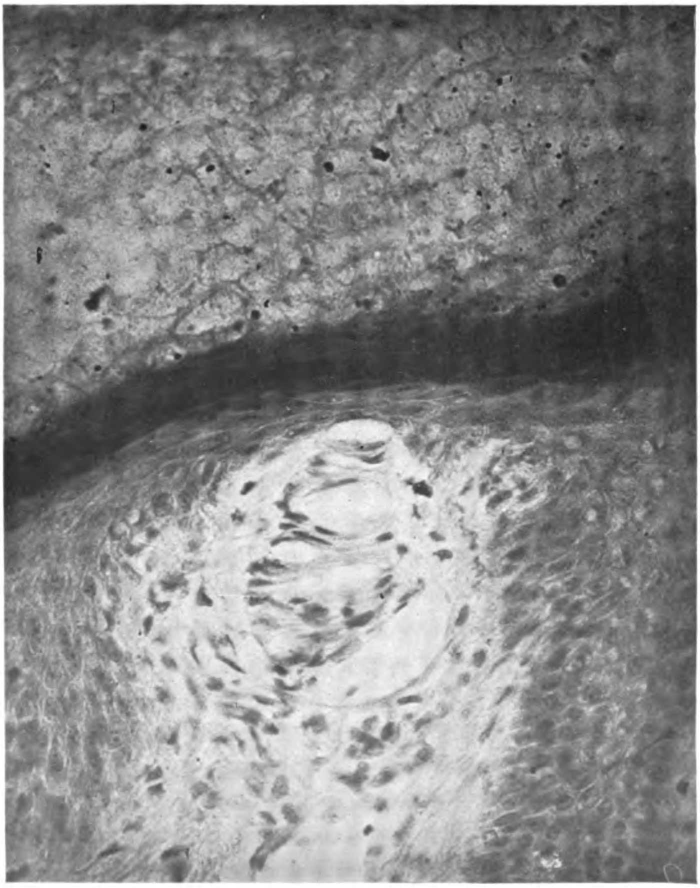
and sensitive longitudinal folds. Beneath the root of the nail the papillae of the matrix are small and less vascular than those of the body-matrix, causing the root to appear more opaque than the body of the nail. The opacity may extend beyond the nail groove, as may be readily observed in the nail of the thumb, producing a semilunar white area termed the *lunula*. The nail is essentially a highly developed stratum lucidum, the outer layer of which is slightly keratinized. The nail is attached, except at its free border, to the nail-bed, but only grows at its root. The nail-bed consists of the Malpighian stratum of the epidermis. The nail consists of three layers, the lowest of which is composed of cells similar to the topmost cells of the stratum Malpighi, the middle layer of the stratum lucidum, and the topmost layer of slightly keratinized cells.

THE HAIRS.

The hairs are appendages of the skin, and, like the nails, are modifications of the epidermis. They are found on nearly all surfaces which are covered by the skin, being absent on the palms of the hands, soles of the feet and anterior portion of the skin of the penis. In some localities the hairs are extremely short,

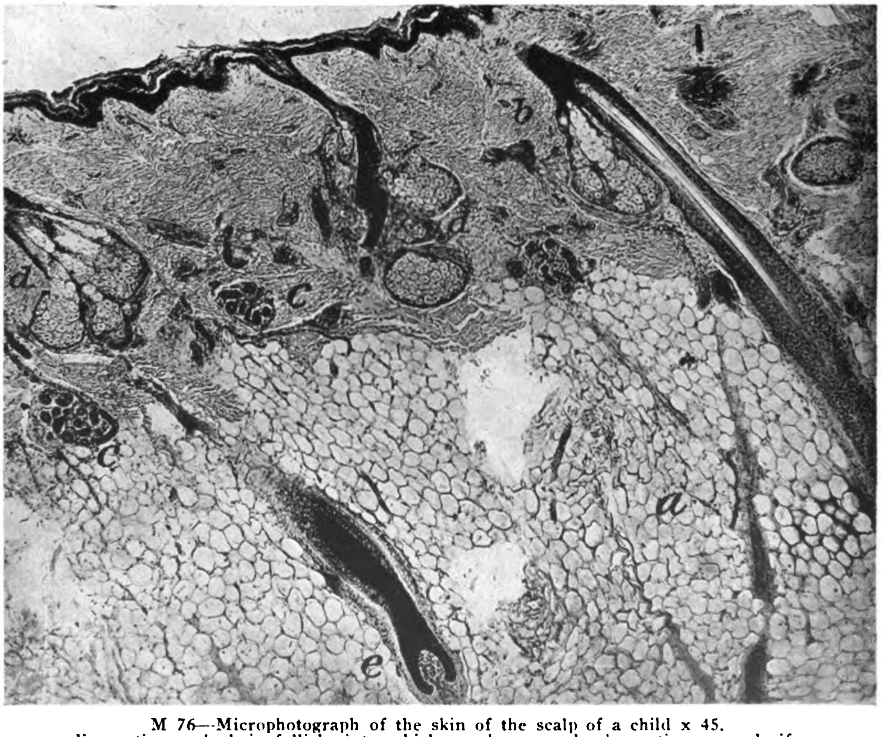


M 73—Microphotograph of a vertical section of the skin of a human heel x 45, showing strata of the skin and corkscrew-shaped ducts of the sudoriferous glands in the stratum corneum.



M 74—Microphotograph of a vertical section of the skin of a finger illustrating a tactile corpuscle.

M 75— Microphotograph of a portion of a section of a child's finger x 45.
a, epidermis; *b*, nail fold; *c*, root of nail; *d*, nail.



M 76—Microphotograph of the skin of the scalp of a child x 45.
a, adipose tissue; *b*, hair follicle into which a sebaceous gland empties; *c*, sudoriferous gland; *d*, sebaceous gland; *e*, hair bulb.

as on the upper surface of the eyelids and on the forehead, while in other regions they may be long and numerous, as on the free border of the eyelids, the scalp, external genital organs, etc.

A HAIR consists of two portions, a *shaft* and a *root*. The shaft is the portion which projects beyond the surface of the body, the root the portion below the surface. The lower end of the root is enlarged forming the *hair bulb*, which is indented on its lower surface to fit over a papilla of the dermis. The root is enclosed by a modification of the epidermis and dermis, termed the *hair follicle*,

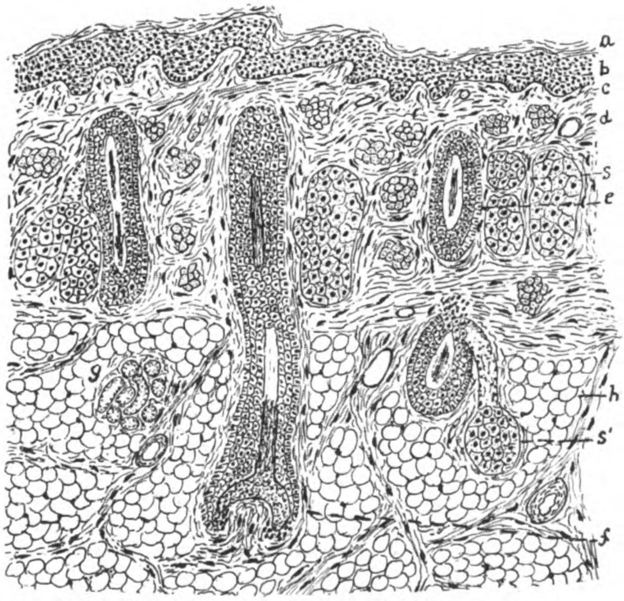


FIG. 126.
Portion of a vertical section of the scalp.
(*a*) stratum corneum; (*b*) stratum Malpighi; (*c*) stratum papillare; (*d*) stratum reticulare; (*s*) portion of sebaceous gland; (*s'*) portion of a sebaceous gland with its duct extending to a hair follicle: (*e*) hair follicle containing a portion of a hair; (*f*) hair bulb fitting over a papilla of the dermis of the hair follicle; (*g*) sudoriferous gland; (*h*) adipose tissue.

which is narrow at the surface, and broad at the lower portion of the root. The hair consists of three portions, the external of which is termed the *hair cuticle*, the middle the *fibrous cells*, and the central portion the *medulla* or *pith*.

The hair cuticle consists of irregular-shaped cells, arranged as a single layer. The fibrous cells form a layer just beneath the hair cuticle, appearing as long fibrous-looking cells. The medulla, or pith, is composed of irregular-shaped granular-looking cells which contain air vesicles and eleidin. The medulla is not present in all hairs. The color of hair depends upon the number of minute air vesicles and the amount of pigment contained in the cells of the medulla and of the fibrous layer. As a rule, the greater the amount of pigment the darker the hair, and the greater amount of air vesicles the lighter the hair.

THE HAIR FOLLICLE consists of modified epidermis and dermis. It consists of an outer fibrous and an inner epithelial portion. The fibrous portion is a modification of the dermis, and consists of three layers, *an outer layer* composed of connective tissue, chiefly of the yellow fibrous variety, the fibres of which are disposed lengthwise of the follicles; a *middle layer,* composed of connective tissue, the fibres of which run circularly around the follicles; and an *inner layer,* composed of a circularly-disposed hyaline membrane, corresponding to a membrana propria, termed the *glassy membrane.* In the middle layer of the fibrous portion of the follicles, in the regions where involuntary muscle fibres occur in the dermis, involuntary muscle fibres exist.

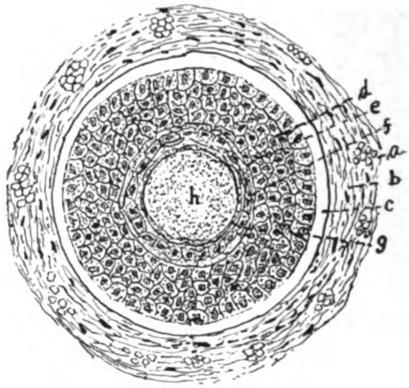


FIG. 127.
A transverse section of a hair and its follicle.
(*a*) outer layer, and (*b*) inner layer of the fibrous portion of the follicle; (*c*) glassy membrane; (*d*) outer root sheath; (*e*) Henle's layer; (*f*) Huxley's layer; (*g*) cuticular layer.

Next to the glassy membrane comes the epithelial portion, which is subdivided into an *outer* and an *inner root sheath.*

The *outer root sheath* is composed of several layers of cells, which are similar to stratified squamous epithelium, and corresponds to the stratum Malpighi of the skin, the cuboidal cells resting upon the glassy membrane.

The *inner root sheath* is composed of three layers. The layer nearest to the outer root sheath is composed of elongated non-nucleated cells, and is termed Henle's layer. The middle layer is composed of one or more rows of polyhedral nucleated cells, and is termed Huxley's layer. The third layer, the layer nearest to the cuticle of the hair, is composed of cells similar to, and closely connected to, those of the cuticle of the hair.

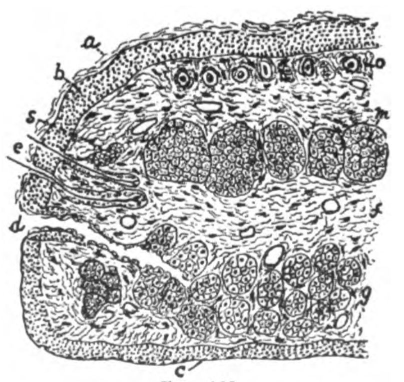


FIG. 128.
Portion of a longitudinal section of the anterior border of the upper eye lid.
(*a*) stratum corneum; (*b*) stratum Malpighi; (*o*) transverse sections of hair follicles; (*m*) orbicularis muscle; (*e*) eye lashes; (*s*) sebaceous gland; (*d*) duct of Meibomian gland (*g*); (*c*) epithelium of conjunctiva; (*f*) fibrous connective tissue.

Some of the involuntary muscle fibres of the corium extend to the hair follicle, forming an *arrector pili.* The contraction of the arrectores pilorum produces an erection of the hairs and a papillary appearance of the skin around the roots of the hairs, giving the condition termed *cutis anserina* (goose skin).

THE GLANDS of the skin are of two varieties, the sebaceous and the sudoriferous.

The *sebaceous glands* are found in connection with the hairs, but may be found in localities which do not possess hairs. They are racemose glands situated in the corium and open usually in the upper portion of the hair follicle. The acini are lined by several layers of polyhedral cells undergoing fatty metamorphosis to produce the *sebum*. The duct is lined by cuboidal-shaped cells. The sebum is an oily liquid at the temperature of the body, which becomes of the consistency of tallow on exposure to the atmosphere. It contains oil globules and debris derived from the disintegration of the cells lining the acini.

FIG. 129.
Portion of a sebaceous gland of the scalp.
(*a*) acinus; (*c*) a secreting cell; (*f*) fibrous tissue; (*d*) duct.

The *sudoriferous glands* commonly termed the sweat glands, are of the simple tubular type, and extend from the free surface of the skin to the lower portion of the stratum reticulare, in some instances into the subcutaneous tissue. Each tube becomes coiled upon itself, the coiled portion being termed the gland, and the portion leading to the surface the duct. The tube is surrounded by the connective tissue and involuntary muscle fibres of the stratum reticulare. The glandular portion is enclosed in a capsule formed by the fibrous tissue of the stratum reticulare, or of the subcutaneous tissue, and consists of the coiled portion of the tubule, which consists of three layers besides the ensheathing capsule of connective tissue and involuntary muscle fibres. The outermost layer is the basement membrane. The middle layer appears as round or quadrilateral-shaped cells, each of which contains a nucleus, which have been termed involuntary muscle fibres, but appear more like cuboidal-shaped cells than transverse sections of involuntary muscle fibres. The inner layer is composed of a row of columnar-shaped cells around a central opening. The portion of the duct near the gland is lined by several layers of cuboidal-shaped cells, but as the duct approaches the surface the cuboidal-shaped cells gradually are replaced by a layer of simple squamous cells, which in turn disappear in the epidermis, so that the portion of the duct which passes through the stratum corneum is represented by a corkscrew-shaped opening without a distinct lining. The secretion is a fluid which sometimes contains degenerated epithelial cells.

FIG. 130.
Portion of a sudoriferous gland of the section used in figure 126.
(*f*) fibrous connective tissue containing involuntary muscle fibres, forming a network which holds the portions of the glands together; (*b*) outer layer of cells; (*c*) inner layer of cells lining the canal (*a*); (v) blood vessels.

The *blood-vessels* of the skin.—The arteries enter the subcutaneous tissue and ramify; some of the branches extend to and form capillary networks around the glands and hair follicles; others supply the dermis and extend into the papillae of the dermis. The veins arise from the capillary networks and pass into the subcutaneous tissue, terminating in the cutaneous branches of the veins.

The *lymphatics* arise in the corium, join those of the subcutaneous tissue, and pass away from the skin in the cutaneous lymphatic channels.

The *nerves* of the skin, after reaching the subcutaneous tissue, divide, the fibres extending to the glands, involuntary muscle fibres, and to the corium where a plexus is formed, from which fibres pass into some of the papillae to become tactile corpuscles, while others pass into the epidermis to terminate between the cells. In the subcutaneous tissue of some portions of the body, some of the nerve fibres terminate as Pacinian corpuscles.

Experiment 130. Stain with haematoxylin and eosin and mount a vertical section of the skin of a finger. Examine and notice the strata of the epidermis and of the dermis. Look for Pacinian and tactile corpuscles. Sketch.

Exp. 131. Stain with Van Gieson stain and mount a section of skin which is covered with hair, as that of the human scalp or of an animal's ear. Examine and study the structure of a hair, of a hair follicle, and of a sebaceous gland. Sketch.

Exp. 132. Stain and mount a vertical section of the skin from the sole of a human foot. Examine and study the structure of the sudoriferous glands and of the subcutaneous tissue. Sketch.

Exp. 133. Stain and mount a longitudinal section of the tip of an infant's finger. Notice and sketch the nail, nail-fold, nail groove, etc.

CHAPTER XIII.

THE URINARY ORGANS.

THE KIDNEY.

The kidney is a compound tubular gland, the excretory duct of which is termed the ureter. Its shape is similar to that of a bean, and about the middle-third of its concave border there is a slit-like opening, termed the *hilum*, through which the ureter, blood-vessels, lymphatics, and nerves pass. The kidney has two coats, an outer dense *fibrous* and an inner *muscular* coat, the latter consisting of an incomplete layer of involuntary muscle fibres. The *fibrous* coat is tough, smooth and firm, forming a complete covering to the organ, and extending through the hilum to line a central cavity in the kidney, termed the *sinus*. The fibrous coat is covered externally by a dense mass of adipose tissue, and sends ramifying projections into the substance of the kidney which meet corresponding projections from the fibrous lining of the sinus. In this manner the kidney is divided up into *lobules*, the number of which varies between eight and eighteen. Although the lobular arrangement of the adult human kidney can not readily be recognized, it can easily be recognized in the kidney of a human foetus or of an animal such as the sheep.

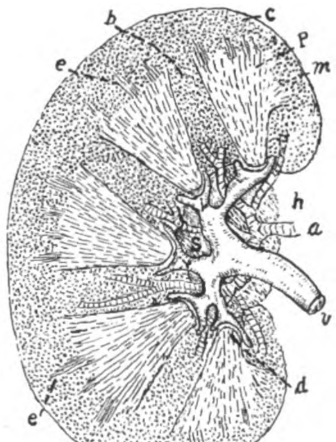


FIG. 131.
The appearance of a kidney which has been cut in half.
(*c*) cortical zone; (*m*) medullary zone; (*p*) Malpighian pyramid; (*b*) column of Bertini; (*e*) medullary rays, or pyramids of Ferrein; (*d*) mammilla or apex of Malpighian pyramid; (*s*) sinus; (*h*) hilum; (*a*) renal artery; (*i*) calyx of ureter (*u*).

The kidney substance is arranged around a central cavity, the sinus, being absent at one portion corresponding to the hilum, and is divided into two well-marked zones, the outer of which is termed the *cortical*, the inner the *medullary portion*.

THE MEDULLARY PORTION is composed chiefly of conical masses of a pale reddish striated appearance, termed the *pyramids* of *Malpighi*, of which there are from eight to eighteen, the number depending upon the number of lobules into which the kidney is divided. The pyramids are arranged with their bases toward the cortical zone, their apices toward and projecting into the sinus. The apex of each Malpighian pyramid is nipple-shaped, and is termed a *mammilla*, or *papilla*. Between the pyramids of Malpighi there are columnar-shaped extensions of the cortical substance, termed the *columns* of Bertini.

THE CORTICAL ZONE is about one-half as wide as the medulla, and has a bright reddish-brown granular appearance. The cortical zone, besides forming a zone beyond the medulla, sends projections between the Malpighian pyramids, termed the *columns* of *Bertini.* The portions of the cortical zone which extend over the bases of the Malpighian pyramids are termed the *cortical arches.* Into the cortical arches extend pyramidal projections from the Malpighian pyramids, termed the *medullary rays* or the *pyramids* of *Ferrein.* The sinus of the kidney contains the dilated portion of the ureter, termed the *pelvis,* in the same manner as a bag would be held in the hand, with the open end projecting from the hand. The pelvis divides into several divisions, generally four, termed *infundibula,* which in turn divide, each subdivision, termed a *calyx,* encloses the apex of a Malpighian pyramid.

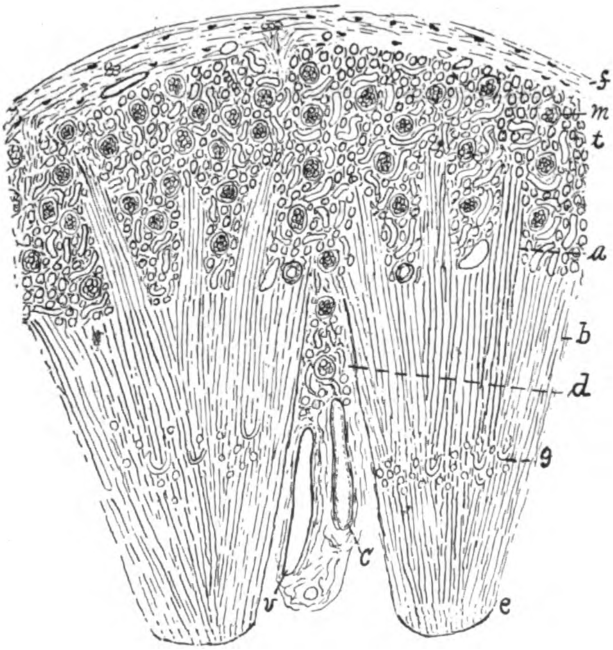


FIG. 132

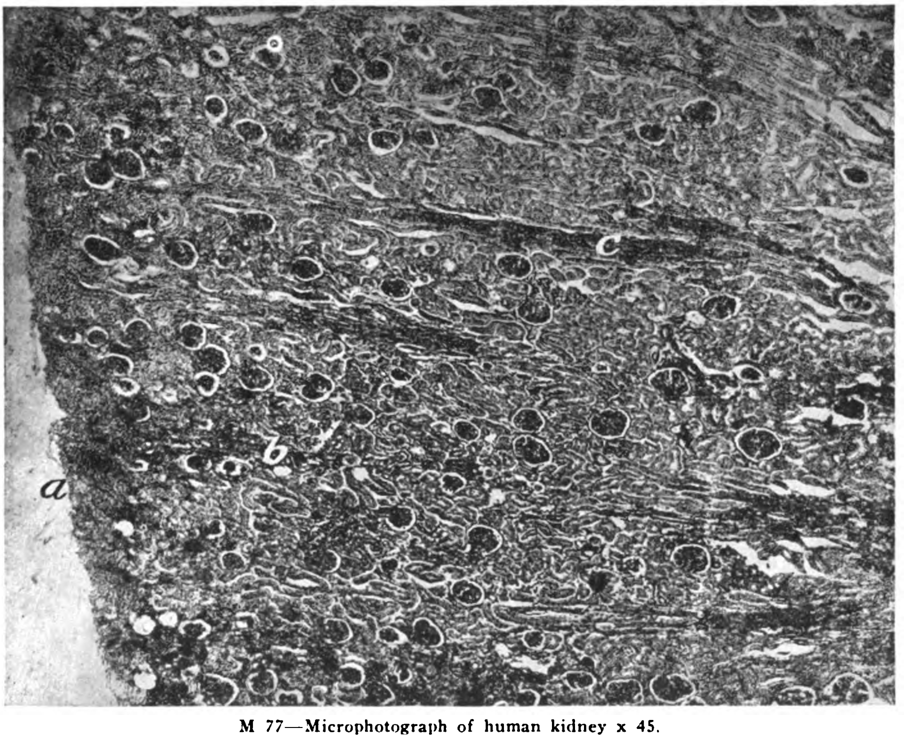
Portion of section of kidney of Guinea-pig.

(*f*) fibrous coat; (*m*) Malipighian body; (*t*) sections of uriniferous tubules; (*a*) pyramid of Ferrein; (*b*) Malpighian pyramid; (*d*) column of Bertini; (*e*) mammilla; (*c*) oblique section of arteria propria renalis, and (*v*) one of vena propria renalis; (*g*) loops of Henle.

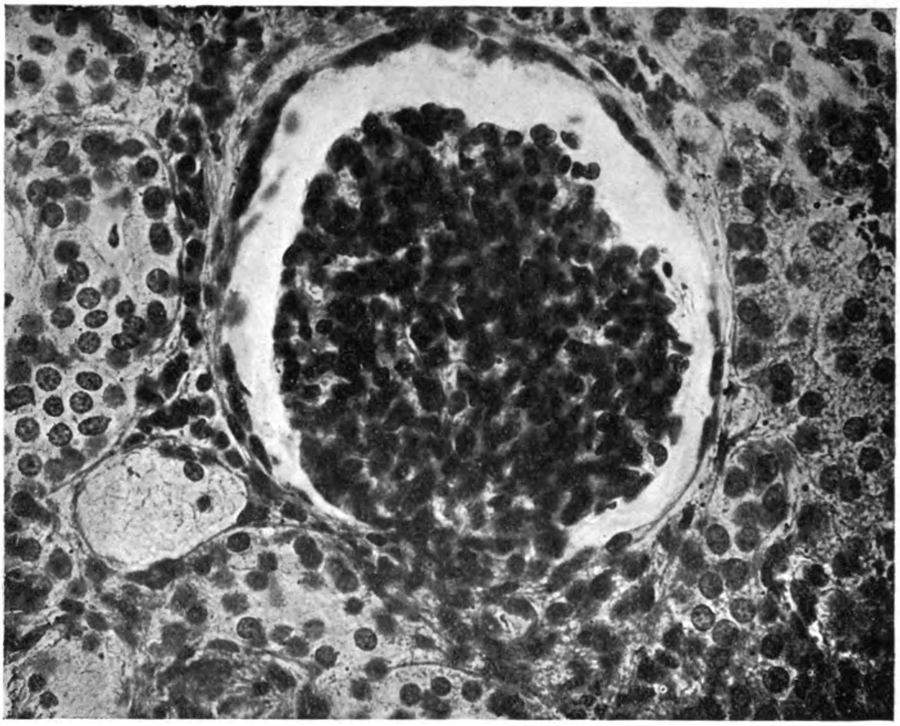
The substance of the kidney consists of uriniferous tubules, blood-vessels, lymphatics, nerves, and a connective tissue network termed the *stroma.*

The uriniferous tubules begin in the cortical substance of the kidney, and each one after following a tortuous course opens on the surface of a mammilla into a calyx.

AN URINIFEROUS TUBULE begins as a funnel-shaped envelope in the cortical substance of the columns of Bertini or of the cortical zone, termed the *capsule of Bowman,* or *Malpighian capsule;* on leaving the capsule it becomes slightly constricted, the constriction being termed the *neck.* The tubule now becomes convoluted, thus forming what is termed the *proximal convoluted tubule,* after which it follows an irregular or spiral course toward a Malpighian pyramid, and is termed the *spiral tubule* of Schachowa. The tubule now enters the base of a Malpighian



M 77—Microphotograph of human kidney x 45.
a, fibrous coat; *b*, cortical substance; *c*, medullary rays.



M 78—Microphotograph of a portion of a section of a human kidney x 390, illustrating a Malpighian body, and the simple squamous cells lining the capsule of Bowman.

M 79—Microphotograph of a portion of an injected kidney of a cat x 158.
a, glomerulus (g) with its afferent vessel (a), and its efferent vessel (e), and the interlobular artery (i) from which the afferent vessel is a branch.

pyramid, its lumen becomes smaller, and it extends down a variable distance toward the apex of the pyramid, as the *descending limb* of Henle's loop, bends upon itself, forming the *loop* of *Henle,* and passes toward the cortex, parallel with the descending limb, as the *ascending limb* of Henle's loop. It then enters the cortical substance as an *irregular* or *zig-zag tubule,* and again becomes convoluted, forming the *distal convoluted tubule* which terminates in a *curved collecting tubule.* The curved collecting tubule joins a *straight collecting tubule,* which passes through a Malpighian pyramid to open on the surface of its mammilla to empty into the pelvis of the ureter through a *foramen papillarium.*

The straight collecting tubules begin at the apex of the mammilla, about sixteen or eighteen in number, divide and subdivide dichotomously, the branches

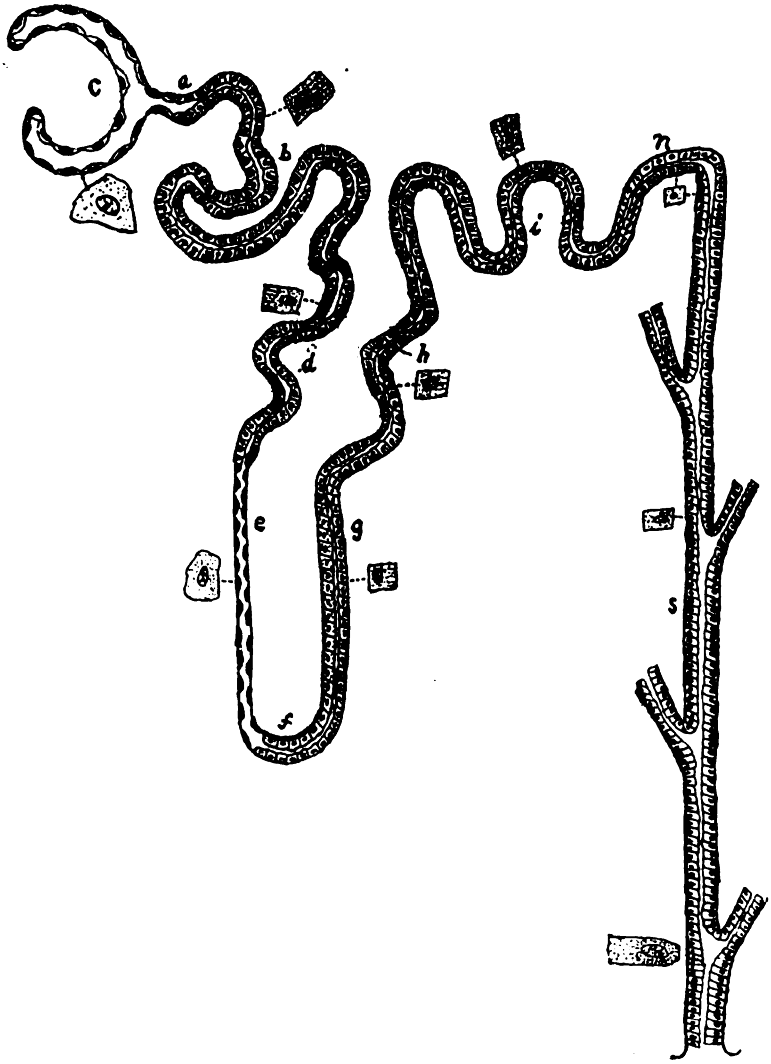


FIG. 133.

A diagrammatic representation of an uriniferous tubule, with lining epithelium.

(*c*) capsule of Bowman; (*a*) neck; (*b*) proximal convoluted tubule; (*d*) spiral tubule of Schachowa; (*e*) descending limb of Henle's loop; (*f*) the loop; (*g*) ascending limb of the loop; (*h*) zig-zag tubule; (*i*) distal convoluted tubule; (*n*) curved collecting tubule; (*s*) straight collecting tubule.

becoming more numerous the farther they are from the mammilla, and form a Malpighian pyramid. Most of the subdivisions cease on reaching the cortical arch, while others extend into the cortical arch, forming the *medullary rays,* or *pyramids of Ferrein.* The structure of an uriniferous tubule is simple, consisting of a basement membrane on which rests a single layer of epithelium. The shape of the epithelial cells varies in different portions of the tubule. In the capsule of Bowman and the neck it is of the simple squamous variety. In the proximal convoluted tubule and the spiral tubule of Schachowa it is composed of polyhedral-shaped vertically striated cells, a nucleus being in the centre of each, and the individual cells recognizable with great difficulty. The descending limb of Henle's loop is lined by simple squamous cells; the loop, and ascending limb by striated cuboidal cells; the zig-zag tubule by striated cuboidal cells; the distal convoluted tubule by cells similar to those of the proximal convoluted tubule, but more distinct; the curved collecting tubule by cuboidal-shaped cells, and the straight collecting tubule by cuboidal and columnar-shaped cells. The portions of the straight collecting tubules near the apex of the pyramid are sometimes termed the tubes of Bellini.

THE BLOOD VESSELS OF THE KIDNEY.—The renal artery passes through the hilum into the sinus, external to the pelvis of the ureter, and divides into four or five branches, which, after giving off branches termed vaginal branches for the nutrition of the neighboring tissues, divide into the main branches of the kidney, the *arteriae propriae renales.* The arteriae propriae renales pass into the spaces between the Malpighian pyramids, there being at least two to each pyramid, and extend through the columns of Bertini to the bases of the pyramids. Each arteria propria renalis arches over the base of the pyramid as an *arterial arch* to anastomose with its fellow of the opposite side. During its passage through the column of Bertini the artery gives off branches to the capsules of Bowman contained in the column. At the base of the Malpighian pyramid the *arterial arch* gives off two sets of branches. One set, the *arteriae interlobulares,* extends toward the periphery of the kidney to terminate in a capillary plexus, termed the *stellate plexus,* just beneath the coats of the organ. In their course toward the periphery, the interlobular arteries give off branches to the capsules of Bowman, each branch passing to a capsule as an *afferent vessel,* divides into several branches which form a coiled mass in the space enclosed by the capsule, the coiled mass being termed a *glomerulus.* A glomerulus and the enclosing *capsule* of *Bowman* compose a *Malpighian body* of the kidney. The vessel, after having formed a glomerulus, emerges as the *efferent vessel,* and forms a *capillary network* around the proximal convoluted tubule. The capillary network thus formed anastomoses with the networks formed by other efferent vessels, the combined network enclosing *all* portions of the tubules which are contained in the cortical portion of the kidney. The other set of branches from the arterial arch, termed the *arteriae rectae,* arise at right angles to the arch, and pass into the Malpighian pyramids. The arteriae rectae of each pyramid terminate as a plexus at its apex for the nourishment of the contents of

Fig. 134–A

A diagrammatic representation of the kidney, showing the blood vessels.

a, arteria propria renalis; *a.a.*, arterial arch; *i.a.*, interlobular artery; *s*, stellate plexus; *a.v.*, afferent vessel; *g*, glomerulus; *e.v.*, efferent vessel; *p*, plexus around convoluted tubules; a^1, arteria recta; p^1, plexus in Malpighian pyramid; v^1, vena recta; *v.a.*, venous arch; *i.v.*, interlobular vein; *v*, vena propria renalis; *c*, capsule of Bowman; *p.c.t.*, proximal convoluted tubule; *s.t.*, spiral tubule; *d*, descending limb of the loop; *e*, the loop; *f*, ascending limb of the loop; *g*, zig-zag tubule; *d.c.t.*, distal convoluted tubule; *h*, curved collecting and *s.c.t.*, straight collecting tubule; *cx*, calyx.

Fig. 134–B

Portion of a human kidney injected with Prussian blue and stained with carmine.

a, arteria propria renalis; *i*, arteria interlobularis; a^1, afferent vessel; *e*, efferent vessel; *c*, convoluted tubule; *p*, plexus around convoluted tubules; *o*, Malpighian body showing a portion of the glomerulus, and the simple squamous epithelium of the capsule; *s*, spiral tubule; *f*, stroma; *g*, glomerulus; *b*, straight collecting tubule; *h*, loop of Henle; *d*, descending limb; *j*, ascending limb; p^1, plexus in Malpighian pyramid; *v*, vena propria renalis.

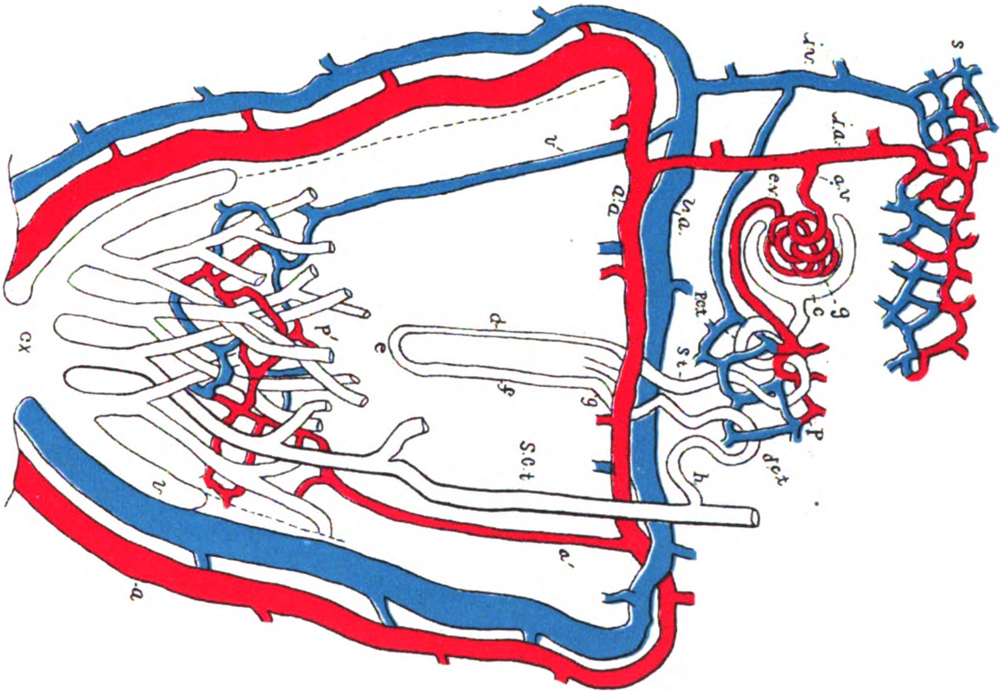


FIG. 134-A

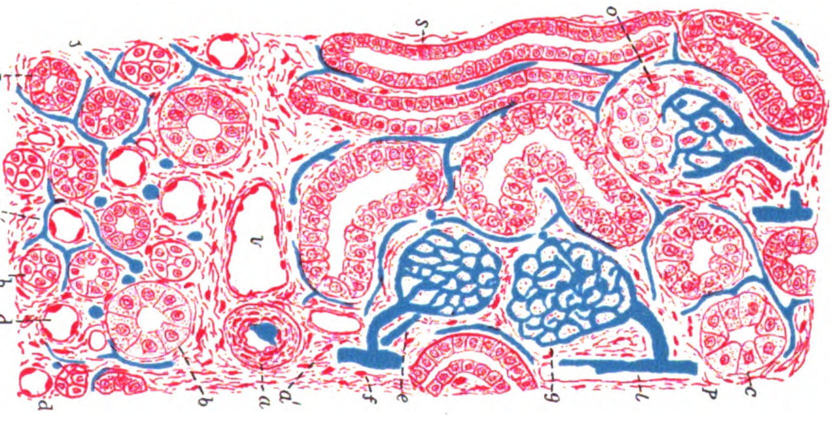


FIG. 134-B

the pyramid. The VEINS have three sources, one at the *stellate plexus*, another at the apex of each *Malpighian pyramid*, the third at the plexus enclosing the convoluted tubules. The vein which arises from the stellate plexus is termed a *vena interlobularis*, and follows a course parallel to the course followed by the corresponding interlobular artery. After receiving the veins which arise from the capillary networks surrounding the convoluted tubules the interlobular vein empties into a venous arch at the base of a Malpighian pyramid, which also receives the veins, the *venae rectae*, arising from the plexus at the apex of the pyramid. The venous arch,

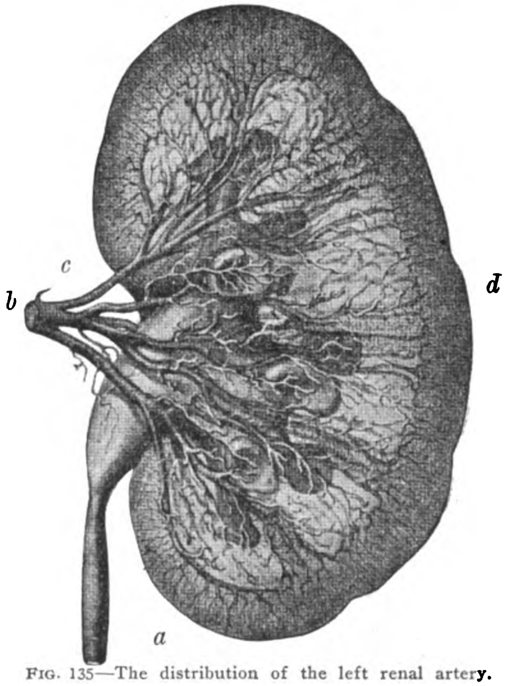


FIG. 135—The distribution of the left renal artery.

Of the six arteriæ propriæ renales, five enter in front of the renal pelvis, and, lying upon the wall of the calyces, are distributed from the arterial arcade to both cortex and medulla. *a*, ureter; *b*, renal artery; *c*, arteriæ propriæ renales; *d*, the dark border is the cortex, within which is the lighter medulla. (After Brödel, from Szymonowicz and MacCallum.)

on reaching the column of Bertini, bends and follows a course parallel to the corresponding arteria propria renalis, being termed the *vena propria renalis*. The venae propriae renales join, and receive veins from the neighboring tissue, forming the renal vein, which passes from the kidney through the hilum.

The STROMA of the kidney consists of a fine interlacing network of areolar tissue derived from the fibrous coat, which holds the other structures together.

The *nerves* are of the non-medullated variety, derived from the renal plexus. They are about fifteen in number, and enter the kidney through the hilum.

The *lymphatics* arise beneath the capsule, and between the uriniferous tubules and blood-vessels. They pass from the kidney through the hilum and terminate in the lumbar lymph glands.

Experiment 134. Examine the kidney of a human foetus and notice the lobulation.

Exp. 135. Examine a kidney which has been cut longitudinally into halves. Notice the cortical zone, the Malpighian pyramids, the columns of Bertini, the pelvis of the ureter, the sinus, and the hilum.

Exp. 136. Stain and mount a section of the kidney. Examine with the low power, and notice the difference between the cortical and medullary portions. Under the high power look for and examine the Malpighian bodies, the sections of the tubules, the coats of the kidney, and the blood-vessels. Endeavor to recognize the different divisions of the uriniferous tubules. Sketch.

Exp. 137. Mount a section of an injected kidney. Examine and notice the glomeruli, the afferent and efferent vessels, portions of the capillary networks, the interlobular arteries, the arteriae rectae, and the arteriae propriae renales. Look for a glomerulus having two vessels projecting from it and distinguish the afferent from the efferent vessel by its larger size. Sketch.

Exp. 138. If the kidney of an ox be accessible, endeavor to tease out in dilute glycerin on a slide the different portions of an uriniferous tubule, the portions of the kidney having been macerating in hydrochloric acid 30% for 24 hours.

THE URETER.

The ureter is a fibro-muscular tube, beginning at the pelvis in the sinus of the kidney, and extending to the bladder. It consists of three coats, mucous, muscular and fibrous.

The mucous coat consists of two portions, epithelial and tunica propria. The *epithelial portion* consists of transitional epithelium which extends into the calices above and is continuous with the epithelium of the bladder below.

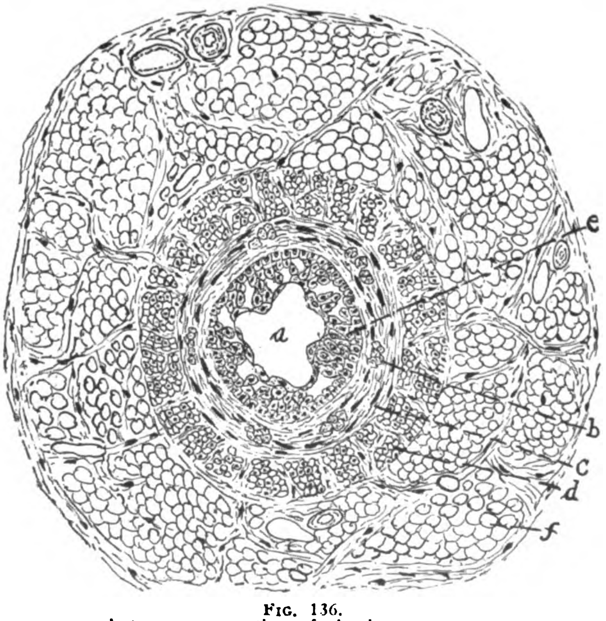
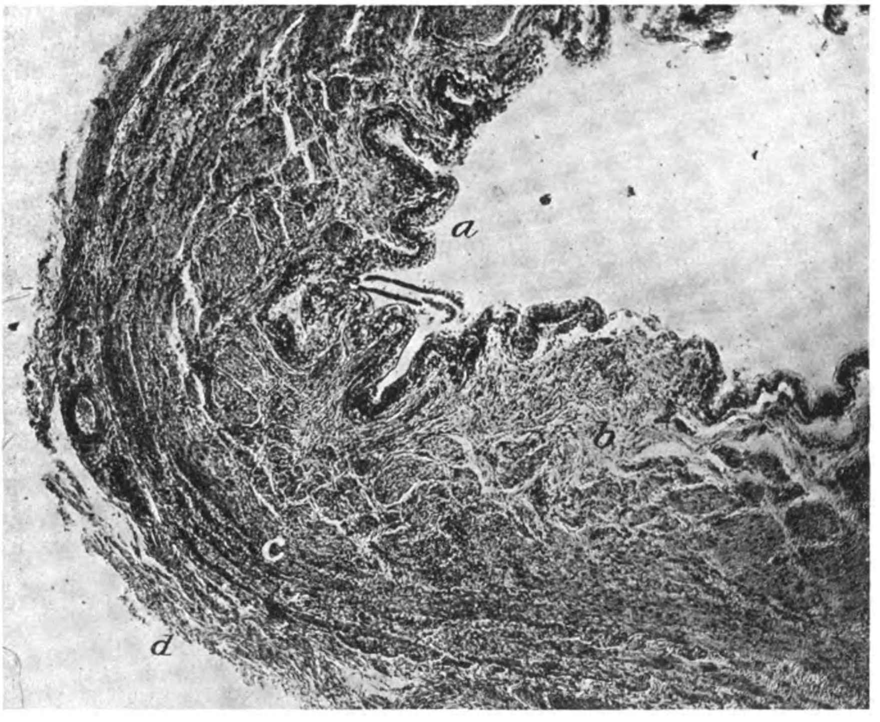


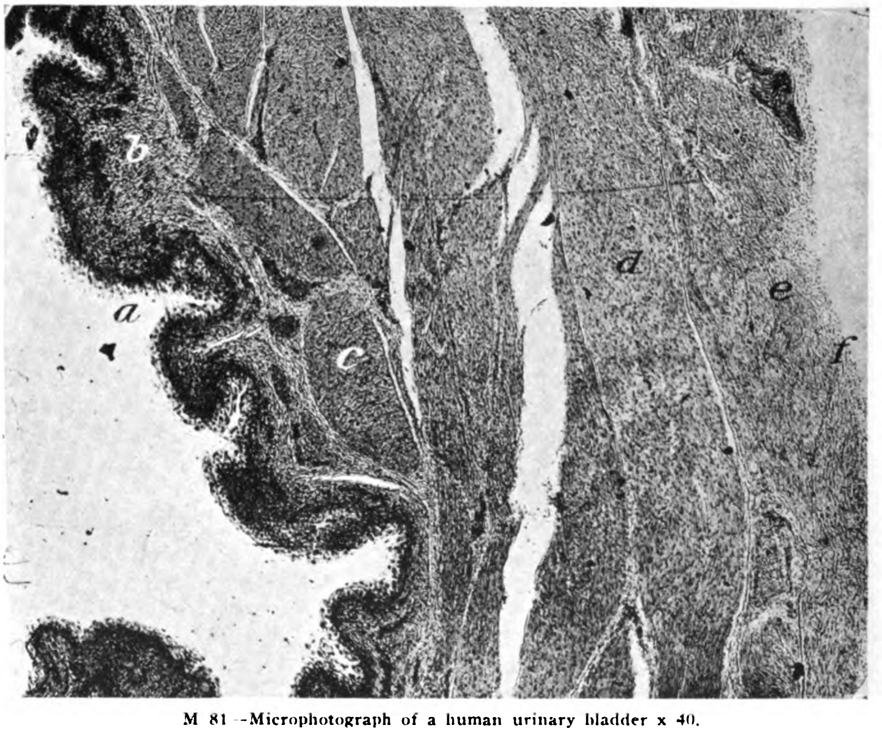
FIG. 136.
A transverse section of the human ureter.
(*a*) lumen; (*e*) transitional epithelium; (*c*) circular layer of involuntary muscle with some longitudinal fibres (*b*); (*d*) outer layer of longitudinally disposed involuntary muscle fibres; (*f*) fibrous coat containing blood vessels, adipose tissue, nerves and lymphatics.

The *tunica propria* is composed of areolar tissue in which capillary blood-vessels ramify and lymphatics arise.

The *muscular coat* is a distinct band of involuntary muscle, continuous above with that of the covering of the kidney, below with the muscular coat of the blad-



M 80—Microphotograph of a portion of a transverse section of the ureter of a cat x 50. *a*, mucosa; *b*, submucosa; *c*, muscular coat; *d*, serous coat.



M 81 --Microphotograph of a human urinary bladder x 40.

a. mucous membrane; *b*. submucosa; *c*, transverse sections of involuntary muscle; *d*, longitudinal section of involuntary muscle; *e*, transverse section of involuntary muscle; *f*, serous coat.

der. It becomes more distinct as the ureter approaches the bladder, consisting in its upper portion of circular fibres, containing a few longitudinal ones internal to the circular fibres; and near the bladder consisting of circular fibres, internal and external to which are longitudinal fibres, thus appearing as three layers.

The *fibrous tissue* of the covering of the kidney continues on the ureter, and becomes its fibrous coat, and consists of areolar and adipose connective tissue, containing ramifying blood-vessels, lymphatics, and nerves.

Experiment 139. Stain and mount a transverse section of the ureter. Examine and sketch. Notice rugae.

THE BLADDER.

The bladder consists of three coats. The outer coat is fibrous, and is continuous with that of the ureter, external to which in some regions of the bladder there is a reflection of the peritoneum, forming a serous coat. The middle coat of the bladder is muscular, and consists of involuntary muscle fibres. The muscle fibres, being continuous with those of the ureter, have a tendency to be disposed in three layers, a middle circular and an inner and outer longitudinal; but as the fibres spread out in the wall of the bladder they become so intertwined that the division into three layers is not very distinct.

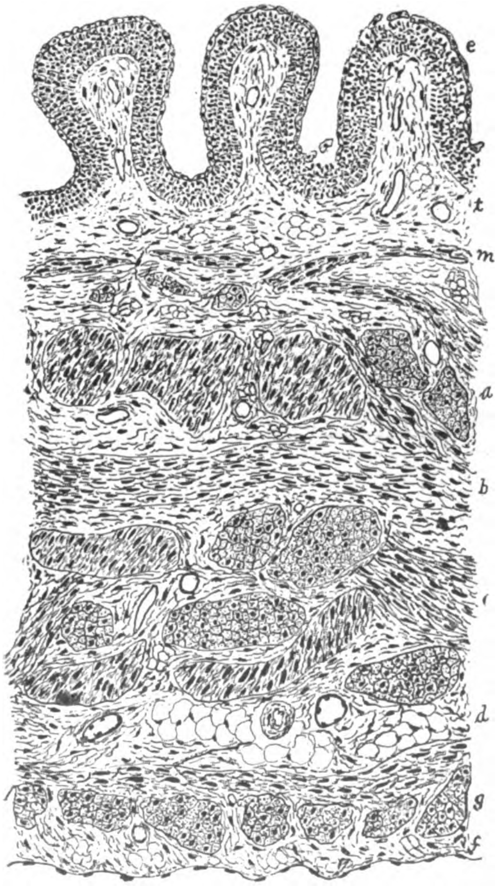


FIG. 137.

A portion of a section of the human urinary bladder. (*e*) transitional epithelium; (*t*) tunica propria; (*m*) involuntary muscle fibres most of which are circularly disposed; (*a*) oblique sections of bundles of involuntary muscle fibres; (*b*) circularly disposed fibres which, with the preceding two layers, make up the inner layer of the muscular coat; (*c*) middle layer, and (*g*) external layer of muscular coat; (*d*) areolar and adipose tissue; (*f*) serous coat.

At the lower end of the bladder the circular fibres increase in number and form a sphincter, the *sphincter vesicae*. The inner coat is a mucous membrane, which is covered by transitional epithelium, and the tunica propria of which contains mucous glands and lymphoid nodules.

The *arteries* to the ureter and to the bladder ramify in the fibrous coat of each, the branches extending to the tunica propria, where they terminate in a capillary plexus. The veins arise and pass from the organs in the same manner as the arteries pass to them. The *lymphatics* arise in the fibrous tissue of the coats and accompany the blood-vessels from the organs. The *nerves* to the ureter are of the non-medullated variety, while those of the bladder are of both varieties.

Experiment 140. Stain, mount and examine a vertical section of the bladder. Notice the coats, the involuntary muscle fibres, and the transitional epithelium. Sketch. Notice the rugae.

THE URETHRA.

The urethra, the membranous tube which leads from the bladder to the exterior, consists of a mucous membrane supplemented by a submucous tissue. The MUCOUS MEMBRANE is continuous with that of the bladder, and is lined by epithelium, which varies in character according to the location. In the *prostatic portion* of the urethra the epithelium is similar to that of the vesical mucous membrane, being of the *transitional variety;* in the *membranous portion* it is of the *stratified columnar* variety; while in the penile portion it is of the *stratified columnar* variety to the fossa navicularis, where it becomes of the *stratified squamous* variety, which is continuous with the stratified squamous epithelium covering the free surface of the penis. In the female the urethra is lined by stratified squamous epithelium, which is continuous with that lining the vagina, excepting a small portion nearest to the bladder, which is lined by the transitional variety.

Beneath the epithelium of the mucous membrane of the urethra there is a *tunica propria,* which is composed of white and yellow fibrous tissue and a variable amount of lymphoid tissue. The tunica propria is beset with papillae, which are most numerous near the external opening of the urethra, the *meatus urinarius.*

THE SUBMUCOUS TISSUE consists of white and yellow fibrous tissue, in which there are mucous glands or follicles, termed the glands of Littré, which open by means of ducts on the free surface of the mucous membrane. The submucous tissue contains involuntary muscle fibres throughout portions of the urethra, which are continuous with those of the bladder. In the prostatic portion the muscle is arranged in two layers, an inner longitudinal, continuous with the internal longitudinal layer of the muscular coat of the bladder, and an outer circular continuous with the corresponding layer of the bladder. The muscle fibres gradually diminish in the membranous, disappearing in the penile portion, becoming replaced by fibrous tissue. On the membranous portion there are also some voluntary muscle fibres, which are derived from the *compressor urethrae* muscle.

Experiment 141. Stain and mount a transverse section of the penis, preferably of an infant. Examine and look for the urethral opening. Sketch the section of the urethra, and designate, by the lining epithelium, which portion it is.

CHAPTER XIV.

THE GENERATIVE ORGANS OF THE MALE.

THE TESTICLE.

The testicle is a compound tubular gland, oval in shape, convex on its anterior border, and somewhat flattened laterally and posteriorly. It has two coats, the outer of which is serous, and the inner is fibrous. The *serous* coat is a reflection from the peritoneum, termed the *tunica vaginalis propria,* and covers the entire organ, except at its anterior border. The *fibrous* coat is a dense covering composed of white fibrous connective tissue of a glistening white appearance, and is termed the *tunica albuginea.* The inner portion of the tunica albuginea is loosely arranged, rich in blood-vessels, and is termed the *tunica vasculosa testis.* At the posterior border of the gland the tunica albuginea forms a dense vertical mass, termed the *mediastinum testis,* or the *corpus Highmori.* From the mediastinum, fibrous septa extend to the periphery of the organ, which become connected with the fibrous coat and divide the gland into lobules, termed the *lobuli testis.* The number of lobules in one testicle is about three hundred. Each lobule is conical in shape, with its base at the periphery, its apex at the mediastinum, and contains one or more of the secreting tubules, termed the *tubuli seminiferi.*

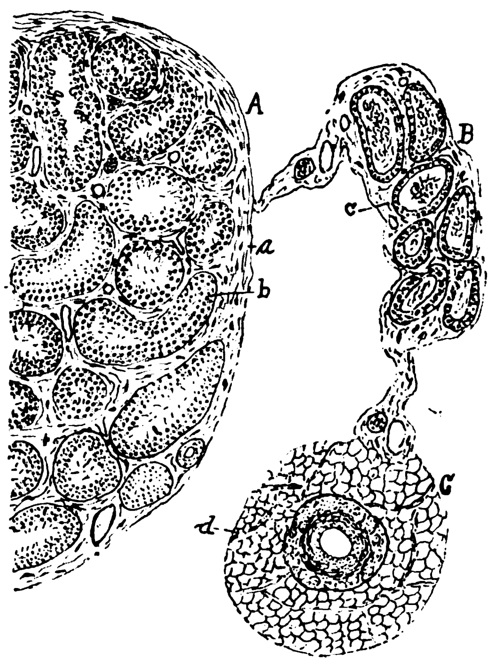


FIG. 138.
Section of testicle of rat.
(A) testicle; (B) portion of globus major of epididymis; (C) epididymis; a) tunica albuginea testis; (b) section of convoluted or tortuous tubule; (c) vasum efferentium containing spermatozoa; (d) adipose tissue.

Each tubule is divided into three portions: (a) the *convoluted* or *tortuous portion,* which makes up the bulk of the lobule, being most tortuous at the base of the lobule and becoming less tortuous toward the apex, assuming (b) a straight course near the apex, termed the *vasum rectum,* which passes into the mediastinum and joins other vasa recta to form (c) an anastomosing network in the mediatinum termed the *rete testis.* The tubules are held together by a loose network of fibrous tissue, the spaces of which network are lined by endothelioid cells (connective tissue cells) and appear to be lymph spaces. On examining stained sections of the testicle, groups of cells are sometimes observed in the intertubular spaces. These groups of cells have caused some uncertainty in the minds of investigators, and various reasons have been assigned accounting for their presence. After carefully examining various sections of the testicle, the author concludes that the groups of cells in the intertubular spaces are merely tangental sections of portions of the tortuous tubules of a different plane than the one in which the sections have been cut. The tubules consist of a basement membrane, upon which rest modified epithelial cells. The epithelial cells of the tortuous portion of the tubule are arranged in several layers, the layer resting upon the basement membrane, termed the *germinal epithelium,* composed of cuboidal-shaped cells, the others layers of spherical-shaped cells. The germinal epithelium consists of two kinds of cells, the *cells of Sertoli,* or sustentacular cells, and *spermatogonia.* A spermatogonium divides, one division persisting as a spermatogonium, while the other is known as a primary spermatocyte. The primary spermatocyte contains the same number of chromosomes as its parent spermatogonium. It divides, forming two secondary spermatocytes, each of which forms two spermatids, which in turn become spermatozoa. The spermatids, consequently the spermatozoa, contain one-half the number of chromosomes as the spermatogonia, and therefore a spermatozoon is not capable of further division, but is prepared to blend with another cell, the ovum after it has thrown off its polar bodies, containing reduced number of chromosomas to form a cell of proper amount of chromosomes to enable it to divide. The epithelium of the vasum rectum consists of a single layer of low cuboidal cells, which represent a transition between the cells of the lowest layer in the tortuous portion of the tubule and the cells lining the tubules of the rete testis. The tubules of the rete testis appear as communicating clefts in the fibrous tissue of the mediastinum, which clefts are lined by a layer of flat cells.

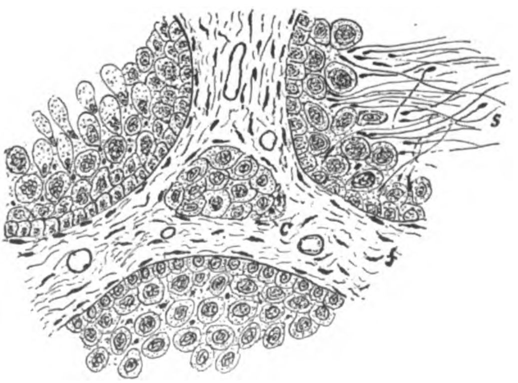
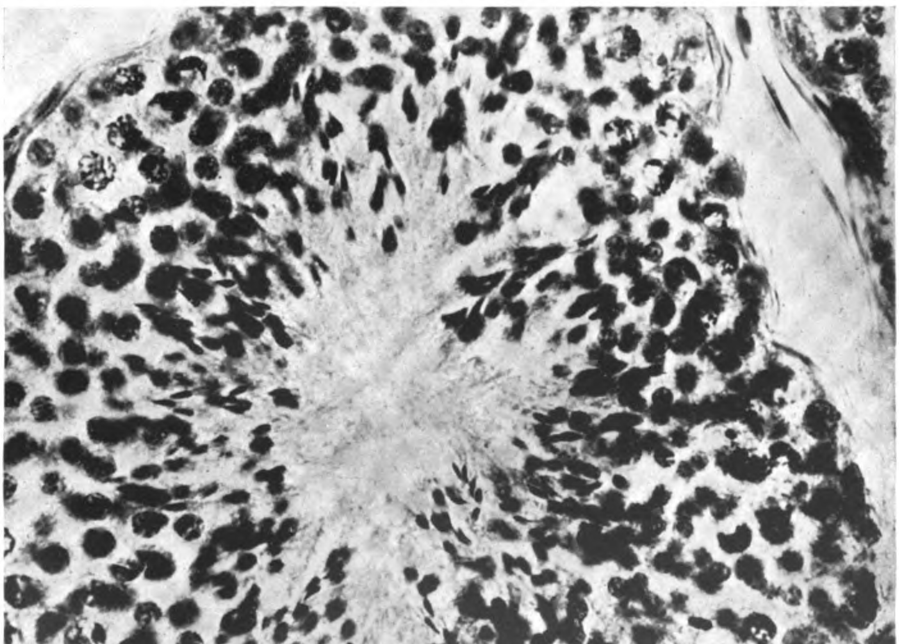


FIG. 139.
Portions of three sections of the tortuous portion of a seminiferous tubule showing different stages of spermatogenesis.
(*s*) spermatozoa; (*f*) the intertubular fibrous tissue containing blood-vessels, and a group of polygonal-shaped cells (c).

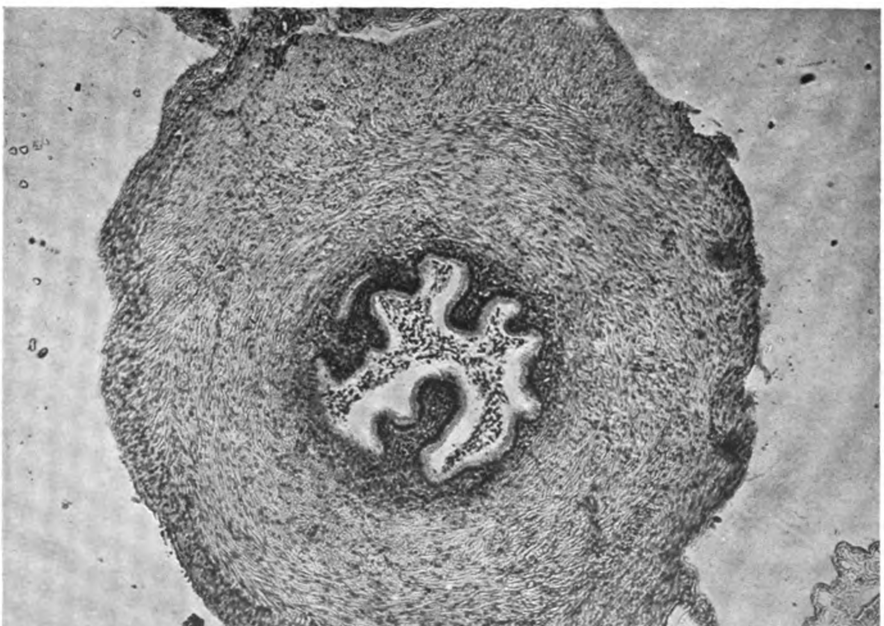
At the upper border of the mediastinum the tubules leave the testicle, and are termed the *vasa efferentia.* There are about fifteen vasa efferentia, each of which consists of a single tube, which becomes convoluted, forming a conical-looking mass, and consists of a basement membrane lined by simple ciliated cuboidal-shaped cells, which represent a transition between the flat cells of the rete testis and the ciliated stratified columnar epithe-

M 82—Microphotograph of a human testicle x 45.
a, tunica albuginea; *b*, section of tortuous portions of seminiferous tubules.



M 83—Microphotograph of a transverse section of the tortuous portion of a seminiferous tubule of a human testicle x 490 illustrating spermatogenesis.

M 84—Microphotograph of a portion of specimen used for M 82 x 45.
a, tunica albuginea; *b*, sections of the tubules of globus major of epididymis; *c*, transverse section of epididymis; *e*, numerous blood vessels in connective tissue.



M 85—Microphotograph of a transverse section of a human vas deferens x 55 illustrating the coats and spermatozoa contained in the lumen.

lium of the epididymis. In some instances an additional layer of flat cells can be observed next to the basement membrane. The vasa efferentia are surrounded by a vascular fibrous network, forming the *coni vasculosi*. The vascular cones are arranged with their apices toward the mediastum, and their bases form the *globus major* of the epididymis. The vasa efferentia, after forming the globus major of the epididymis, open into a single duct, termed the *epididymis* (Gr. επι, upon; διδυμος, testicle), which passes in a tortuous manner from the upper border of the testicle to the lower border, where it forms a convoluted mass, termed the *globus minor* of the epididymis, and continues as the *vas deferens*. In some instances, a tube termed the *vas aberrans* (Haller) extends from the lower portion of the epididymis or from the beginning portion of the vas deferens, terminating as a blind extremity. It is similar in structure to the vas deferens.

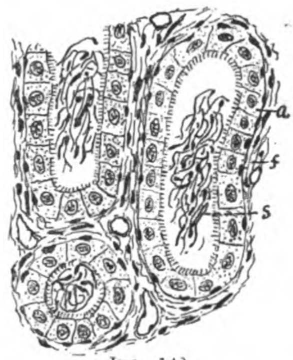


FIG. 140.
Sections of vasa efferentia of specimen used in fig. 138.
(*a*) ciliated epithelium; (*f*) fibrous connective tissue; (*s*) spermatozoa.

THE EPIDIDYMIS consists of three coats, a mucous, a muscular and a fibrous. The mucous coat consists of an epithelial portion composed of ciliated stratified columnar epithelium, and a small amount of areolar connective tissue as a tunica propria. The muscular coat consists of a thin layer of involuntary muscle fibres. The fibrous coat consists of white fibrous connective tissue the fibres of which are chiefly disposed longitudinally. External to the fibrous coat there is a layer of areolar tissue containing some adipose tissue, blood-vessels, lymphatics and nerves, enclosed by a band of circularly disposed white fibrous tissue analogous in appearance and structure to the tunica albuginea of the testis.

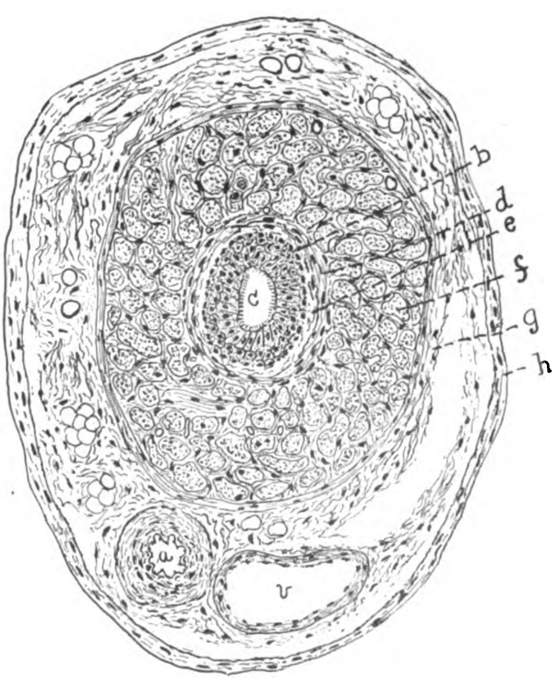


FIG. 141.
Transverse section of the epididymis of a rat.
(*c*) lumen; (*b*) ciliated stratified columnar epithelium; (*e*) tunica propria; (*d*) circularly disposed muscle fibres; (*f*) bundles of white fibrous connective tissue; (*g*) fibrous tissue containing blood-vessels, adipose tissue, nerves, lymphatics; (*h*) fibrous coat; (*a*) artery; (*v*) vein.

THE VAS DEFERENS is a tube which has three distinct coats. The inner, or *mucous*, coat is lined by stratified columnar epithelium. Beyond the basement membrane there is a small amount of fibrous tissue, the tunica propria, which connects it with the muscular coat. The middle, or *muscular*, coat consists of involuntary muscle fibres disposed in three layers, a middle circular, and an inner and outer longitudinal. The outer, or *fibrous,* coat is composed chiefly of white fibrous tissue containing adipose tissue, vessels and nerves. The mucous coat of prepared specimens appears to be thrown into longitudinal folds or rugae.

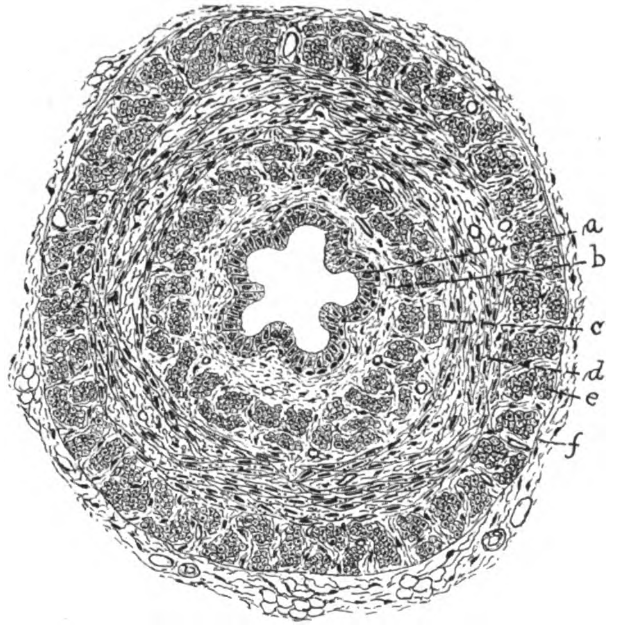


FIG. 142.
A transverse section of the vas deferens.
(*a*) stratified columnar epithelium; (*b*) tunica propria, (*c*) internal, (*d*) middle, and (*e*) external layers of the muscular coat; (*f*) fibrous coat.

Experiment 142. Stain with haematoxylin and eosin, and mount a section of the testicle. Examine and sketch several sections of the seminiferous tubules, the intertubular tissue, septa, and tunica albuginea.

Exp. 143. Stain with Van Gieson stain and mount a section of a rat's testicle. Notice the same portions as in the preceding experiment. Look for spermatozoa in the sections of the tubules and also the cells in different stages of spermatogenesis. Look for vasa efferentia outside of the tunica albuginea. Sketch.

Exp. 144. Stain and mount a tranverse section of the epididymis. Examine and notice the lining epithelium. Look for involuntary muscle fibres. Sketch.

Exp. 145. Stain and mount a transverse section of the vas deferens. Examine and sketch the three coats.

THE VESICULAE SEMINALES.

The vesiculae seminales, the two pouch-like reservoirs for the semen, consist each of a coiled tube of varying diameter, which has pouch-like diverticula extending from it. Each vesicle is composed of three coats, an inner or *mucous* coat, lined by stratified columnar epithelium; a middle or *muscular* coat, composed of involuntary muscle fibres disposed in three layers, the internal and external of which are composed of fibres arranged longitudinally, while the middle layer is composed of circularly-disposed fibres; and an outer, or *fibrous,* coat, derived from the neighboring fascia (the recto-vesicle), which holds the coils and the diverticula of the tube in a mass. The continuation of the vas deferens, after its junction with the tube of the vesicula seminalis, is termed the ejaculatory duct.

Each ejaculatory duct terminates in the prostatic portion of the urethra, and consists of three thin coats. The outer, or *fibrous,* and the inner, or mucous coats, are similar to the corresponding coats of the vas deferens with the exception that the epithelium is of the simple columnar variety instead of the stratified type. The middle, or *muscular,* coat is composed of two layers of involuntary muscle, very poorly developed, the outer of which is composed of circularly, the inner of longitudinally disposed fibres.

.THE PENIS.

The penis, the organ of the male adapted for the purpose of copulation, consists of specially-arranged fibrous tissue covered by skin. Through it, lengthwise, passes the urethra for the transmission of the seminal fluid, as well as the urine, to the exterior of the body.

THE SKIN of the penis is remarkable on account of its thinness, dark color, looseness, and not containing fat in its subcutaneous tissue. It is continuous at the root of the penis, with the skin of the pubes and scrotum. Anteriorly it projects over the *glans penis* as the *prepuce,* the free border of the prepuce being connected by means of mucous membrane to the constricted portion behind the glans penis, termed the neck or *cervix penis.* The glans penis is covered by mucous membrane, the epithelium of which is of the stratified squamous variety continuous with that lining the terminal portion of the urethra. The mucous membrane which covers the glans penis does not contain sebaceous glands, but does contain sensitive papillae. In the mucous membrane behind the *corona glandis,* and in that which forms the *fraenum preputii,* there are small sebaceous glands, termed the *glandulae Tysonii odoriferae,* which secrete a sebaceous substance which emits a peculiar characteristic odor.

The main substance of the penis consists of fibrous tissue, disposed in three cylindrical masses, two of which are on the same level, the other below the two, the three collections thus disposed presenting an appearance similar to that presented by a "double-barrel shotgun, with ramrod below." The two upper masses are termed the *corpora cavernosa,* the lower mass the *corpus spongiosum.*

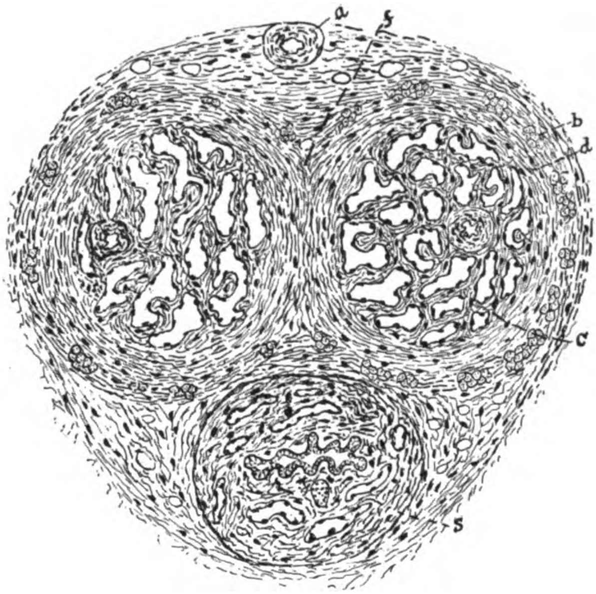


FIG. 143.
A transverse section of the penis of a child.
(*a*) dorsal artery of penis; (*f*) septum pectiniforme; (*b*) longitudinally disposed fibres, and (*d*) circularly disposed fibres of connective tissue of the sheaths to the corpora cavernosa (*c*); (*s*) corpus spongiosum containing a transverse section of the urethra in its centre.

THE CORPORA CAVERNOSA are covered by a sheath composed of white and yellow fibrous tissue disposed in two layers, the *outer* of which is composed of longitudinal fibres arranged as a sheath common to both of the corpora; the *inner* composed of circular fibres disposed as a sheath to each of the corpora. Where the circular layers blend together between the corpora cavernosa an incomplete septum is formed, termed the *septum pectiniforme*. The fibrous sheath sends inshoots into the corpora, which ramify and form a network with wide, irregular-shaped spaces between the fibres. The inshoots consist of white and highly developed yellow fibrous tissue, among which are involuntary muscle fibres. This tissue is termed *erectile tissue*.

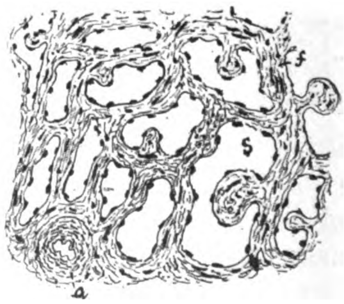
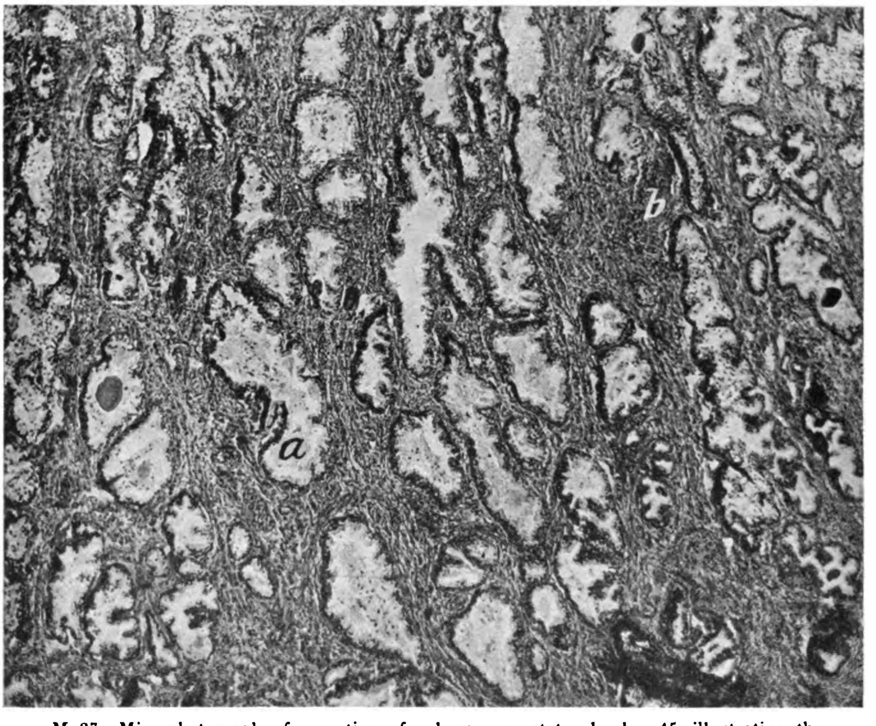


FIG. 144.
A portion of corpus cavernosum of specimen used in fig. 143, showing erectile tissue.
(*s*) blood sinus; (*f*) fibrous bands containing involuntary muscle fibres; (*a*) artery.

THE CORPUS SPONGIOSUM is similar in structure to the corpora cavernosa, except that its fibrous sheath is thinner but more elastic than that of the corpora cavernosa. In its sheath and in the tissue surounding the spongy portion of the urethra (which is contained in the corpus spongiosum) there are usually some involuntary muscle fibres derived from the muscular tissue contained in the wall of the membranous portion of the urethra.

M 86—Microphotograph of a transverse section of a child's penis x 8.

a, fibrous coat enclosing the corpora; *b*, septum pectiniformi; *c*, corpus cavernosum; *d*, corpus spongiosum containing transverse section of the urethra; *e*, connective tissue containing blood vessels, etc.



M 87—Microphotograph of a section of a human prostate gland x 45, illustrating the alveoli (*a*), and the interalveolar tissue (*b*).

The tissue around the corpora is fibrous connective tissue, which contains numerous blood-vessels, lymphatics, and nerves. The *arteries* entering the penis ramify in the fibrous tissue, branches extending into the erectile tissue to terminate in sinuses. The walls of the arterioles blend with the septa of the erectile tissue, as a consequence of which the blood passes into the spaces. Veins arise in the same manner as the arteries terminate, and convey the blood from the penis. The *nerves* of the penis are of both varieties, the medullated fibres being derived from the internal pudic nerve, the non-medullated from the hypogastric plexus of the sympathetic system. Some of the nerves terminate as Pacinian corpuscles, others as genital corpuscles. The *lymphatic* vessels consist of two sets. The superficial set arises in the skin of the penis and in the mucous membrane of the glans and cervix, and passes to the inguinal glands. The deep set arises in and around the corpora and joins the lymphatics of the pelvis.

Experiment 146. Examine the specimen of the penis used in Exp. 141. Notice the arrangement of the corpora, the section of the urethra contained in the corpus spongiosum, the erectile tissue, the section of mucous membrane, or of skin, at the periphery of the section, and the numerous blood-vessels. Sketch.

THE PROSTATE GLAND.

In close proximity to the neck of the bladder and somewhat encircling the prostatic portion of the urethra there is a gland which secretes a thin, glairy fluid having a slightly acid reaction, which seems to be for the purpose of diluting the fluid coming from the testes. This gland is known as the prostate body or gland.

The *prostate* gland is a compound racemose gland possessing numerous excretory ducts, varying between twelve and thirty in number. It has two coats somewhat blended together, an outer fibrous and an inner muscular. The inner, composed of involuntary muscle fibres, accompanies the fibrous inshoots or trabeculae into the gland as they extend in and divide the gland up into lobules. The ducts start at the free surface of the mucous membrane of the prostatic portion of the urethra and at first are lined by the same kind of epithelium as that lining this portion of the urethra, transitional epithelium, but very soon the transitional variety is displaced by the simple columnar type, which continues on as the ducts divide and subdivide to terminate in acini. The acini or alveoli are the terminal dilatations of the ducts and are lined by low form of simple columnar epithelium

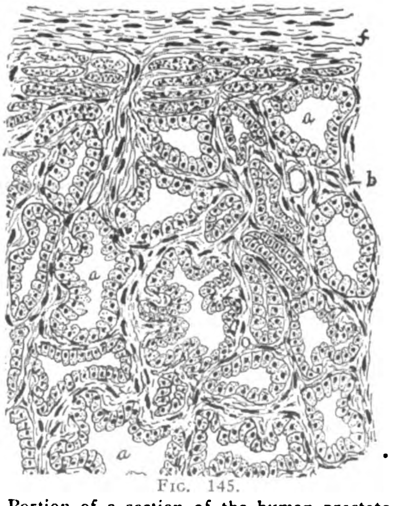


FIG. 145.
Portion of a section of the human prostate gland.
(*f*) fibrous coat containing involuntary muscle fibres; (*a*) acinus; (*b*) trabecula.

modified so as to give the secretion characteristic to the gland. Sometimes what appears to be an additional layer of cells can be observed next to the basement membrane. The acini are held together by the fibrous tissue network derived from the trabeculae which contains a comparatively large amount of involuntary muscle. In the alveoli, especially of old men, peculiar concentricly arranged bodies termed *corpora amylaceae* are sometimes found.

The *arteries* are derived from the vesical, hemorrhoidal, and pudic arteries, and accompany the trabeculae into the gland finally terminating as a capillary network around and between the acini. Veins arise from the capillary network and pass out in the same way as the arteries enter.

The *lymphatics* arise in the interfascicular clefts of the fibrous tissue, join one another and pass to the neighboring lymph glands.

The *nerves,* consisting of medullated and non-medullated fibres, pass along in the trabeculae to the acini and form a plexus beneath the glandular epithelium.

Experiment 147. Stain and mount a section of the prostate gland. Notice the irregular outline of the acini; the lining epithelium; the involuntary muscle fibres between the acini, as well as in the trabeculae and on the surface of the gland. Look for the concentric bodies. Sketch.

CHAPTER XV.

THE REPRODUCTIVE ORGANS OF THE FEMALE.

THE OVARY.

THE OVARY is an oval-shaped organ corresponding in the female to the testicle of the male. It has a *serous coat,* which surrounds the organ, being absent only at the point of attachment of the ovarian ligament. It is formed by a reflection of the peritoneum, which differs from other serous membranes in having a dull gray instead of a glistening white appearance, and a layer of short columnar-shaped cells, known as the *germinal epithelium,* instead of a layer of flat endothelial cells. The substance of the ovary consists of a *stroma, Graafian vesicles* or *follicles,* and *corpora lutea.*

THE STROMA consists of a network of connective tissue, among the fibres of which are *spindle-shaped cells* similar in appearance to connective tissue corpuscles. The portion of the stroma just beneath the serous covering of the organ is more dense than the rest of the stroma, and is termed the *tunica albuginea* of the ovary, which is not a distinct coat like that of the testicle. In the stroma are the Graafian vesicles, corpora lutea and numerous blood-vessels.

The *Graafian vesicles* are usually round, and contain the ova. The ova are derived from the germinal epithelium. Each epithelial cell which is to become an ovum, while passing from the periphery of the gland toward the centre, assumes a covering of cells, which probably is formed by the spindle-shaped cells of stroma, the covering cells reproducing rapidly, so that, in the fully-developed vesicle, the ovum is surrounded by a covering of cells which is continuous with several layers of cells applied to the fibrous covering of the vesicle. A fluid secretion of the cells accumulates in the vesicle. The vesicles are most numerous, but immature, in the outer portion of the stroma, just beneath the tunica albuginea.

A MATURE GRAAFIAN VESICLE is surrounded by an envelope of the stroma, termed the *theca folliculi.* The theca folliculi consists of two layers, an outer dense layer containing a few blood-vessels, termed the *tunica fibrosa;* an inner layer the fibrous tissue of which is as a loose network rich in blood-vessels,

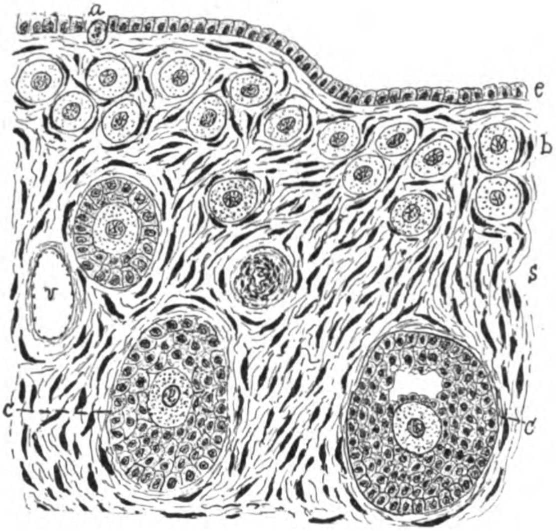


FIG. 146.
Section of ovary of cat.
(*e*) germinal epithelium; (*a*) one of the germinal epithelial cells passing inward to become an ovum; (*b*) area of young Graafian follicles; (*s*) stroma containing spindle-shaped fibres, an artery and a vein (*v*); (*c*) region of advanced Graafian follicles.

termed the *tunica vasculosa.* Next to the tunica vasculosa there are cells arranged in several layers, forming the ***membrana granulosa.*** The cells which are continuous with the membrana granulosa, and surround the ovum, form a membrane termed the ***discus proligerus.*** In some cases the discus proligerus is separated from the membrana granulosa, except at one place of attachment, the space thus formed is termed the ***antrum*** and is occupied by a liquid secretion of the cells, the *liquor folliculi.* The OVUM is surrounded by the cells of the discus proligerus; those near the ovum become arranged perpendicularly to the ovum, giving the *zona radiata.* Next to the zona radiata, and nearer to the ovum, there is a

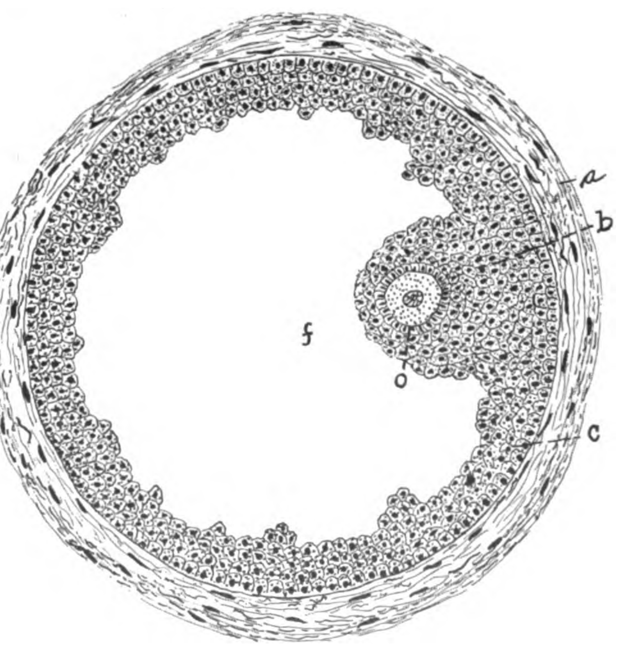
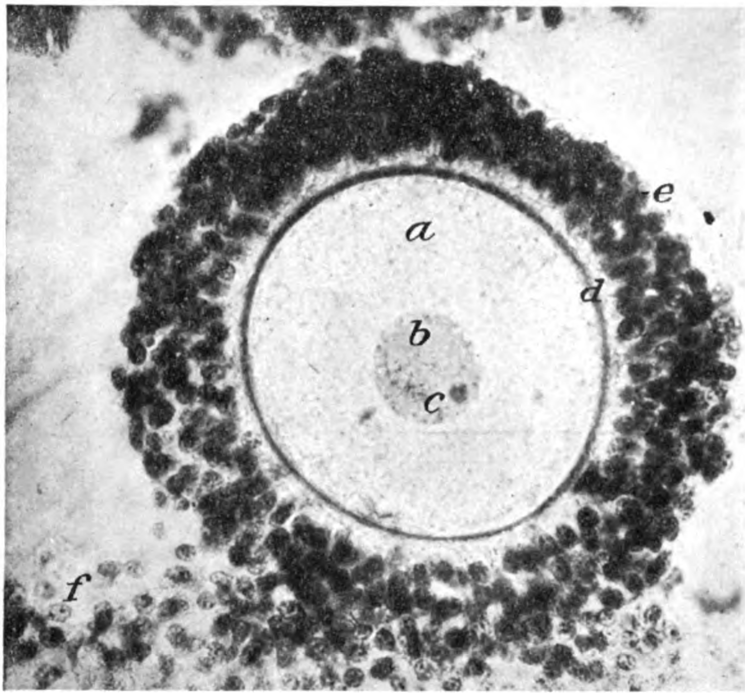


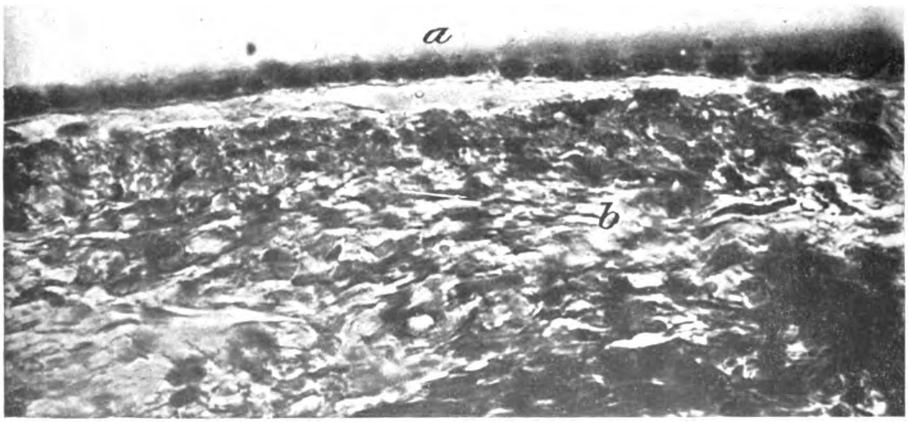
FIG. 147.
A Graafian follicle (high power).
(*a*) theca folliculi; (*b*) discus proligerus; (*c*) membrana granulosa; (*f*) cavity occupied by liquor folliculi; (*o*) ovum.

membrane which, on account of its transparency, is termed the *zona pellucida.* It appears to be composed of cells of the discus proligerus which have lost their

M 88—Microphotograph of a section of the ovary of a cat x 45.
a, periphery containing numerous young Graafian follicles; *b*, Graafian follicles in advanced stages of development; *c*, corpora lutea.



M 89—Microphotograph of a human ovum x 390, illustrating the structure of a typical cell. *a*, protoplasm showing network of spongioplasm; *b*, the nucleus bounded by its nuclear membrane; *c*, nucleolus; *d*, cell wall; *e*, cells of discus proligerus; *f*, cells of membrana granulosa.



M 90—Microphotograph of a portion of the periphery of ovary of a cat x 390. *a*, germinal epithelium; *b*, stroma cells.

nuclei and have become more or less flattened against the true cell wall of the ovum. The limiting membrane or cell wall of the ovum is termed the *vitelline membrane,* and is closely applied to the inner surface of the zona pellucida. It may be observed if during the preparation of a specimen of an ovary, the membrane shrinks from the zona pellucida (Fig. 148). Enclosed by the vitelline membrane is the protoplasm of the ovum, which is termed the *vitellus* and consists principally of oil globules. In the protoplasm there is a nucleus termed the *germinal vesicle,* in which is a nucleolus termed the *germinal spot.* In some Graafian vesicles there may be more than one ovum. After the Graafian vesicle becomes mature it gradually approaches the periphery of the ovary, ruptures, and the ovum, with some of the cells of the discus proligerus, especially the zona pellucida and radiata, adhering to it, is discharged from the ovary. The remains of the vesicle undergo metamorphosis to become a *corpus luteum.*

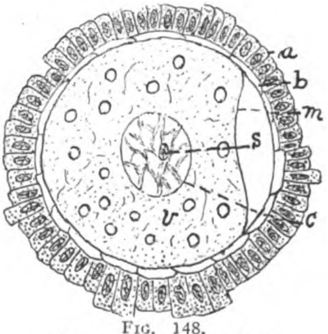


FIG. 148.
Ovum greatly magnified.
(*a*) zona radiata; (*b*) zona pellucida; (*m*) vitelline membrane shrunken from zona pellucida; (*c*) germinal vesicle; (*s*) germinal spot; (*v*) vitellus.

The *corpora lutea* are yellowish-looking masses formed by the Graafian vesicles after they have discharged their ova. They are of two kinds, the *true* and the *false corpora.*

A *true corpus luteum* is one formed by the remains of a vesicle which has discharged an ovum which becomes fecundated. The *false corpus luteum* is one formed by the ruptured vesicle which has discharged an ovum which does *not* become fecundated.

When the vesicle ruptures, the ruptured blood-vessels of the theca folliculi pour blood into the now partially-collapsed vesicle. The cells of the membrana granulosa increase in number, and the escaped blood is gradually absorbed, leaving behind some of the pigment of the colored corpuscles, so that the vesicle is now filled with cells derived from the membrana granulosa and pigment, and has a yellow color due to the latter. Newly formed connective tissue, containing embryonic connective tissue, corpuscles and capillaries, makes its appearance between the cells. The tissue thus formed by contracting causes a destruction of the cells, until they eventually disappear. Finally the fibrous tissue contracts, and the vesicle becomes like a cicatrix, yellow in color, due to the pigment obtained from the blood, and is known as a *corpus luteum.* The pigment gradually disappears. The true corpora lutea differ from the false in being *larger,* in undergoing the retrograde changes more slowly, and in retaining the pigment longer. The Graafian vesicles are very numerous, "the entire number

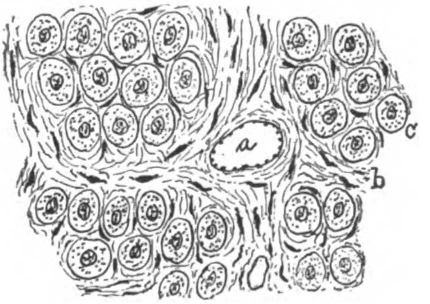


FIG. 149.
Portion of corpus luteum.
(*a*) blood-vessel; (*b*) newly formed fibrous tissue; (*c*) cells derived from membrana granulosa.

contained within the two ovaries of a child being estimated at over seventy thousand" (Piersol). The Graafian vesicles mature at regular intervals (about every twenty-eight days), the ova passing to the uterus by means of the oviducts to be retained by the uterus if fecundated; or thrown off by the uterus, if not fecundated, in the menstrual discharge. The vesicles continue to mature from the age of puberty to the age at which the *menopause* occurs, which usually is at forty-five years.

The *ovarian artery* enters the ovary at its attached border and ramifies in the stroma, the branches extending to the periphery and Graafian vesicles. The veins arise in the stroma and pass out to the pampiniform plexus of veins. The *lymphatics* arise in the clefts of the fibrous tissue in the stroma and walls of the vesicles.

The *nerves* are derived from the pelvic and ovarian plexuses, and supply the stroma and the walls of the vesicles.

Experiment 148. Stain and mount a section of a cat's ovary. Examine and study the structure of the germinal epithelium, the stroma, Graafian vesicles, and corpora lutea. Notice the large number of young vesicles just beneath the epithelium. Sketch.

Exp. 149. Stain with Van Giesen stain a section of human ovary. Notice especially the connective tissue. Sketch.

THE OVIDUCT.

THE OVIDUCT, or Fallopian tube, has three coats, a serous, a muscular, and a mucous. The *serous* coat is a reflection from the peritoneum. The *muscular* coat consists of two layers of involuntary muscle fibres, an external longitudinal and an internal circular. The *mucous* coat is continuous with the peritoneum at the fimbriated extremity of the tube, and with the mucous membrane of the uterus at its uterine extremity. The epithelium lining the tube is of the ciliated simple columnar variety. The tunica propria of the mucous membrane is composed of white and yellow fibrous tissue. The mucous membrane is thrown into numerous folds, especially at the fimbriated extremity of the tube.

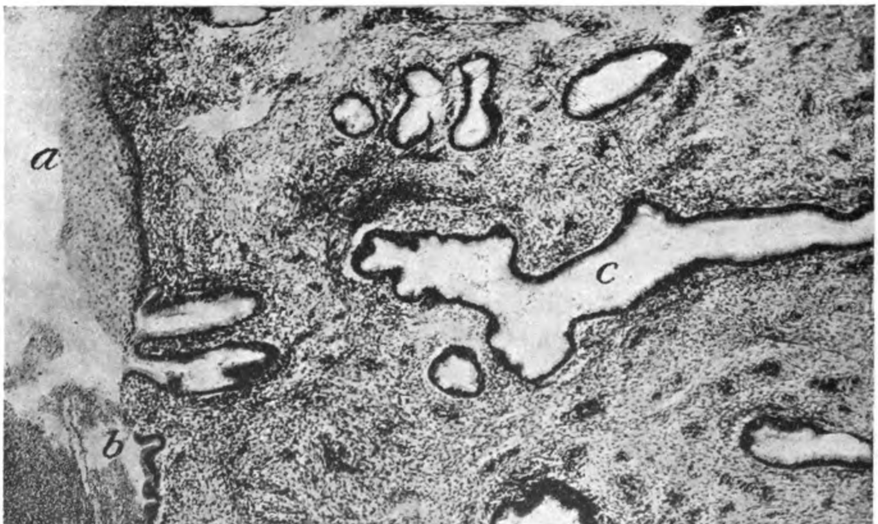
Experiment 150. Stain and mount a transverse section of the oviduct. Examine and sketch the coats under both powers.

FIG. 150.
Portion of a transverse section of the oviduct of a cat.
(*a*) serous coat; (*b*) outer or longitudinal layer of involuntary muscle; (*c*) inner or circular layer of involuntary muscle; (*d*) tunica propria; (*f*) fold of mucous membrane lined by ciliated columnar epithelium; (*e*) lumen.

M 91—Microphotograph of a portion of a transverse section of a human Fallopian tube, x 20.
a, villi of the mucosa; *b*, inner; *c*, middle, and *d*, outer layer of muscular coat.

M 92—Microphotograph of a transverse section of the uterus of a cat x 40.

a, **uterine cavity lined by the endometrium;** ***b***, **tunica propria of endometrium containing the uterine glands cut in different sections;** ***c***, **muscular coat;** ***d***, **connective tissue containing numerous blood vessels.**



M 93—Microphotograph of a section of the uterus illustrating the junction of the cervix with the corpus uteri x 45.

a, stratified squamous epithelium of the cervical mucosa; *b*, the ciliated columnar epithelium of the corporeal portion of the mucosa; *c*, uterine glands of the cervix.

THE UTERUS.

THE UTERUS is composed of three coats, a serous, a muscular, and a mucous.

THE SEROUS COAT is a reflection from the peritoneum, and does not cover the entire uterus.

THE MUSCULAR COAT is composed of bundles of involuntary muscle fibres which run in various directions and can not be divided into distinct layers, but for convenience are arranged in three, an outer, a middle, and an inner. The *outer layer*. termed the stratum serosum, is composed of involuntary muscle fibres, disposed in circular and longitudinal bundles, which are continued into the structures attached to the uterus, i. e., the oviducts and ligaments. The *middle layer,* termed the stratum vasculosum, on account of the numerous blood-vessels therein contained, is composed of involuntary muscle fibres running in all directions. The *inner layer,* termed the stratum mucosum, is composed of fibres disposed in all directions, those most internal being disposed chiefly in a circular manner, and may be regarded as a highly developed muscularis mucosae.

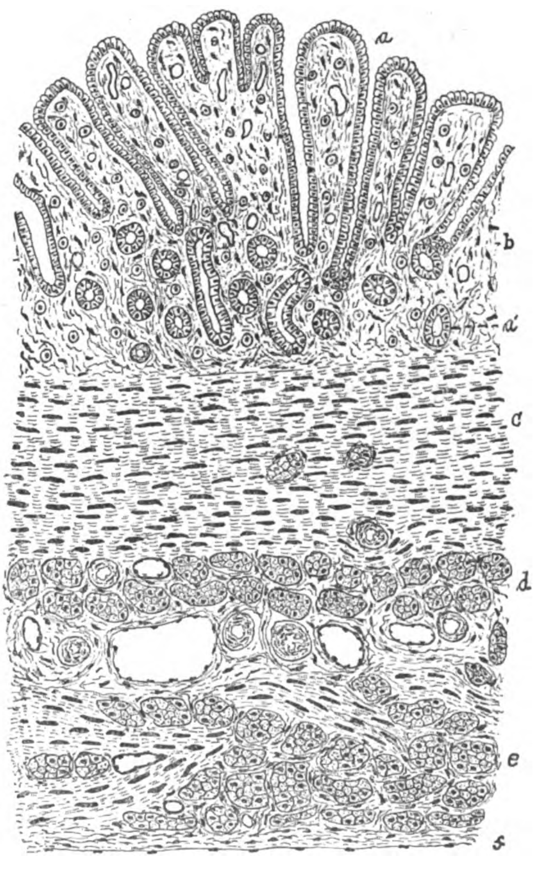


FIG. 151.
Portion of a section of the uterus of a cat.
(*a*) uterine gland; (*a'*) transverse section of uterine gland; (*b*) tunica propria; (*c*) inner layer, (*d*) middle layer containing numerous blood vessels, and (*e*) outer layer of the muscular coat; (*f*) serous coat.

THE MUCOUS COAT consists of a tunica propria, upon which rests the epithelium which is of the ciliated simple columnar variety. The basement membrane, with its lining epithelium, extends from the general surface of the mucous membrane as tubular (simple and compound) glands, termed the *uterine*

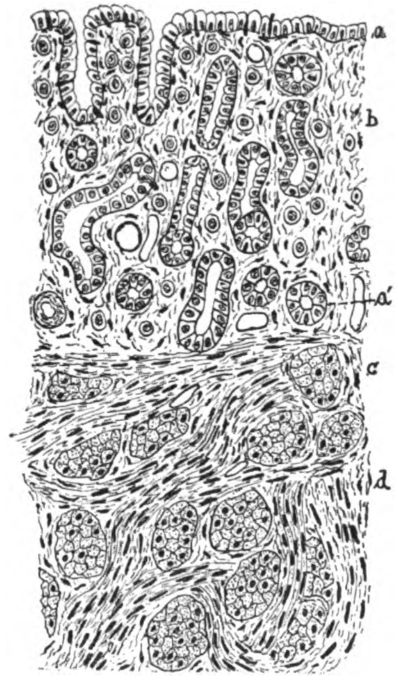


FIG. 152.
Portion of a section of the human uterus. (*a*) epithelial lining of mucous membrane: (*b*) tunica propria, containing uterine glands; (*a'*) transverse section of uterine gland; (*c*) the so-called inner layer of the muscular coat analogous to a muscularis mucosae; (*d*) portion of the so-called middle layer of muscular coat.

glands, to and sometimes among the fibres of the inner layer of the muscular coat. The mucous membrane of the cervix uteri is lined on its upper portion by epithelium similar to that of the mucous membrane of the body of the uterus, but in the lower portion of the cervix the epithelium is of the stratified squamous variety, continuous with that lining the vagina. Besides the uterine glands, there are in the cervical mucous membrane *mucous follicles* which give the characteristic white glairy mucous secretion of the cervix uteri. When retention of the secretion occurs, the *ovula Nabothi* are formed.

The *arteries* to the uterus are derived from the ovarian and uterine arteries. They pass beneath the serous coat into the muscular coat and ramify, some of the branches formed supplying the muscle fibres of the muscular coat, while others pass to and ramify in the tunica propria of the mucous membrane. The arterioles terminate in irregular-shaped spaces, the walls of which become blended with the connective tissue between the bundles of muscle fibres. In this manner the blood flows directly into the spaces in the connective tissue, termed the uterine sinuses. The veins begin in the muscular coat in the same manner as the arteries terminate.

The *lymphatics* arise in the interfascicular clefts of the tunica propria and of the intermuscular connective tissue, and join to form channels in the subendothelial tissue of the serous coat.

The *nerves* of the uterus consist of both varieties, the medullated fibres being derived from the lower sacral nerves; the non-medullated fibres from the hypograstic and ovarian plexuses of the sympathetic.

Experiment 151. Stain, mount and examine a transverse section of the human uterus. Notice the muscular tissue, blood-vessels, mucous membrane, and glands. Sketch.

THE VAGINA is a cavity surrounded by a musculo-membranous wall which consists of three coats, a mucous, a muscular, and a fibrous. The mucous membrane consists of two layers, an *epithelial* which is of the stratified squamous variety, and a *tunica propria* which is composed of white and yellow fibrous tissue in which is diffuse lymphoid tissue. A few simple tubular glands may be present in this coat. The muscular coat consists of two layers of involuntary muscle, an outer longitudinal layer, and an inner layer of circular fibres not so well marked as the other layer. The fibrous coat is the outermost, and consists of white fibrous connective tissue which serves to hold the muscle coat to adjacent structures.

Experiment 152. Stain with haematoxylin and eosin and mount a section of the vagina. Examine under both powers, and sketch the stratified squamous epithelium and muscle under the high power.

THE CLITORIS, the analogue of the penis, is composed of cavernous or erectile tissue, similar to that of the corpora cavernosa of the penis, covered by mucous membrane, of which the epithelial portion is of the stratified squamous variety, and the tunica propria is of the white fibrous tissue, possessing papillae in some of which are capillary networks, and in others special nerve endings especially *genital corpuscles.*

Experiment 153. Stain and mount a section of the clitoris. Examine under both powers. Notice the erectile tissue, and look for genital corpuscles. Sketch.

CHAPTER XVI.

THE MAMMARY GLAND, THE THYROID GLAND, AND THE SUPRARENAL BODY.

THE MAMMARY GLAND.

Each mamma is composed of about fifteen racemose glands, which are enclosed by a fibrous capsule. The excretory tubes, termed the *tubuli lactiferi* or *galactophori,* begin as small orifices on the nipple of the mamma, and extend into the substance of the gland. Near its origin each tubule becomes dilated, forming a small reservoir termed an ***ampulla,*** for the accumulation of milk between the periods of suckling. After forming an ampulla, the tube continues into the mamma, dividing and subdividing, the terminal branches terminating in clusters of saccular acini. The cluster of acini formed by each terminal tubule constitutes a *lobule,* and the lobules formed by each lactiferous duct constitute a lobe. The lobes, lobules, and acini are held together by connective tissue septa derived from the fibrous capsule of the mamma, and ramifying blood-vessels contained in the septa. The *septa,* besides containing connective tissue some of which is adipose, contain involuntary mucle fibres.

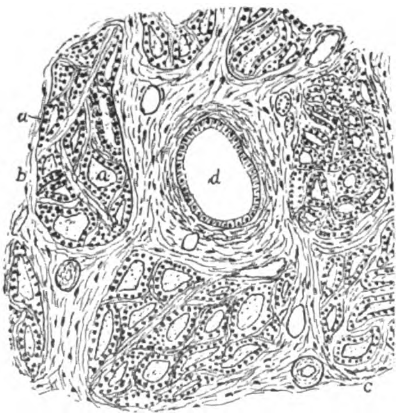
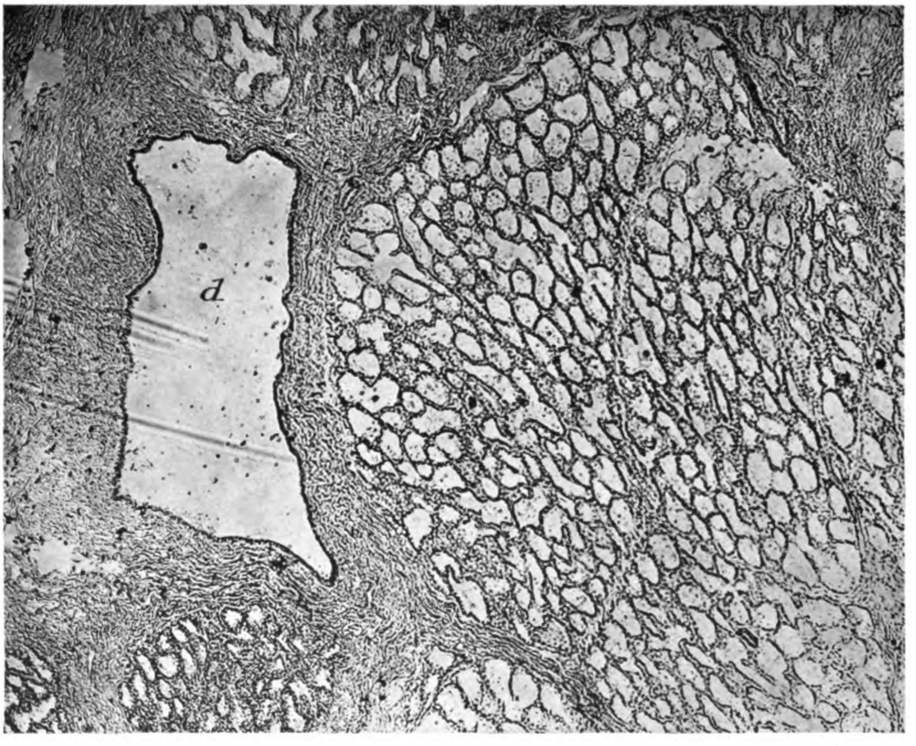


FIG. 153.
Portion of a section of human mammary gland (low power).
(*a*) galactophorous duct; (*a*) acinus; (*b*) a lobule; (*c*) trabecula.

The *acini* are pouch-like dilatations which are lined by a layer of granular-looking cuboidal-shaped cells. During lactation the cells increase in number, and their protoplasm becomes invaded by oil-globules. The oil-globules are at first small and gradually increase in size, the increase being so great as to push the nucleus and the remaining protoplasm to the cell wall (as in the conversion of the cells of areolar tissue into fat cells of adipose tissue), and finally the pressure within the cell becomes so great that the cell wall ruptures at the point of least resistance, and the oil-globules are discharged into the lumen of the acinus, thence into the tubule. The terminal tubules are lined by a layer of low cuboidal-shaped



M 94— Microphotograph of human mammary gland x 45, illustrating the lobulation, the alveoli, and duct (*d*).

cells, which gradually are replaced by a layer of columnar-shaped cells, which are in turn replaced by stratified squamous epithelium at the orifice, continuous with that of the epidermis. The basement membrane of the tubules is supplemented by involuntary muscle fibres derived from the corium of the skin of the nipple. In the beginning of lactation the flow of milk is preceded by *colostrum*, which consists of a liquid containing oil globules, epithelial cells termed the colostral corpuscles, and the debris formed by the disintegration of some of the cells contained in the acini.

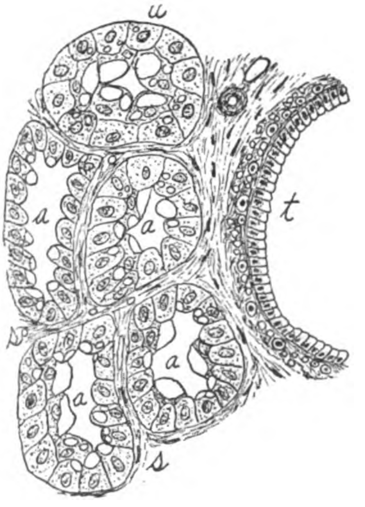


FIG. 154.
Portion of a mammary gland (high power).
(*t*) galactophorous duct, the coat of which contains transverse sections of elastic fibres and involuntary muscle fibres; (*a*) acini containing cells in various stages of milk production; (*s*) interacinal septa.

The *nipple* of the mamma may be regarded as a macroscopic papilla of the skin. It is covered by stratified squamous epithelium rich in pigment. Beneath the epithelium there is a mass of fibro-elastic tissue which contains the lactiferous tubules, blood-vessels, and involuntary muscle fibres, and corresponds to the corium of the skin. The involuntary muscle fibres, by their contraction, cause erection of the nipple. The areola around the base of the nipple is darkly pigmented, becoming more so during pregnancy, and contains sudoriferous and sebaceous glands. The subcutaneous tissue of the nipple and of the areola is remarkable on account of not containing fat.

The *arteries* to the mamma are derived from the thoracic branches of the axillary, the intercostals, and the internal mammary. They pass through the fibrous capsule of the gland, and send branches to the lobes and lobules which form capillary networks between the acini. Veins arise from the capillaries and pass from the gland in the same manner as the artery enters, to terminate in the axillary and internal mammary veins.

FIG. 155.
Portions of acini of mammary gland highly magnified.
(*c*) lining cells of an acinus; (*f*) fat globules; (*a*) interacinal connective tissue.

The *lymphatics* arise in the interfascicular clefts of the septa and of the capsule, and are closely connected with the axillary lymph glands.

The *nerves* of the mamma are of both varieties, the medullated variety supplying especially the skin covering the gland, some of the medullated fibres extending to the areola and nipple terminate in Pacinian corpuscles, others in tactile corpuscles, which give the sensitiveness to those regions.

Experiment 154. Stain, mount and examine a section of the mamma. Notice under the low power the fibrous septa, sections of acini and duct, and blood-vessels. Under the high power, look for the lining cells of the acini and involuntary muscle fibres in the septa. Sketch.

THE THYROID GLAND.

THE THYROID gland is commonly classed among the respiratory organs on account of its location. It is a compound tubular gland during its early stages of development, the duct of which communicates with the primitive pharynx, but as its development proceeds the duct becomes obliterated, so that in its adult form it consists of closed acini held together by connective tissue and ramifying blood-vessels.

The adult gland is surrounded by a capsule composed of areolar connective tissue continuous with that of the neighboring structures. The fibrous capsule sends projections into the gland, which extend between the lobes, lobules, and acini. The ACINI are usually round or oval in shape, and are composed of a basement membrane upon which rests a layer of cuboidal or short columnar-shaped cells. Within the acini there is a yellowish, viscid, semi-liquid material termed the *colloid substance,* which is secreted by the cells lining the acini, the yellow color of which being obtained from the disintegrated colored corpuscles of the blood. There are also present in prepared sections between the acini collections of cells which are some of the lining cells of acini of a different plane than that in which the sections have been cut. Between the neighboring acini there is fibrous tissue, derived from the capsule of the gland, which contains some involuntary muscle fibres, and numerous connective tissue corpuscles sometimes applied as a layer lining the interfascicular clefts. The clefts in the interacinal septa join each other and form channels between the lobules, which channels communicate with larger channels contained in the fibrous capsule. In the clefts and channels are leucocytes, lymphoid cells, and colored blood-corpuscles. The colored corpuscles of the blood may be observed in different stages of disintegration.

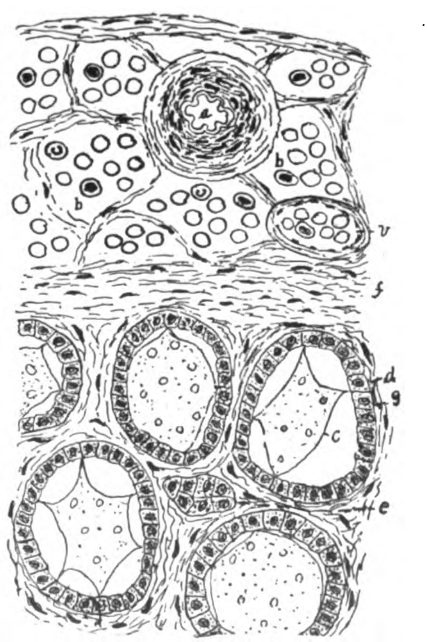
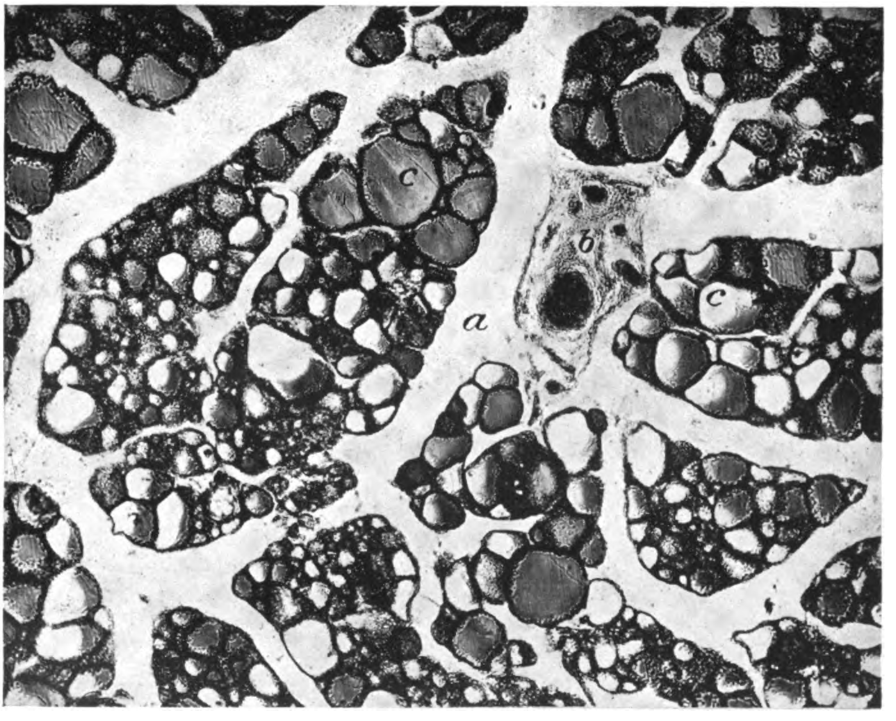
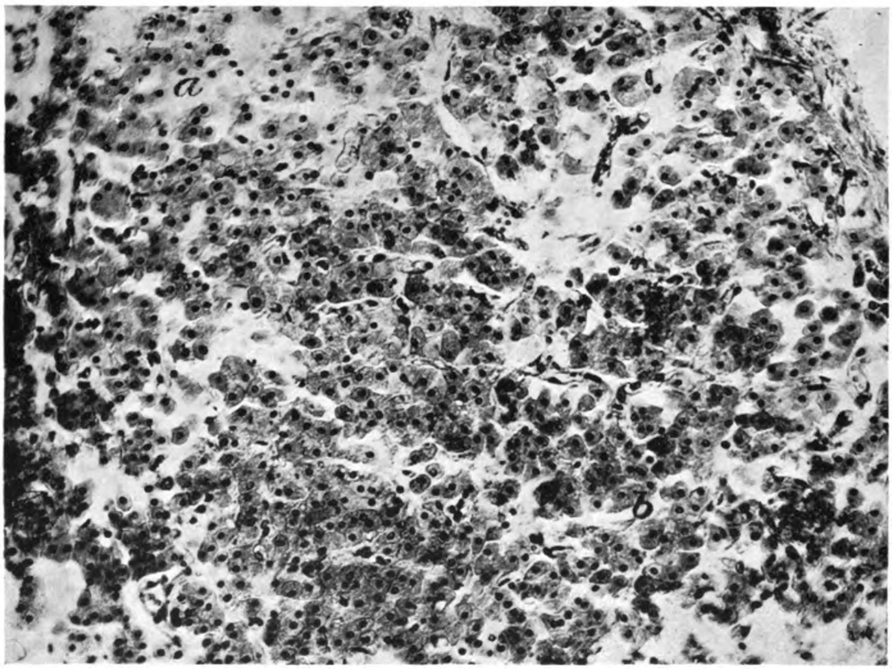


FIG. 156.
Portion of the thyroid gland.
(*f*) fibrous coat with artery (*a*) veins (*v*), and spaces containing blood (*b*); (*g*) lining cells of the acinus; (*d*) interacinal connective tissue; (*e*) interacinal group of cells.



M 95—Microphotograph of a section of the thyroid gland of a dog x 45.
a, interlobular spaces for connective tissue trabeculae (*b*); *c*, acini, some of which contain colloid substance.



M 96—Microphotograph of a section of a human parathyroid gland. *a*, oxyphil cells; *b*, principal cells.

The arteries of the gland enter its fibrous capsule and branch, the branches passing into the gland with the fibrous inshoots from the capsule, reach the interacinal septa, and terminate in capillaries. The walls of the capillaries blend with the fibrous tissue of the septa, thus allowing the blood to flow directly into the interfascicular clefts. Veins arise in the same manner as the arteries terminate, and pass along the septa to the capsule, and from the gland. The *lymphatics* arise in the septa in the same manner as the veins, and in the fibrous capsule; the channels formed communicate with the collections of lymphoid substance within, and the lymphatic channels without, the capsule.

The *nerves* which pass to the gland are of both varieties. Besides innervating the blood-vessels, their terminations, although not known, probably extend between the acini to form a plexus beneath the basement membranes of the acini.

In accordance with the structure of the gland, and the myxoedematous condition of the tissues of the body which follow its extirpation, it appears to the author that the thyroid gland is a blood-elaborating gland, which acts as follows: The lining cells of the acini cause disintegration of some of the colored corpuscles of the blood, and act upon the plasma which passes through them in such a manner that its mucin-forming power is diminished; the plasma containing pigment derived from the disintegrated colored corpuscles, composing the colloid substance, passes from the acini to be carried off by the veins, or the lymphatic channels.

THE PARATHYROID GLANDS.

Each PARATHYROID gland is surrounded by a fibrous capsule which sends trabeculae into the gland, which divide and subdivide, the ultimate fibres forming a reticulum in the meshes of which are cells, epithelial in character. The cells are spherical or ovoid in shape and are divided into two types, termed *principal,* and *oxyphil* or acidophilic cells. The two types of cells may be intermingled irregularly, or the acidophilic cells may be arranged in groups with the other type of cells disseminated irregularly between the groups.

The *principal* cells are more numerous than the other variety, each possessing a nucleus large and spherical, and chromatic granules irregularly distributed and clear spaces, causing the nucleus to appear as if vacuolated.

The *oxyphil* cells have small spherical nuclei rich in chromatin, and the protoplasm of these cells contain acidophilic granules. In some glands, especially those of lower animals, remains of the primitive duct may be found, which are lined by simple columnar epithelium.

The glands are very vascular, the arteries penetrating the capsule, and accompanying the trabeculae terminate in sinuosoidal spaces from which the venules arise.

Experiment 155. Stain, mount and examine a section of the thyroid gland. Look for and study the appearance of the lobules, acini, interacinal septa, blood-vessels, fibrous capsule, the colloid material contained in the acini, and the lining epithelial cells. Sketch.

THE SUPRARENAL BODY.

The suprarenal body is usually classed as one of the ductless glands, although some investigators claim that it is a portion of the nervous system.*

It is a pyramidal or "cocked-hat" shaped organ, situated above and anterior to the superior border of the kidney. It is enclosed by a fibrous capsule which sends projections (trabeculae) into the substance of the organ, dividing it up into smaller portions. The substance of the suprarenal body consists of a dense area termed the *cortical portion,* enclosing a less dense area termed the central or *medullary portion.*

THE CORTICAL PORTION consists of three zones, formed by the trabeculae and their branches, termed the zona glomerulosa, the zona fasciculata, and the zona reticularis.

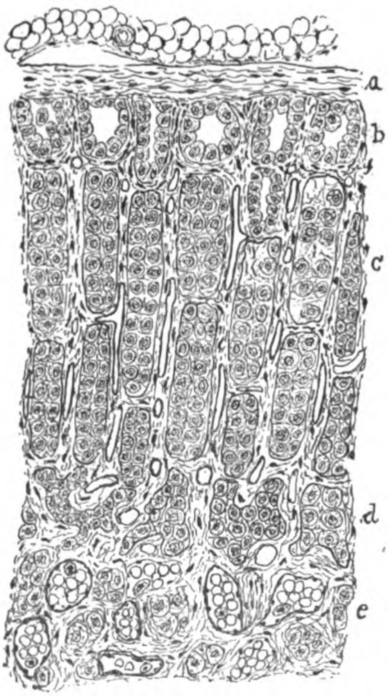


FIG. 157.
Vertical section of suprarenal gland.
(a) Fibrous coat external to which is adipose tissue; (b) zona glomerulosa; (c) zona fasciculata; (d) zona reticularis; (e) medullary substance containing blood sinuses, connective tissue, and groups of cells.

The *zona glomerulosa,* the most external zone, consists of irregular oval or round compartments formed by the trabeculae, containing brush-like extensions from the enclosing trabeculae; cells which are similar in appearance to lymphoid cells; colored blood-corpuscles; and pigment.

The *zona fasciculata,* the middle zone, consists of long compartments, formed by the trabeculae which radiate toward the central portion of the organ, containing irregular quadrilateral-shaped spaces in which are cells similar to lymphoid cells; colored blood-corpuscles; and pigment.

The *zona reticularis,* the zone adjoining the medullary portion of the organ, consists of irregular-shaped spaces formed by the trabeculae, and containing elements similar to those of the other zones.

THE MEDULLARY portion of the suprarenal body consists of irregular-shaped compartments, containing elements similar to those of the cortical substance, between which are irregular-shaped sinus-like spaces from which the veins arise.

*The author considers the suprarenal body as a blood elaborating gland, aiding the spleen *in its* function. The blood coming to the gland filters through the network formed by the trabeculae and their lateral projections, and is modified during its passage from the periphery toward the medullary portion. Probably some of the cells, which so closely resemble lymphoid cells, take up the pigment derived by the disintegration of the colored blood-corpuscles and become colored corpuscles.

M 97—Microphotograph of the human suprarenal gland x 40.
a, medullary portion; *b*, cortical substance showing the three zones.

The *arteries* which pass to the suprarenal body are derived from the aorta, the phrenic, and the renal. They ramify in the fibrous capsule of the organ, some of the branches forming a capillary network in it, while others accompany the trabeculae into the substance of the organ and form a capillary network. The blood is collected in the *venous sinuses* of the medullary portion, and carried from the organ by the suprarenal vein, which empties into the inferior vena cava or into the renal vein.

The *lymphatic* vessels arise in the interfascicular clefts of the capsule and trabeculae and empty into the lumbar glands.

The *nerves* are of the non-medullated variety and form a plexus in the medullary portion of the suprarenal body, the fibres of which possess numerous minute ganglia.

Experiment 156. Stain, mount and examine a section of the suprarenal body. Notice the arrangement of the cortical portion into zones. Examine the structure of the cells. Examine the medullary portion, and notice the venous sinuses. Sketch the general outlines under the low power, and portions of the cortical and medullary regions under the high power.

Exp. 157. Stain with Van Giesen stain and mount a section of a suprarenal gland. Under both powers notice especially the connective tissue network.

Exp. 158. Stain and mount a section of a suprarenal gland which has been injected. Notice the capillary network between and around the group of cells of the cortical zone. Sketch.

CHAPTER XVII.

THE EYE.

The eye, the organ which contains the pheripheral terminations of the optic nerve, consists of three coats enclosing a central cavity which contains refracting media. The tunics or coats of the eye are three, the sclera, the choroidea, and the retina.

THE SCLERA.

The sclerotic (Gr. σκληρος, hard) coat, the outer tunic of the eye, is divided into two portions, a posterior portion (about five-sixths of the sclera) termed the *sclera propria,* and an anterior portion (the remaining one-sixth) termed the *cornea.*

THE SCLERA PROPRIA is surrounded by a membrane lined by endothelioid cells termed the *tunica vaginalis oculi,* and consists of interlacing bundles of white fibrous tissue and elastic fibres, and connective tissue corpuscles. Its inner surface is composed of loosely-arranged fibrous tissue which contains pigment, and is termed the *lamina fusca.* Externally the sclera propria blends with the conjunctiva. At the posterior portion of the eye the sclera becomes *cribiform,* the fibres of the optic nerve passing through the openings. The central opening of the *cribiform lamina,* termed the *porus opticus,* is larger than the others, and transmits the *arteria centralis retinae.*

THE CORNEA is transparent, and consists of four layers:

1. The outermost layer is composed of stratified squamous epithelium continuous with that of the conjunctiva.

2. The next layer is fibrous, and is the proper substance of the cornea. It consists of bundles of transparent fibres continuous with those of the sclera propria, arranged as laminae. The outer border of the layer being more densely arranged than the remaining portion, has been termed the anterior elastic lamina (Bowman), or anterior limiting layer (Reichert). The remainder of the fibrous layer of the cornea is loosely arranged, the bundles of fibres, running transversely and occasionally branching, enclose the elongated interfascicular spaces, termed the *corneal spaces,* which contain connective tissue corpuscles, termed the *corneal corpuscles.*

3. Covering the inner border of the fibrous layer there is a thin, transparent, highly-elastic membrane termed the *membrane of Descemet,* the posterior limiting membrane, or the posterior elastic membrane.

4. Lining the membrane of Descemet there is a layer of flat *endothelioid cells.*

At the junction of the cornea and the sclera propria the fibres of which the posterior elastic membrane is composed, continue into the iris as the *ligamentum pectinatum*. The fibres of the ligament enclose spaces termed the *spaces of Fontana*,

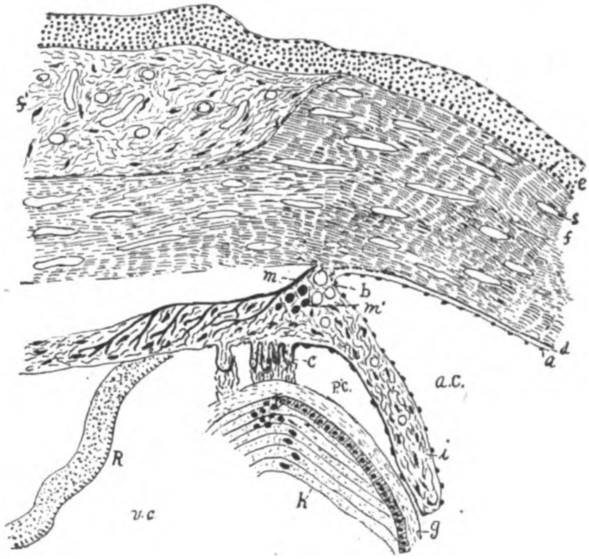


FIG. 158.
Portion of a section of the eye of a guinea-pig (low power).
(*e*) stratified squamous epithelium; (*f*) fibrous portion of cornea; (*s*) corneal space; (*d*) membrane of Descemet; (*a*) endothelioid layer of cornea; (*f'*) fibrous tissue of sclerotic coat; (*i*) iris; (*b*) lymph channels (Fontana); (*m*) ciliary muscle; (*m'*) ring muscle of Müller; (*c*) ciliary body; (*g*) lens capsule; (*k*) lens fibres; (*R*) retina; (*a.c.*) anterior chamber; (*p.c.*) posterior chamber; (*v.c.*) vitreous chamber.

at the circumference of the iris, which communicate with a large circular canal in the sclera propria near its junction with the cornea, which canal is termed the *canal of Schlemm* or the *sinus circularis iridis*. The endothelioid cells lining the internal surface of the cornea continue on to line the corneal surface of the iris.

THE CHOROIDEA

The choroid coat is the vascular coat of the eye, and lies internal to the sclera propria. At the junction of the cornea and the sclera propria the choroid coat hangs as a curtain (iris), perforated at a point to the nasal side of its centre by an opening (pupil).

It is composed of three layers:

1. The layer nearest to the sclera consists of loosely-arranged fibrous tissue composed of white and yellow fibres; connective tissue corpuscles which contain pigment; and lymph corpuscles. The outer surface of the layer is lined by endothelioid cells. The layer is termed the *lamina suprachoroidea*, and is separated from the lamina fusca of the sclera by a space termed the *subscleral space*.

2. The middle layer is termed the *vascular* layer, and is composed of white and yellow fibrous tissue, among which are blood-vessels and pigmented connec-

tive tissue corpuscles. In the outer portion of the layer the blood-vessels are large, and the veins often assume a tortuous course and are termed the *venae vorticosae*. The inner portion of the layer contains the capillary networks, and is sometimes termed the *choriocapillaris* or the *tunica Ruyschiana.*

3. The inner layer is a hyaline homogeneous layer, termed the *lamina vitrea*, which is closely applied to the retina.

THE IRIS.

The iris is composed of the following structures:

1. The anterior surface is lined by a layer of *endothelioid cells* similar to and continuous with the layer of cells lining the internal surface of the cornea. In dark-colored eyes these cells contain pigment.

2. A *stroma* which consists of an interlacing network of fibrous tissue, among which are blood-vessels, and connective tissue corpuscles which contain pigment in dark-colored eyes. The fibres are chiefly arranged radially toward the pupil, some being circularly disposed around it.

3. *Muscle fibres* of the involuntary variety. Around the pupil the fibres are arranged in a circular manner, forming the *sphincter* of the pupil. The remaining fibres are arranged radially toward the pupil from the circumference of the iris, and are termed the *dilators* of the pupil.

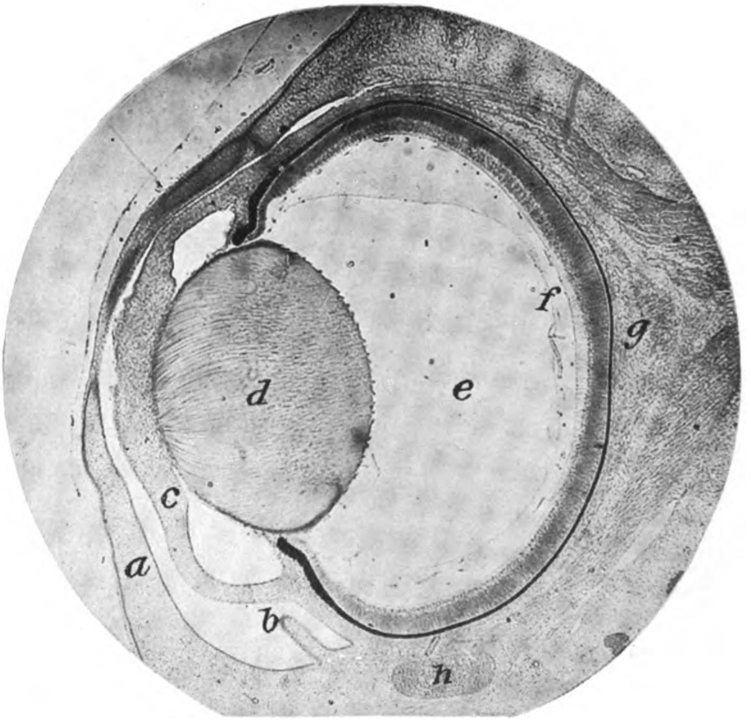
4. The posterior surface of the iris is covered by a thick stratum of pigmented cells which are derived from the pigmented layer of the retina. Owing to the purple color of the layer it is termed the *uvea.*

THE CILIARY MUSCLE.

The ciliary muscle (Bowman) consists of involuntary muscle fibres disposed in two sets. One set arises at the junction of the sclera propria and the cornea, intimately related with the peripheral termination of the dilator fibres of the pupil, and extend posteriorly to terminate in the choroid coat, near the ciliary processes. The other set is disposed circularly around the circumference of the iris, and is termed the *ring muscle* of Müller.

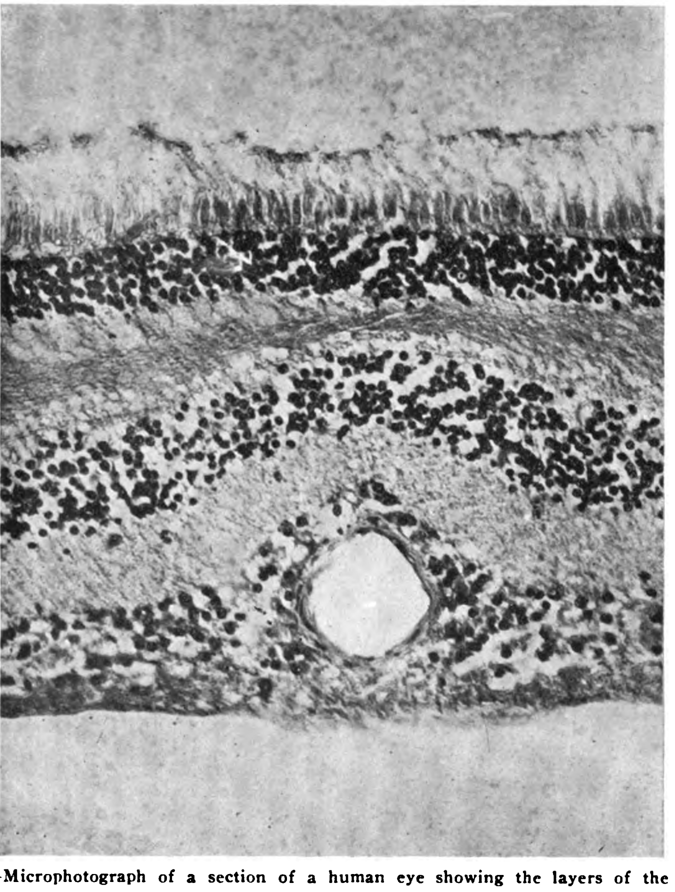
THE CILIARY PROCESSES.

The cilliary processes are fringe-like projections of the choroidea consisting of the middle layer and the lamina vitrea. They are very numerous, being about seventy in number in one eye, and are rich in blood-vessels and pigmented connective tissue corpuscles. Their outer borders corresponding to the lamina vitrea are not pigmented. The fibrous tissue of which they are composed gradually blend with the fibres of the suspensory ligament of the lens.



M 98—Microphotograph of a portion of a section of the head of a pig-embryo x 20, illustrating the arrangement of the parts of an eye.

a, eye-lid; *b*, fold of conjunctiva; *c*, cornea; *d*, lens; *e*, vitreous humor cavity; *f*, retina; *g*, undifferentiated choroid and sclerotic coats; *h*, eye-muscle.



M 99—Microphotograph of a section of a human eye showing the layers of the retina.

THE RETINA.

The retina, the internal tunic of the eye, lines the posterior portion of the eye, extending forward to the ciliary processes, where it terminates as a serrated free border, termed the *ora serrata.* The retina contains the termination of the optic nerve, and is capable of responding to visual impressions throughout its extent, except at the point of entrance of the arteria centralis retinae (which in reality is due to the absence of the retina at that point). The posterior portion of the retina responds more readily than the anterior portion, one spot being more sensitive than the remainder, which is situated at the centre of the retina and is termed the yellow spot or the *maculata lutea* of Sömmerring, in the centre of which there is a depression termed the *fovea centralis.*

The retina may be divided into ten layers:

1. THE PIGMENTED LAYER, the layer next to the choroid coat, consists of a layer of hexagonal columnar-shaped nucleated cells. The cells are pigmented and send filamentous projections between the constituents of the next layer.

2. The layer of RODS and CONES. This layer consists of the cells which receive the visual impressions. The cells are of two kinds, rods and cones. Each *rod* is divided into two segments, an outer and an inner. The outer segment is columnar or rod-shaped, and is transversely striated, appearing to be composed of flat discs superimposed upon each other. The inner segment is slightly broader than the outer segment for a distance about equal to the length of the outer segment, then tapers to form a narrow fibre, which soon becomes enlarged to enclose the rod nucleus, then becoming narrow again continues to the outer molecular layer. The outer border of the inner segment is striated lengthwise, while the portion between the outer border and the point at which it tapers is granular. A *cone* is similar to a rod, except that the outer segment is conical and shorter than the corresponding segment of the rod, and that the portions of the inner segment are broader than the corresponding portions of the inner segment of the rod.

The cones appear to be capable of causing more accurate vision than the rods. They are most numerous in the fovea centralis, least numerous or absent in the anterior portion of the retina.

3. THE MEMBRANA LIMITANS EXTERNA is composed of fibres derived from the fibres of Müller, from which fibrous projections extend between the rods and cones. This membrane is situated on a level with the beginning of the tapering portion of the inner segments of the rods and cones.

4. THE OUTER NUCLEAR LAYER is composed of the nucleated portions of the rods and cones. They are of two kinds, termed the rod-granules and the cone-granules. A *rod-granule* is spindle-shaped, and consists of a nucleus and two tapering ends, the distal end being continuous with a rod, while the proximal

end becomes varicose and terminates in an enlargement at the border of the next layer. A *cone-granule* is similar to a rod-granule, except that its nucleus and the tapering ends are broader than the corresponding portions of the rod-granule.

5. THE OUTER MOLECULAR LAYER is a thin layer composed of a fine fibrillar network, among which are small granular bodies which probably are nuclei. The fibrillae, of which the network is composed, are derived from proximal ends of the rod- and cone-granules, and from the fibres of Müller.

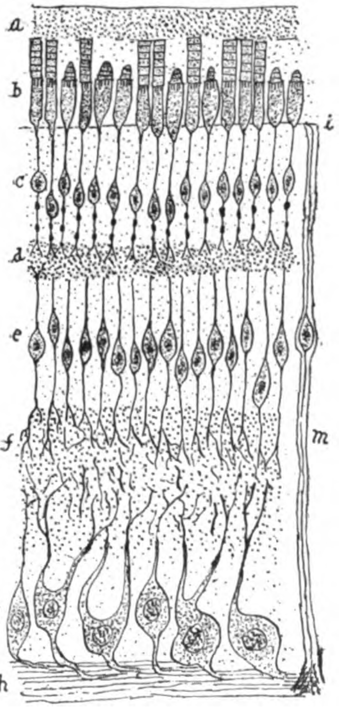


FIG. 159.
The retina of the eye (partly diagrammatic). (*a*) pigmented layer; (*b*) layer of rods and cones; (*c*) outer nuclear layer; (*d*) outer molecular layer; (*e*) inner nuclear layer; (*f*) inner molecular layer; (*g*) vesicular layer; (*h*) fibrous layer; (*i*) external limiting membrane; (*m*) fibre of Müller.

6. THE INNER NUCLEAR LAYER is composed of three kinds of cells: (a) Bipolar cells, one process of each cell extending to the outer molecular layer, probably communicating with a rod or a cone, while the other process extends to the inner molecular layer; (b) Multipolar cells, the processes of each cell extend into one of the molecular layers; (c) Cells connected with or contained in the fibres of Müller.

7. THE INNER MOLECULAR LAYER is thicker than the outer molecular layer, and contains ramifying fibrillae, among which are granular-looking nuclei.

8. THE VESICULAR LAYER consists of a single row of large bipolar ganglionic or nerve-cells. The proximal process of each cell is connected to a fibre of the next layer, while the distal process ramifies, the ramifications passing into the inner molecular layer.

9. THE FIBROUS LAYER is composed of nerve cells derived from the optic nerve. The fibres lose their medullary sheaths during their passage through the lamina cribrosa of the sclera, and probably send a primitive fibrilla to join the proximal process of each cell of the vesicular layer.

10. THE MEMBRANA LIMITANS INTERNA is formed by the fibres of Müller, and separates the retina from the capsule of the vitreous humor of the eye.

The layers of the retina are held together by a connective tissue network, the fibres of which are termed the *fibres* of *Müller*. They commence at the inner border of the retina (adjacent to the vitreous body) as bases of cones, the joined bases forming the internal limiting membrane of the retina. The fibres extend into and between the portions of the various retinal layers, terminating at the external limiting membrane. In the inner nuclear layer of the retina the fibres of Müller appear to be nucleated, giving the cellular appearance mentioned.

As the retina extends anteriorly toward the ora serrata, it gradually diminishes in thickness and sensitiveness. The cones gradually diminish in number and disappear, then disappear the rods, then the vesicular, fibrous and reticular layers. The radial fibres of Müller become more distinct. The pigmented layer continues on to the ciliary processes as the *pars ciliaris,* and on the posterior surface of the iris as the *pars iridica retinae.*

THE LENS.

The lens is situated immediately behind the pupil, and is the most important of the refracting media. It is enclosed by a CAPSULE which is a transparent elastic membrane, the portion covering the anterior surface of the lens being about twice as thick as the portion covering the posterior surface. The capsule is lined by a layer of *low columnar-shaped cells,* except at its posterior portion. By some authors the layer of cells is considered as a portion of the lens substance and not as a portion of the capsule. At irregular intervals small spaces may be observed between the cells and the membrane of the capsules, termed the *supra-epithelial spaces.* Between the epithelial cells and the lens-substance there is a distinct space termed the *sub-epithelial space.*

THE LENS SUBSTANCE is a biconvex mass, and consists of fibres arranged in lamellae which run concentrically around the centre of the lens. The central portion of the lens being more dense than the peripheral portion, is termed its nucleus. The fibres are formed by the epithelial cells lining the capsule, and in their early stages of development contain distinct nuclei, which disappear as the fibres become older. On transverse section, the fibres appear as sections of prisms with polygonal-shaped bases.

THE SUSPENSORY LIGAMENT of the lens, or zonula of Zinn, is composed of ligamentous fibres which arise from the fringe-like folds of the ciliary processes and from the depressions between the folds, and are inserted in the equatorial portion of the lens-capsule, some of the fibres extending into its anterior portion.

The lens, with its capsule and suspensory ligament, divides the interior of the eye into two unequal portions. The anterior portion is occupied by the aqueous humor, the posterior portion by the vitreous body or humor.

The anterior portion is subdivided into two chambers by the iris, the anterior of which, termed the *anterior chamber,* is bounded by the posterior surface of the cornea and the anterior surface of the iris; the posterior of which termed the *posterior chamber,* is bounded anteriorly by the posterior surface of the iris, posteriorly by the anterior portion of the lens-capsule. The chambers communicate through the pupil, and contain the aqueous humor, which consists of water containing a small amount of salts, the chief of which is sodium chloride.

The posterior portion of the interior of the eye is occupied by the VITREOUS BODY, which consists of *mucoid tissue* in its early stages of development; of water, salts, and wandering cells in its adult condition, the mucoid cells having disappeared. The anterior surface of the body is depressed to accommodate the posterior surface of the lens. Enclosing the vitreous body, except at its anterior surface, there is a transparent homogeneous membrane, termed the hyaloid membrane, which becomes fibrous as it nears and blends with the zonula of Zinn.

The *arteries* of the eye, derived from the ophthalmic artery, are divided into two sets, *retinal* and *ciliary,* which are distinct from each other except at the point of entrance of the optic nerve, where they communicate by means of a few anastomosing branches.

THE RETINAL SET are branches from the retinal artery, and supply nourishment to the retina. One of the branches pierces the vitreous humor of the embryo, termed the *hyaloid* artery, which disappears later, and is represented by a few fibres in the adult humor.

THE CILIARY SET is subdivided into three groups, short, long, and anterior.

1. *The short ciliary arteries* arise from the ophthalmic artery and surround the optic nerve as it enters the eye. They pass through the sclerotic coat into the choroid, which it supplies in addition to the ciliary processes.

2. *The long ciliary arteries,* of which there are two, pass through the sclera, each passing through the sclerotic and choroid coats on one side of the eye, to the ciliary muscle, and encircle the periphery of the iris, forming the large arterial circle from which branches pass radially toward the pupil and form a smaller circle among the fibres of the sphincter of the pupil.

3. *The anterior ciliary arteries,* derived from the muscular branches of the ophthalmic artery, pass through the sclera propria near its junction with the cornea, and terminate in the large arterial circle of the iris.

The *lymphatics* arise in the clefts between the fibrous tissue of the various structures of the eye, as the corneal and scleral spaces; the canal of Petit (the triangular-shaped circular canal bounded anteriorly by the suspensory ligament of the lens, posteriorly by the vitreous humor, internally by a portion of the lens-capsule); the subscleral space; the interfascicular clefts of the choroidea; ciliary processes, ciliary muscle, and iris; the perivascular spaces; the hyaloid canal; and the perineural spaces of the optic nerve. The excess of aqueous humor passes from the anterior chamber into the spaces of Fontana. The lymphatics join and form larger channels, which pass from the eye along with the optic nerve.

The *nerves* of the eye, other than the optic, are termed the *long* and the *short ciliary* nerves. The *long ciliary* nerves are derived from the nasal branch of the ophthalmic nerve, and after receiving the short ciliary nerves derived from the ophthalmic ganglion, pierce the sclerotic coat near to the optic nerve, and accompany the ciliary arteries to be distributed to the ciliary muscle and the iris.

Experiment 159. Stain, mount and examine a longitudinal section of the eye, preferably of a small animal as the rat or guinea-pig. Notice and sketch, under the low power, the general appearance and arrangement of the different portions. Under the high power, examine and sketch portions of the cornea, sclera, choroidea, ciliary processes, iris, and lens with its capsule.

Exp. 160. Stain and mount a section of the head of an embryo (pig or kitten), the section having been cut so as to include the eye. Notice the lids still closed, and the various parts as in Exp. 159. Notice the lens fibres, and the cells on anterior border of lens.

Exp. 161. If a prepared specimen of the retina can be obtained, examine it and notice the different layers. Sketch under the high power several rods and cones.

CHAPTER XVIII.

THE ORGAN OF HEARING.

The organ of hearing consists of three portions, the *external ear,* the middle ear or *tympanum,* and the internal ear or *labyrinth.*

THE EXTERNAL EAR consists of two portions, an expanded portion termed the *pinna* and a canal termed the *external auditory meatus.*

THE PINNA, commonly termed the ear, is composed of cartilage, connective tissue and muscle, and is covered by skin. The *cartilage* is a thin layer of the yellow fibrous variety, which follows the general outlines of the pinna, but is not present in the lobule of the pinna. It is incompletely divided into segments, which are held together by bands of yellow fibrous tissue termed *ligaments.* The *connective tissue* consists chiefly of the yellow fibrous variety, that of the lobule being adipose. The *muscular tissue* is of the voluntary variety, and differs in amount in different pinnae. The *skin* which covers the pinna is thin, and possesses sebaceous glands and short hairs.

THE EXTERNAL AUDITORY MEATUS is a canal, formed by the auditory process of the temporal bone and cartilage, lined by an invagination of the skin. The *cartilaginous portion* forms nearly one-half the length of the canal, and is continuous with and similar to the cartilage of the pinna. The *osseous* portion of the wall of the canal is composed of an inner and an outer layer of compact bone enclosing a layer of the cancellous variety.

The *skin* lining the meatus is thin and closely united to the cartilaginous and osseous portions of the canal-wall. It extends to and is reflected upon the membrana tympani. Near the orifice of the meatus it is covered by long hairs, and contains sebaceous glands. The ceruminous glands are compound tubular glands which extend from the surface of the skin into the subcutaneous tissue of the cartilaginous portion of the canal.

THE TYMPANUM.

The tympanum, or middle ear, is separated from the external auditory meatus by a membranous structure termed the MEMBRANTUM TYMPANI, which consists of three layers: a middle *fibrous layer* composed of white and yellow fibrous tissue, some of the fibres being arranged radially from the center, others circumferentially; an *external layer,* the reflection of the skin of the external auditory meatus; an *inner layer,* which is a portion of the mucous membrane which lines the tympanum. Covering the foramen rotundum there is a *secondary tympanic membrane* similar in structure to the membranum tympani, consisting of three layers: a middle fibrous; an external layer (tympanic surface) composed of mucous membrane continuous with that of the tympanic cavity; an internal layer composed of endothelioid cells. The mucous membrane lining the tympanum consists of a tunica propria and an epithelial portion. The epithelium is of the ciliated cuboidal variety in the lower portion of the tympanum near the opening of the Eustachian tube and non-ciliated in the remaining portions of the tympanum. The mucous membrane extends into the mastoid cells, where it is lined by non-ciliated epithelium.

THE INTERNAL EAR.

The internal ear, termed the labyrinth on account of its complexity, consists of a membranous sac (lining the irregular hollowed-out cavity in the petrous portion of the temporal bone, termed the osseous labyrinth) and structures contained in the sac, together forming the membranous labyrinth.

The membranous labyrinth is connected to the osseous canals by fibrous projections, the spaces left between the membranous and osseous labyrinths being filled by the *perilymph.*

The wall of the membranous labyrinth consists of two portions, an outer fibrous portion and an inner hyaline portion lined by a layer of cells which secrete the endolymph.

The membranous labyrinth is composed of a *vestibule,* three *semicircular canals* and the *cochleal canal.*

The vestibule consists of two portions termed the *utricle* and the *saccule.* The semicircular canals are membranous tubes suspended in the osseous semicircular canals, the inner border of which is papillated, with dilated ampullae nearly filling the osseous ampullae.

THE COCHLEA is conical in shape, having a columnar projection termed the *modiolus* or columella extending from the centre of its base nearly to its apex. Projecting from the circumference of the modiolus there is a lamina of bone which passes spirally from the lower portion to its termination, termed the *lamina spiralis.* The lamina projects about half way across to the membranous wall. The terminal edge of the lamina is connected to the membranous wall by a fibrous projection from it, which consequently is spirally arranged, and is termed the *ligamentum spirale.* In this manner two canals are formed, the upper of which is termed the *scala vestibuli,* the lower the *scala tympani.* The upper canal is subdivided by a membrane, termed the *membrane* of *Reissner,* which extends from the ligamentum spirale to the edge of the lamina spiralis, the triangular-shaped canal thus formed being termed the *scala media* or canalis cochleae.

The canalis spiralis modioli (Rosenthal) is a spiral canal which winds around the modiolus at the junction of the lamina spiralis with the modiolus. The connective tissue of the upper surface of the lamina spiralis becomes thickened near the termination of the lamina, which is termed the *limbus laminae spiralis* and terminates as a groove termed the *spiral groove*. The ligamentum spirale is composed of fibrous tissue derived from the endosteum of the bony wall of the cochlea. As the ligamentum spirale approaches the lower border of the spiral

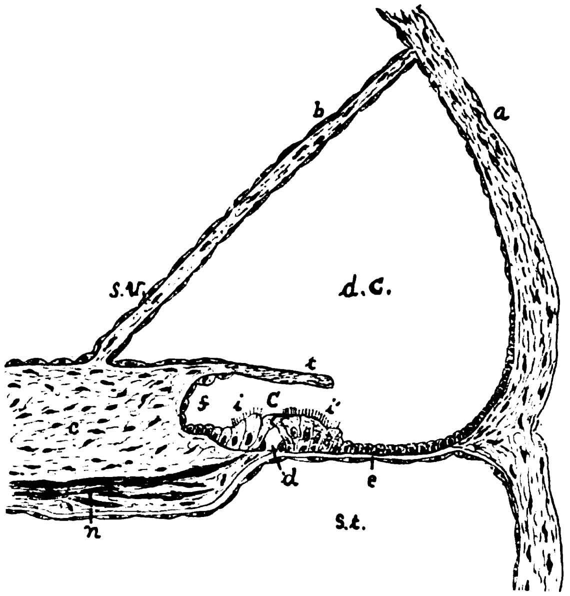


FIG. 160.
Diagrammatic representation of a portion of the human cochlea.
(*a*) ligamentum spirale; (*c*) lamina spiralis; (*b*) membrane of Reissner; (*e*) basilar membrane; (*d. c.*) canal of the cochlea; (*s. t.*) scala tympani; (*s v*) scala vestibule; (*t*) membrana tectoria; (*f*) spiral groove; (*C*) organ of Corti; (*i*) internal ciliated epithelium; (*i'*) external ciliated epithelium; (*d*) canal or tunnel of Corti; (*n*) nerve fibres.

groove the upper border becomes more dense and hyaline and is termed the basilar membrane, upon which rests a layer of cuboidal-shaped cells. Extending from the upper surface of the lamina, arising between the attachment of Reissner's membrane and the termination of the limbus, to the wall of the cochlea, there is a delicate membrane termed the *membrana tectoria* or the *membrane* of *Corti*. The canal formed between Corti's membrane and the basilar membrane is termed the *ductus cochlearis* or *ductus auditorius*, in which is contained the *organ* of Corti.

THE ORGAN OF CORTI consists of cells peculiarly arranged:

The *rods* of *Corti* are attached to the basilar membrane, and are divided into an inner and an outer row. The bases of the cells of the inner row are separated from the bases of the cells of the outer row, and the cells of one row lean toward and meet the corresponding ones of the other row, thus forming an arch which encloses a canal termed the *zona arcuata,* which ascends through the length of the cochlea. The inner rods are more narrow and numerous than the outer, and are somewhat ulna-shaped.

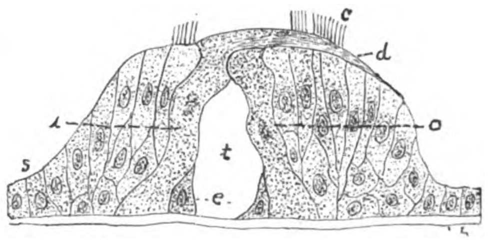


FIG. 161.
The organ of Corti (partly diagrammatic).
(*e*) protoplasmic cells; (*t*) tunnel of Corti; (*o*) outer rod, and (*i*) inner rod of Corti; (*b*) basilar membrane; (*a*) inner hair cell; (*c*) outer hair cells; (*s*) epithelium of spiral groove; (*d*) reticular lamina.

In the angular corners of the zona arcuata at the base of the cells there is usually a row of granular cells. To the inner side of the inner rods there is a layer of cells columnar in shape and ciliated at their free borders termed the *inner hair cells,* next to which the cells are cuboidal and continue as a lining to the sulcus spiralis. The upper portion of the outer rods have been compared in appearance to the neck, head and bill of a swan. External to the outer rods there is a layer of ciliated columnar-shaped cells termed the *outer hair cells,* beyond which there are cells which are non-ciated and cuboidal in shape. The cells gradually become endothelioid on the ligamentum spirale.

Extending over the outer hair cells there is a *reticular lamina* or membrane of Kölliker, which appears to arise from the upper border of the inner rods and receive the projection (phalangeal process) from the outer rods. The membrane is composed of several rows of "fiddle-shaped" fibres termed *phalanges.* In the membrane there are small openings through which the cilia of the outer hair cells project. The membrane of Corti, or membrana tectoria, is above but not in contact with the reticular lamina.

The *internal auditory artery* divides into two branches, cochlear and vestibular. The cochlear artery divides into branches which enter the modiolus and terminate as capillaries in the lamina spiralis. The vestibular artery supplies the membranous labyrinth. Veins arise from the capillary networks and terminate in the superior petrosal sinus.

The *auditory nerve* divides into two branches, cochlear and vestibular. The vestibular nerves supply the membranous labyrinth. The cochlear nerve divides into branches which pass in the modiolus, thence into the spiral lamina to the organs of Corti.

Experiment 162. Stain, mount and examine a section of the pinna. Notice the skin, cartilage, yellow fibrous tissue and muscular tissue. Sketch.

Exp. 163. Stain, mount and examine a vertical section of decalcified cochlea. Notice the modiolus, lamina spiralis, ligamentum spirale, and the organ of Corti. Sketch.

CHAPTER XIX.

THE ORGAN OF SMELL.

The organ of smell, besides containing the peripheral terminations of the olfactory nerve, is the beginning portion of the respiratory tract. It consists of two portions, the nose and the nasal fossae.

THE NOSE is a pyramidal-shaped projection covered by skin, and is composed of an osseous and cartilaginous framework lined by mucous membrane and covered by muscle and connective tissue.

The *osseous portion* of the framework is composed of the nasal bones and the nasal processes of the superior maxillae, which are similar to the other bones of the face in consisting of an internal and an external layer of compact bone enclosing cancellous bone.

The *cartilaginous portion* consists of cartilages one of which, that of the septum, is of the white fibro-variety, the others being of the hyaline variety.

The muscular tissue is situated external to the framework and is of the voluntary variety.

The *connective tissue* is scanty, consists of the areolar variety, and is most abundant in the lobe of the nose.

The *skin* is continuous with the skin of the cheeks, superior lip and forehead, and with the mucous membrane lining the nose at the nostrils. It is thin throughout most of its extent, the thicker portions being on the alae nasi and tip, and contains numerous sebaceous glands. It contains hairs which are of considerable length at the nostrils. The mucous membrane of the nose is lined by stratified squamous epithelium.

THE NASAL FOSSAE are lined by mucous membrane which is intimately connected to the periosteum and the perichondrium of the bones and cartilages over which it lies. It is continuous anteriorly with the mucous membrane of the nose, and posteriorly with the mucous membrane of the pharynx. The mucous membrane consists of two portions, the tunica propria and the epithelium. The tunica propria consists of fibrous tissue, in which there may be some adenoid tissue, and contains muco-serous glands termed *Bowman's glands.* The *epithelium* of the mucous membrance lining the nasal fossae is of the modified stratified columnar variety, which differs in the respiratory and olfactory regions. The *respiratory* region, which is the lower portion of the fossae, is lined by epithelium similar to the variety lining the trachea, *ciliated stratified columnar* variety containing *goblet cells.* The *olfactory region,* the upper portion of the fossae, is lined by stratified columnar epithelium, some of the cells of which have been modified in order to receive and transmit odors, becoming *neuro-epithelial cells.* The cells of the olfactory region of the mucous membrane are of three varieties:

(a) *Sustentacular cells,* which are columnar-shaped and form an outer layer, the free border of the cells forming the *membrana limitans olfactoria.* The protoplasm of the cells contain pigment of a yellow color. The lower portion of each cell extends into the lower strata, as a filamentous projection which in some instances branch.

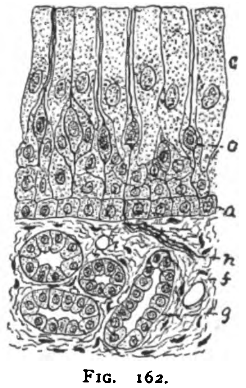


FIG. 162.
Olfactory mucous membrane. (*a*) lowest layer of epithelial portion consisting of cuboidal-shaped cells; (*c*) sustentacular cells; (*o*) olfactory cells; (*n*) nerve fibre; (*f*) fibrous tissue; (*g*) gland of Bowman.

(b) *Olfactory cells* which are spindle-shaped, each consisting of an enlargement which contains the nucleus, and two tapering ends, the distal of which extends between the neighboring sustentacular cells and terminates at the free surface of the mucous membrane as a single extremity, and in some animals as several extremities similar in appearance to cilia; the proximal end passes through the lower stratum of cells to become connected with a fibrilla of the olfactory nerve.

(c) A stratum of cells, consisting of one or more layers resting upon the basement membrane, the cells being polygonal in shape and probably produce cells to replace the other varieties when required.

The *arteries* to the nose form a close-meshed network in the tunica propria of the mucous membrane. The veins arising from the capillaries are numerous, large and sinus-like.

The *nerves* of the organ of smell are of the medullated variety, most of which innervate the component parts of the organ; while one, the *olfactory,* is the nerve specialized for the sense of smell. The olfactory nerve is distributed to the mucous membrane of the upper portion of the septum and of the inner surface of the superior and middle turbinated bones, its ultimate fibrillae being continuous with the olfactory cells.

Experiment 164. Stain, mount and examine a section of the nose. Notice the skin, cartilage, and lining epithelium. Sketch.

Exp. 165. Stain, mount and examine a section of a decalcified superior turbinated bone. Notice the mucous membrane with its lining epithelium, and the structure of the bone. Sketch.

CHAPTER XX.

THE NERVOUS SYSTEM.

THE MEMBRANES—The spinal cord and the brain are enveloped by three membranes: the dura mater, the arachnoidea, and the pia mater.

THE DURA MATER is the outermost of the three membranes, and consists of a network formed by white and yellow fibrous tissue and a few blood-vessels. Its outer surface is closely connected to the inner surface of the skull bones forming an internal periosteum; and loosely to the inner periosteum of the vertebrae by means of connective tissue extensions. Its inner surface is lined by a layer of endothelioid cells.

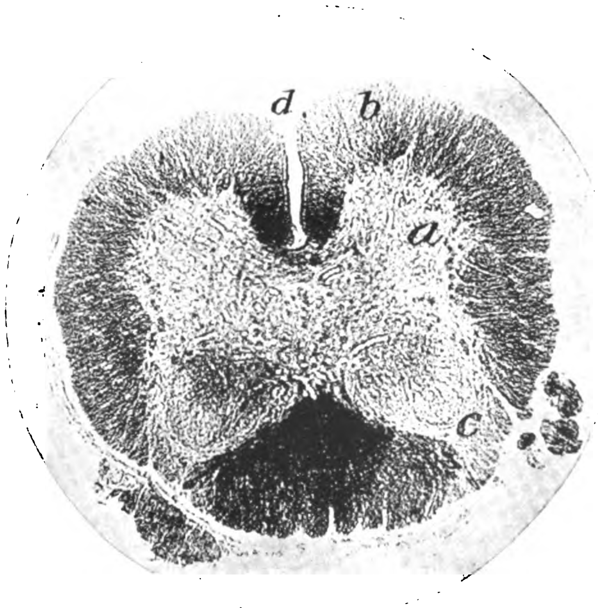
THE ARACHNOID (Gr. αράχνης, a spider's web) membrane is non-vascular and composed of white fibrous tissue. Both of its surfaces are lined by endothelioid cells. Between it and the dura mater there is a space termed the *subdural space,* while the space which exists between it and the inner membrane is termed the *subarachnoideal space.* This membrane is attached to the dura externally, and to the pia mater internally, by filamentous bands of connective tissue.

THE PIA MATER, the innermost of the membranes, is composed of white and yellow fibrous tissue in which ramify blood-vessels. It is divided into two layers the outer of which is dense and covered by a layer of endothelioid cells; the inner of which is loosely arranged and extends into the fissures and depressions of the spinal cord and the brain, terminating as a reticulum in the cerebro-spinal substance.

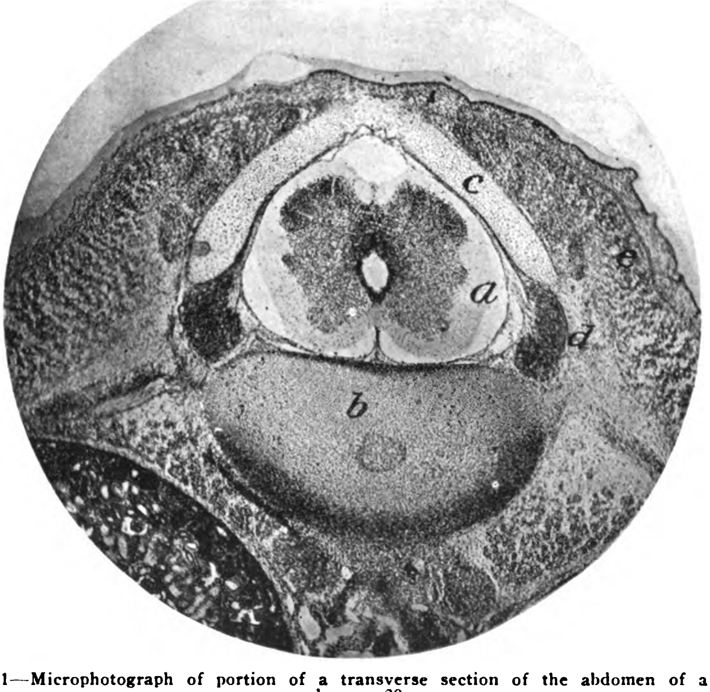
The spinal cord is suspended in the vertebral canal by means of the *ligamenta denticulata,* each of which is situated between the origins of the anterior and posterior roots of the spinal nerves, attached to the pia mater internally, the dura mater externally.

THE SPINAL CORD.

The spinal cord is composed of white and gray matter, the former occurring as a covering external to the latter. Extending from the anterior median (longitudinal) line there is a fissure termed the *anterior median fissure.* In the corresponding posterior median line there is a slight depression, from the bottom of which extends an areolar connective tissue septum, the depression and the septum being termed the *posterior median fissure.* The fissures extend into the cord for



M 100—Microphotograph of the spinal cord of a child x 5.
a, anterior cornu; *b*, white matter of cord; *c*, posterior cornu; *d*, anterior median fissure.



M 101—Microphotograph of portion of a transverse section of the abdomen of a pig-embryo x 20.

a, spinal cord; *b*, body of vertebra in centre of which is the remains of the notochord; *c*, neural arch; *d*, spinal ganglion (which is shown in M 30, under greater magnification); *e*, musculature of the back.

a variable distance, tending to divide it into two lateral halves. The portion of the cord between the internal terminations of the fissures is termed a commissure, and connects as a bridge the two lateral halves. The commissure is composed of white and gray matter, the former consists of transverse fibres situated anteriorly and is termed the *white commissure,* the latter is situated posterior to the white commissure and is termed the *gray commissure.* In the centre of the gray commissure is the *central canal,* which is lined by a layer of ciliated columnar-shaped cells.

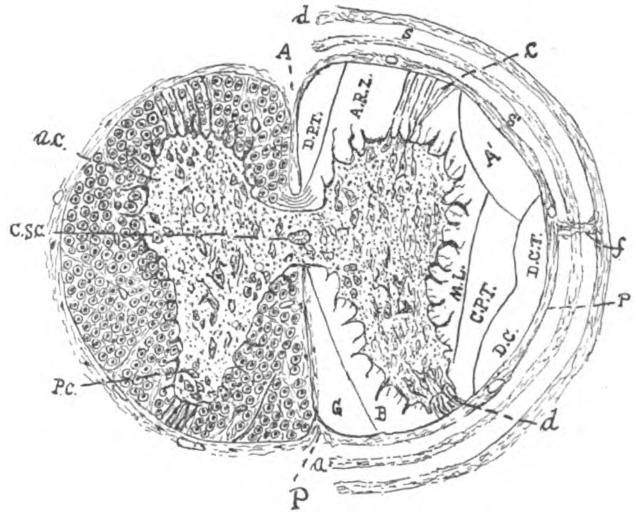


FIG. 163.

A transverse section of the spinal cord, the right half of which is diagrammatic, while the left half represents half of a section of the cord of a dog, under the low power.

(*A*) anterior portion of cord (anterior median fissure); (*d*) dura mater; (*s*) subdural space; (*a*) arachnoid membrane; (*s'*) subarachnoidal space; (*p*) pia mater; (*P*) posterior median fissure; (*f*) ligamentum denticulatum; (*a. c.*) anterior cornu; (*c. s. c.*) central spinal canal; (*p. c.*) posterior cornu; (*D. P. T.*) direct pyramidal tract; (*A. R. Z.*) anterior root zone; (*c*) anterior root fibres; (*M. L.*) mixed lateral tract; (*D. C. T.*) descending cerebellar tract; (*D. C.*) direct or dorsal cerebellar tract; (*C. P. T.*) crossed pyramidal tract; (*A'*) antero-lateral cerebellar tract; (*G*) column of Goll; (*B*) column of Burdach.

Each lateral half of the cord contains a crescent-shaped mass of gray matter, the convex border of which is toward, and connected by means of the gray commissure to, the convex border of the other. The *posterior cornu* of the crescent reaches nearly to the surface of the cord, is narrow throughout most of its length, becoming broader at its outer extremity, the broad portion being termed the *caput cornu.* The *anterior cornu* is broad and does not extend near to the surface. From each cornu fibres extend to form the respective roots of the spinal nerves. By means of the cornu and the root-forming fibres the white matter of each half of the cord is divided into three columns: anterior, lateral, and posterior.

The WHITE MATTER of the cord consists of medullated nerve-fibres held together by the network formed by the neuroglia and the inshoots from the pia mater, and disposed in bundles termed *tracts*. The anterior column is divided into two tracts, the *direct pyramidal* (Türck's) and the *anterior root zone;* the posterior column into two, the *column* of *Goll* and the *column* of *Burdach;* the lateral column into five, the *crossed pyramidal,* the *descending cerebellar,* the *direct cerebellar,* the *antero-lateral cerebellar* (Gower's), and the *mixed lateral.*

According to the degenerative method of experimentation the direct pyramidal, the crossed pyramidal and the descending cerebellar are descending tracts; the posterior median (Goll), the direct cerebellar, and the antero-lateral (Gower's) are ascending tracts.

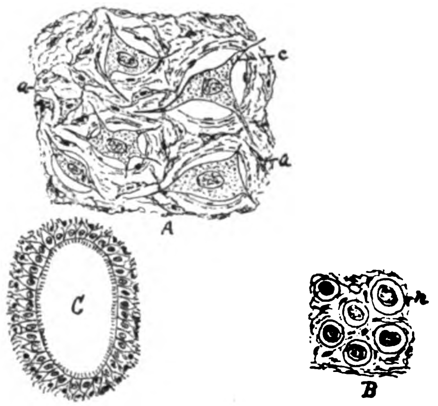


FIG. 164.
Portion of the spinal cord (high power).
(*A*) gray matter showing (*c*) nerve cells, and (*a*) neuroglia cells; (*B*) white matter showing cross section of nerves (*n*); (*C*) central spinal canal showing ciliated epithelium.

THE GRAY MATTER of the cord consists of nerve-cells and their processes, held together by neuroglia. The nerve-cells are distributed throughout the gray matter, some of which are collected into groups. The groups are:

1. Several groups of large multipolar cells situated in the anterior cornu, the axis cylinder processes of which form the anterior roots of the spinal nerves.

2. A group of large cells situated in the inner portion of the base of the posterior cornu, the axis cylinder processes of which pass into the direct cerebellar tract of the white matter of the cord. This group of cells is termed *Clark's column.*

3. A group of cells situated in a projection from the outer side of the body of the crescent termed the lateral cornu, which group is termed the *intermedio-lateral tract.*

Experiment 166. Stain with haematoxylin and eosin, mount and examine a transverse section of the spinal cord. Under the low power, sketch the outlines of the white and gray matters. Under the high power, sketch the central canal, nerve-cells, and sections of nerve-fibres.

Exp. 167. Stain with Van Giesen stain a section of the spinal cord, and mount, examine and sketch.

THE MEDULLA OBLONGATA.

The medulla consists of gray and white matters which are continuous with the corresponding matters of the cord. It is divided into lateral halves by an incomplete septum.

THE WHITE MATTER of each half of the medulla is arranged in four columns; the anterior pyramid, the lateral tract, the restiform body, and the posterior pyramid.

The fibres of the *anterior pyramid* are continuations of those of the direct pyramidal tract of the corresponding side of the cord and of the crossed pyramidal tract of the opposite side of the cord. After receiving fibres from the lateral tract of the medulla, the fibres of the pyramid are distributed to the cerebrum and to the cerebellum. Those which pass to the cerebrum are arranged in two sets, the inner of which passes as a distinct bundle internal to the olivary body, while the outer encloses the olivary body, from which it receives fibres, to become the *olivary fasciculus.* The fibres which pass to the cerebellum run as a bundle below and external to the olivary body to blend with the restiform body.

The fibres of the *lateral tract* are continuations of fibres of the lateral tract of the corresponding side of the cord. Some of them pass to the anterior pyramid of the opposite side of the medulla, some pass beneath the olivary body to aid in forming the fasciculus teres, others join the restiform body and pass to the cerebellum.

The *olivary body* is composed of gray and white matter, the former, termed the *corpus dentatum* of the olivary body, exists as a capsule open at its upper extremity; while the latter consists of medullated fibres, passing into or from the interior of the capsule, which aid in forming the olivary fasciculus.

The *restiform body* is composed of fibres which are continuous with those of the column of Burbach (fasciculus cuneatus). It blends with fibres from the anterior pyramid and lateral tract of the medulla. It enters the pons and divides into two sets of fibres, one of which accompanies the posterior pyramid to the cerebrum, while the other passes to the cerebellum as its inferior peduncle.

THE GRAY MATTER of the lower portion of the medulla is continuous with that of the cord and, like it, is arranged as two lateral crescents joined by a gray commissure which contains in its centre the central canal. The central canal as it extends upward becomes wider and lozenge-shaped to become the fourth ventricle. The anterior cornu of each crescent as it extends upward becomes larger and penetrated by the decussating fibres from the crossed pyramidal tract of the cord. The decussating fibres divide the cornu into two portions. The portion which is divided off by the fibres is termed the *lateral nucleus* of gray matter, while the portion which is penetrated by the fibres is termed the *formatio reticularis* of the medulla and consists of gray and white matter. The posterior cornua as they extend upward diverge, the caput of each becomes larger and appears as a mass of gray matter near the surface which is termed a *tubercle* of Rolando, while the remaining portion of the cornu blends with the gray commissure to aid in forming the boundary of the central canal and later the floor of the fourth ventricle. As the central canal expands to become the fourth ventricle, portions of the gray matter which forms its wall extend on each side into the posterior pyramid and the restiform body forming the *nucleus gracilis* of the pyramid and the *nucleus cuneatus* of the restiform body (fasciculus cuneatus). The fourth ventricle is a continuation of the central canal of the cord, and its peculiar shape is due to masses of fibres which form its boundaries. Its floor contains a longitudinal median depression which terminates below in the *calamus scriptorius*. Situated in the upper portion of the floor there is an eminence on each side of the median depression, termed the fasciculus teres, which consists of gray and white matter. Most of the cells of the floor of the fourth ventricle are collected into groups from which arise cranial nerves. The groups in the lower portion of the floor give origin to the *hypoglossal* and the *spinal accessory* nerves. The next group, which is situated near the upper extremity of the calamus scriptorius, gives origin to the *vagus*. The next group gives origin to the *glosso-pharyngeal;* while the group near the upper end of the floor gives origin to the *auditory* nerve. Passing across the floor of the ventricle from the median depression are the transverse *white striae*, some of which pass into the auditory nerve. Passing from the anterior median fissure of the medulla white fibres, termed *arciform* fibres, extend transversely on the anterior surface of the medulla. The internal surface of the fourth ventricle is lined by ciliated columnar-shaped cells, resting upon a basement membrane termed the *ependyma*.

THE PONS VAROLII.

The pons is divided into two lateral halves by an incomplete septum which is continuous with the septum of the medulla. Each half is composed of white and gray matter. The white matter is composed of medullated fibres some of which pass transversely, while the others pass longitudinally. The transverse fibres are arranged in two sets, superficial and deep, the former of which is on the anterior surface of the pons and is composed of fibres derived from the middle peduncles of the cerebellum, the fibres of one peduncle being continuous in the vertical median line of the pons with those of the other. The deep transverse fibres are derived from the middle peduncles of the cerebellum, among which are fibres which pass from the superior olivary fasciculus of one side of the pons to the accessory auditory nucleus of the other side. The longitudinal fibres of the pons are derived from the medulla and pass across the deep transverse fibres, at right angles to them, to the cerebrum. The irregular-shaped spaces formed by the crossing of the longitudinal and deep transverse fibres contain gray matter, forming the *formatio recticularis pontis*.

Longitudinal fibres:

1. The fibres from the anterior pyramid pass through the pons to form the crusta of the crus cerebri.

2. The olivary fasciculus divides into two bundles, one of which passes to the corpora quadrigemina, while the other blends with the fibres of the lateral tract of the medulla.

3. The fibres from the lateral tract and posterior pyramid of the medulla, after receiving fibres from the olivary fasciculus and restiform body, become mixed with gray matter forming the fasciculus teres of the fourth ventricle, whence they continue upward to aid in the formation of the tegmentum of the crus cerebri.

The formatio reticularis of the medulla, after sending off a portion to form the olivary body, extends into the pons, becoming continuous with the formatio reticularis pontis.

THE CEREBELLUM.

The cerebellum is composed of white and gray matters.

THE WHITE MATTER consists of two kinds of fibres, the peduncular and the fibrae propriae. The peduncular fibres arise from the cortical gray matter of the cerebellum and extend from each cerebellar hemisphere to the cerebrum, to each other, and to the medulla. They are divided into three sets termed peduncles:

1. The *superior peduncle* (processus e cerebello ad testes) is composed of fibres, some of which arise from the cerebellar cortex, others from the corpus

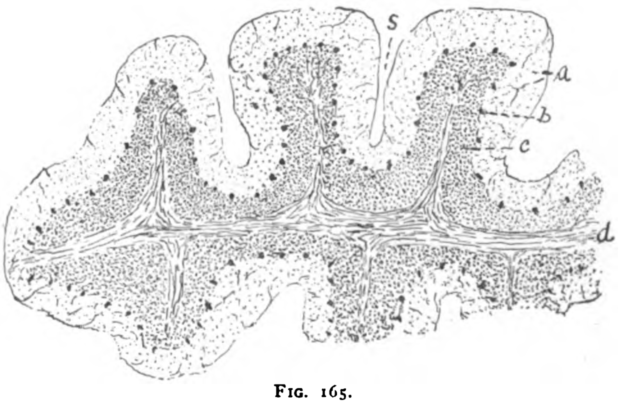


FIG. 165.
Portion of the cerebellum (slightly magnified).
(*s*) sulcus; (*a*) outer layer of gray matter; (*b*) cells of Purkinje; (*c*) inner layer of gray matter; (*d*) white substance of cerebellum.

dentatum cerebelli. It passes inward and forward to the cerebrum, forming in its course the antero-lateral boundary of the fourth ventricle, to pass beneath the testes of the corpora quadrigemina. Some of the fibres of the peduncle continue in the corresponding half of the cerebrum, while the internal fibres decussate with internal fibres of the superior peduncle from the other cerebellar hemisphere to pass into the cerebral hemisphere of the other side.

2. The *middle peduncle* (processus ad pontem) is composed of fibres which arise from the cortex of each cerebellar hemisphere and pass through the pons as its transverse fibres, becoming continuous at the median septum pontis.

3. The *inferior peduncle* (processus ad medullam) is composed of fibres which connect the cerebellum with the medulla oblongata. The fibres arise in the cortical substance of a cerebellar hemisphere and form the restiform body which in its course forms the postero-lateral boundary of the fourth ventricle.

The fibrae propriae of the cerebellum are of two kinds, commissural and arcuate.

The *commissural* fibres pass from the cortical substance of one cerebellar hemisphere to that of the other.

The *arcuate* fibres connect one region of the cortical substance to another region in the same hemisphere.

THE GRAY MATTER of the cerebellum exists as a cortical and a central portion. The central portion, termed the corpus dentatum cerebelli, is similar in structure to the corpus dentatum of the olivary body. The *cortical portion* exists as a covering to the projections of white matter, which, with the projections, give the characteristic "arbor vitae" appearance. It is divided into three zones: an external granular, a middle vesicular, an internal granular.

The *external granular-looking zone* is composed of a fine fibrillar network, some of the fibrillae being derived from the inshoots from the pia mater, others from the neuroglia-cells, and others from the cells of the vesicular zone below. Among the fibres there are numerous granular-looking masses usually round in shape which apparently are nuclei of neuroglia- and nerve-cells the processes of which aid in forming the reticular network.

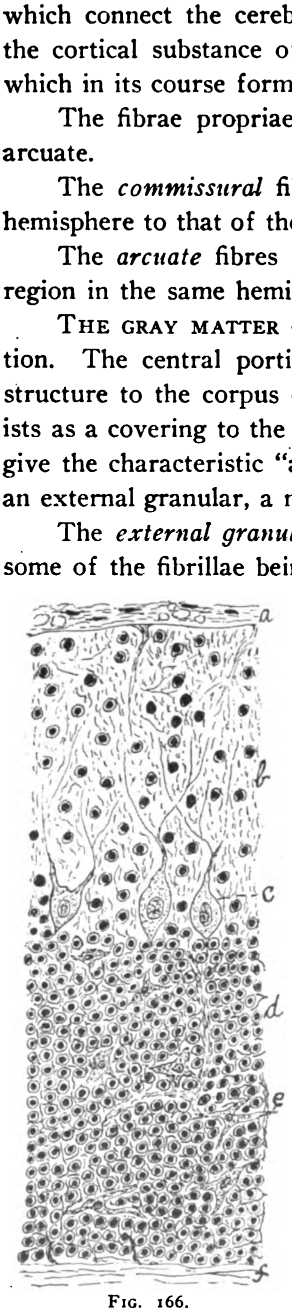
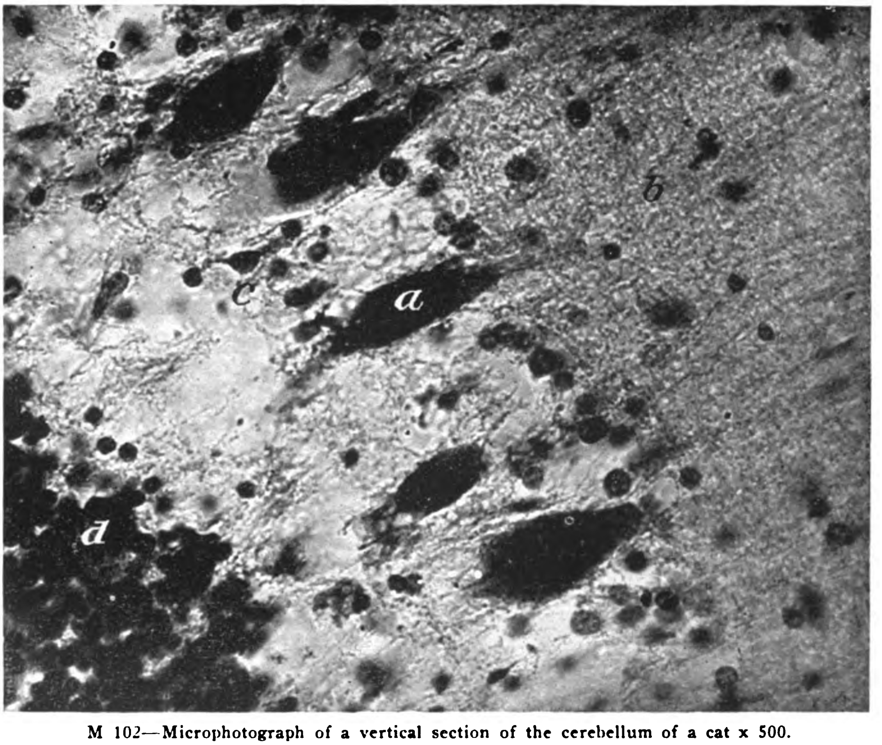


FIG. 166.
A portion of the specimen used in fig. 165 (under high power). (*a*) pia mater; (*b*) outer molecular layer; (*c*) cell of Purkinje; (*d*) inner molecular layer; (*e*) stellate cells (neuroglia); (*f*) fibrous portion or white matter.

The middle or *vesicular zone* consists of large flask-shaped cells, termed the cells of Purkinje, arranged with their large part toward the internal zone and their tapering end toward the external zone. The outer end of each cell divides, the divisions subdividing, the ramifications aiding in the formation of the network of the outer zone. The inner larger portion of each cell sends out a filamentous projection into the inner zone which is probably continuous with a nerve fibre of the white matter of the cerebellum.

The *inner granular-looking zone* rests upon the white matter of the cerebellum and appears similar to the outer zone, consisting of large and small granular-looking bodies, some of which apparently are nuclei of ganglionic cells, others of neuroglia cells, held together by the network formed by their processes.

Experiment 168. Stain and mount a section of the cerebellum. Examine with the low power and notice the "arbor vitae" appearance. Under the high power, sketch several cells of Purkinje, with their processes.



M 102—Microphotograph of a vertical section of the cerebellum of a cat x 500.
a, cells of Purkinje; *b*, outer layer of gray matter; *c*, neuroglia cell with glia fibres; *d*, internal granular portion or inner layer of gray matter.

THE CEREBRUM.

The cerebrum is composed of white and gray matter, the latter occurring as a covering to the convolutions and sulci of the hemispheres, as collections in the white matter, and lining the ventricles.

THE CORTICAL GRAY MATTER consists of nerve-cells usually pyramidal in shape, and neuroglia cells, held together by a network formed by inshoots from the pia mater and ramifying processes of the cells. It is usually disposed in five layers.

1. The *superficial layer* is similar in appearance to the outer granular layer of the cerebellum, consisting of round masses which appear to be nuclei of neuroglia cells held together by the fibrillar network.

2. The *second layer* consists of nerve-cells usually pyramidal in shape very similar in appearance to spear-heads. The processes from the angles of the cells branch and form a fibrillar network, while the process arising from the side of the cells (corresponding to the shaft of a spear), being an axis cylinder process, extends through the lower layers to become continuous with a nerve fibre of the white matter.

3. The third layer is composed of structures similar to those of the previous layer except that the nerve-cells are larger.

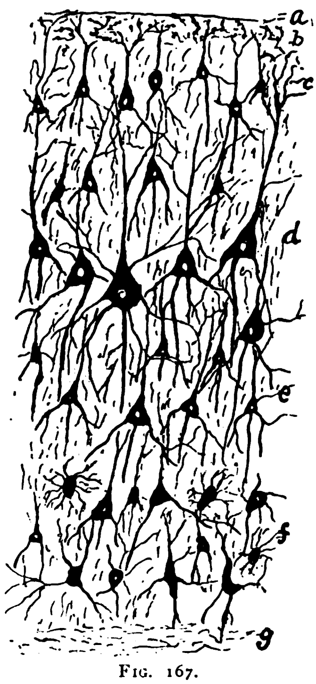


FIG. 167.
Portion of a section of the cerebrum cut vertical to the surface (stained with chloride of gold). (*a*) pia mater; (*b*) molecular layer; (*c*) layer of small pyramidal-shaped cells showing a telodendron; (*d*) large pyramidal cells: (*e*) layer of small pyramidal-cells; (*f*) irregular-shaped cells; (*g*) white matter of cerebrum.

4. The fourth layer consists of structures similar to those of the two previous layers and represents a transition between the third layer and the fifth. Among the cells medullated nerve fibres occur.

5. The fifth layer, the layer bordering upon the white matter, is composed of round or spindle-shaped cells, among which are numerous medullated nerve fibres.

THE COLLECTIONS OF GRAY MATTER termed the basal ganglia are: the corpus striatum, the corpora quadrigemina, the optic thalamus, the locus niger, and the corpora geniculata.

THE CORPUS STRIATUM consists of two collections of gray matter, separated by a bundle of medullated nerve fibres termed the *internal capsule*. The intraventricular collection is termed the *nucleus caudatus;* the extraventricular collection the *nucleus lenticularis*. They consist of large and small multipolar cells among which pass medullated fibres.

THE OPTIC THALAMUS is composed of multipolar and fusiform cells arranged in two masses, an inner and an outer nucleus, separated by an incomplete vertical septum. Internally it is separated from the corpus striatum by the internal capsule.

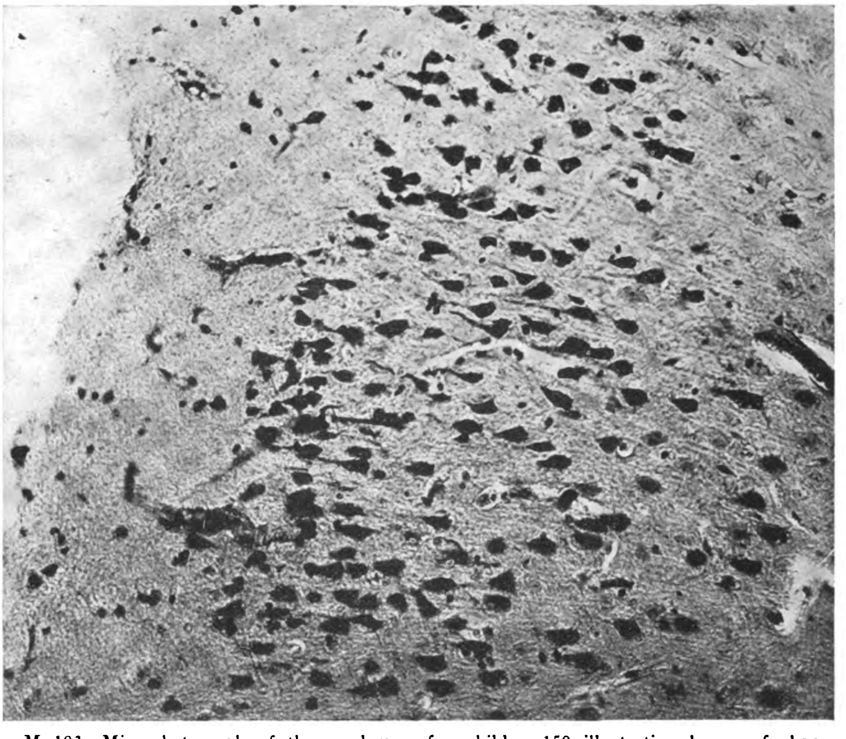
THE CORPORA QUADRIGEMINA consists of four bodies arranged as two pairs, one of each pair being on each side of the median line of the cerebrum. The anterior pair, termed the *nates,* consist of multipolar cells among which pass the fibres of the optic nerve. The superficial covering of each natis is termed the *stratum zonale,* which consists of medullated nerve fibres. The portion immediately beneath the stratum zonale is termed the *stratum cinerum* and occurs as a dense mass of gray matter containing multipolar nerve-cells resting upon the underlying fibres of the optic nerve. The next portion, termed the *stratum opticum,* consists of gray matter through which pass fibres to form the optic nerve. The lowest layer with the corresponding layer of the other natis forms the *central nucleus* which forms the floor of the aqueduct of Sylvius, its multipolar cells being grouped together to give origin to the third, fourth, and fifth cranial nerves.

The posterior pair of the corpora quadrigemina, termed the *testes,* are composed of gray matter containing multipolar nerve-cells and surrounded by medullated nerve fibres.

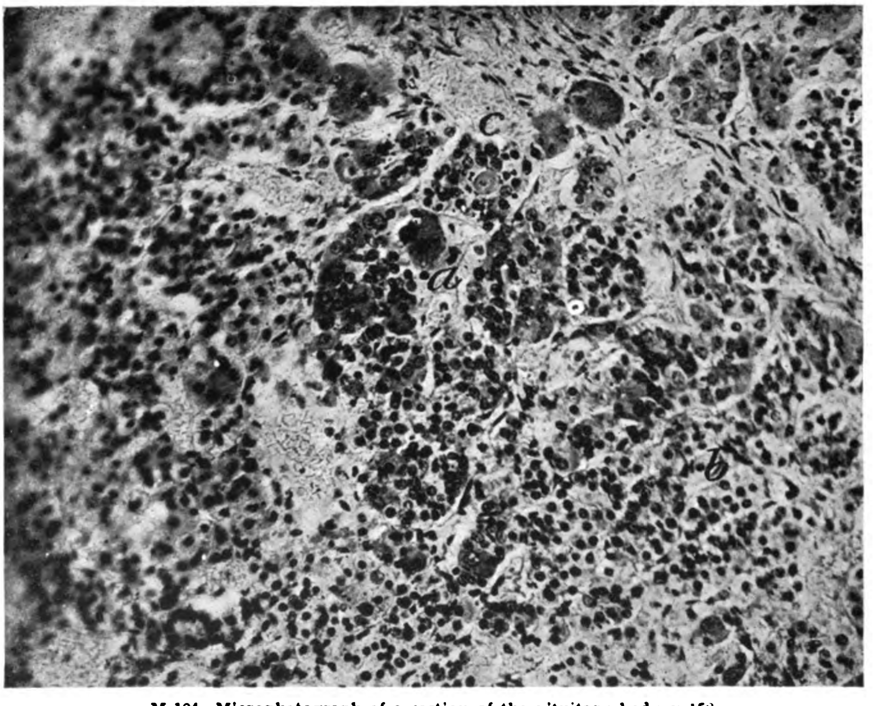
THE CORPORA GENICULATA.—The external corpus appears laminated, and consists of alternating thick layers of gray, and thin layers of white, matter. The cells of the gray matter are multipolar and pigmented. The internal corpus does not appear laminated and consists of gray matter, the nerve-cells of which are small, fusiform and not pigmented.

The white matter of the cerebrum is composed of medullated nerve fibres which are devoid of neurilemmae. The fibres are divided into three sets: *peduncular,* which include the fibres derived from the pons Varolii contained in the crura cerebri; *commissural,* which consists of fibres which connect portions of one hemisphere with those of the other; *collateral* or arcuate, which consists of fibres which connect portions of a hemisphere together.

EACH CRUS CEREBRI is composed of three portions: an upper, a middle and a lower. The middle portion, termed the *locus niger,* acts as a septum between the other two portions and consists of small pigmented multipolar cells. The upper portion, termed the *tegmentum,* consists chiefly of a continuation of the formatio reticularis pontis and fibres derived from the superior peduncle of the cerebellum. The lower portion, termed the *crusta,* consists of fibres derived from the anterior pyramid of the medulla oblongata which pass as the *internal capsule* to the cortex cerebri.



M 103—Microphotograph of the cerebrum of a child x 150 illustrating layers of characteristically shaped cells of the cortex.



M 104—Microphotograph of a section of the pituitary body x 158, showing the glandular remains and alveolar groups (*a*); small cells (*b*); and large oval cells (*c*).

The fibres continuing from the internal capsule and the other fibres of the peduncular set spread out in a fan-shaped manner to pass to the cortex. The fourth ventricle continues as a small canal, the Sylvian aqueduct, into the cerebrum, where it spreads out to form the third and the lateral ventricles.

COMMISSURES.—The anterior commissure is composed of medullated fibres which perforate the corpus striatum of each side to extend to the cortex cerebri. The posterior commissure is composed of medullated fibres which connect together the optic thalami posteriorly. The middle commissure is composed of gray matter which connects the inner portions of the optic thalami to each other.

Experiment 169. Stain, mount and examine a section of the cerebrum, the section having been cut perpendicular to the surface. Look for the various layers of the cortical gray matter, and sketch, under the high power, portions of each layer.

THE PINEAL GLAND OR EPIPHYSIS CEREBRI is covered by the *pia mater* which sends trabeculae into the gland, incompletely dividing it into lobes, which finally forms a reticulum, in the meshes of which are two types of cells, *neuroglia* and *interneuroglia* cells.

The *neuroglia* cells are fusiform or stellate, possessing deeply staining nuclei and fibrous extensions termed *glia fibres* which intermingle with the fibres of the connective tissue reticulum.

The *interneuroglia cells* are oval or polygonal in shape and possess a lightly staining vacuolated nucleus.

Pigment granules are found in this gland sometimes in both types of cells, sometimes in one type, and sometimes in extracellular groups or clumps.

THE PITUITARY BODY, on account of its development, shows in its anterior portion groups of epithelial cells simulating glandular alveoli; and in its posterior portion cerebral structures. The epthelial cells of the anterior or glandular portion are of two kinds, viz: *Chromophilic cells* which are large oval cells, nuclei usually centrally located, and coarse granular protoplasm which has a special affinity for acid dyes; and *Chief cells* which are more numerous but smaller than the other variety, cuboidal in shape, nuclei toward periphery, and finely granular protoplasm which has a special affinity for the basic dyes. The posterior portion of the body consists of nerve cells, fibres, connective tissue, and vessels.

APPENDIX.

Specimens may be obtained and examined in some instances without previous preparation, as in the case of blood, bone-marrow, etc., the specimens being obtained on a slide, covered with a cover-slip and examined.

In some cases specimens are to be studied better after being teased. TEASING consists of the careful tearing apart of tissues, generally of a fibrous nature, with needles with appropriate handles, termed *teasing needles*. During this process one needle is to be used to hold down firmly on the slide the specimen, while the other is gently drawn several times through the specimen lengthwise. In order to keep the tissue moist while being teased, a drop or two of an indifferent fluid should be placed on the specimen. The fluids which may be used are:

Normal salt solution, A 0.75% aqueous solution of sodium chloride—1.5 g. sodium chloride to 200 c. c. distilled water.

Kronecker's fluid: Sodium chloride 5 g.; sodium carbonate 0.06 g.; distilled water 100 c. c.

Schultze's iodized serum: A saturated solution of iodin or tincture of iodin in amniotic fluid.

When it be desired to cause portions of tissues or organs to fall apart, the specimen should be *macerated* with one of the following macerating fluids:

1. Alcohol 33% (Ranvier) which is applicable for macerating epithelia. Small pieces of the tissue, such as intestine, should be placed in this fluid from 4 to 24 hours. The specimen should then be placed upon a slide with a few drops of the fluid and gently tapped several times and covered and examined.

2. Caustic potash solution 35% macerates in 15 to 60 minutes. Useful in macerating epithelia and muscle.

3. Hydrochloric acid, 20% to 30% aqueous solution, macerates in 12 to 24 hours. Useful in macerating glands and isolating uriniferous tubules. The fluid is to be washed out with distilled water and specimens spread on slide in dilute glycerin.

When it is desired to obtain sections of specimens as permanent mounts, the specimens are to undergo special preparation.

The preparation of the specimens usually consists of the following processes:

1. *Fixation*.—The tissue or organ is obtained as quickly as possible after the death of the animal and cut into small pieces, about one-half inch long, one-quarter inch wide and one-quarter inch thick, which are placed in a solution adapted for *fixing* the component parts of the specimen and preserving them from undergoing disintegration or putrefaction.

2. *Dehydration.*—After the constituent portions of the specimens have been properly fixed, the specimen is then dehydrated by means of alcohol.

3. *Embedding.*—The dehydrated specimen is prepared for embedding; the embedding material used may be either paraffin or celloidin.

4. *Cutting.*—The embedded specimen is then cut with either a razor or a microtome (Gr. μικρὸς, small; Τέμνω, to cut), preferably the latter.

5. *Staining.*—The sections may be caused to adhere to slides by means of some adhesive material, such as "albumin fixative," and then stained; or they may be stained before being placed upon slides.

6. *Clarifying.*—After sections have been properly stained the embedding material is either removed from them or clarified, and they then are mounted in Canada balsam or dammar upon slides, covered with cover slips and labeled.

If the sections are to be fixed upon the slides before being stained, the slides are smeared with a thin layer of some transparent adhesive substance, such as "albumin fixative," in which the sections are placed; the sections are then treated in the same manner as in the method used for staining and mounting sections before they are placed upon slides, with the exception that the solutions are placed upon the sections, instead of placing the sections into the solutions.

If the sections are to be stained before being placed upon the slides they are passed through the reagents (see table) contained in staining dishes, clarified and mounted upon slides.

If it be desired to stain a specimen in bulk before it is embedded, it is fixed, dehydrated, stained, embedded and then cut into sections, which may be clarified and mounted.

In some instances when sections of a specimen are desired in a short time the specimen is fixed and sections are cut, the specimen being caused to adhere to the specimen holder of the microtome by means of water which has been made to freeze around it; or it may be held by a piece of an organ which, when previously hardened, has sufficient firmness (as a piece of the liver).

FIXING MEDIA.

The fixing media are used for the purpose of fixing the component parts of a specimen as soon as possible after it has been taken from the body, in order that post mortem changes may not take place.

The specimen should be cut into small pieces and suspended in the fluid. As soon as the fluid becomes clouded, it should be removed and replaced with fresh fluid.

The chief fixing media are:

FORMOL or formalin, which is perhaps the best general fixing medium. It is a 40% solution of formaldehyde gas in water.

℞ Formol, 5 to 10 per cent.
Water, 95 to 90 per cent.

The specimen should remain in this solution 24 hours to two weeks, depending upon the size of the specimen, and then transferred to 95% alcohol. For the fixation of specimens from the central nervous system, 3% potassium bichromate may be added.

ALCOHOL (ethyl alcohol) which is a generally used fixing medium. The specimen may be passed through solutions of alcohol in water of different percentage passing from the lower to the higher; or it may be placed at once into a 95 per cent. solution of alcohol in water. The absolute alcohol of commerce being about 95 per cent., it is necessary in some instances to convert it into absolute alcohol by removing the water, which may be done by placing dehydrated copper sulphate crystals into the flask of 95 per cent. until the copper sulphate crystals cease to turn blue, and then by carefully decanting or distilling off the liquid, absolute alcohol may be obtained. Lime may be used instead of the copper sulphate crystals, but the time required will be longer.

In order to obtain alcohol of different percentages than the 95 per cent., the following method is recommended: Divide 95 by the percentage desired; multiply the quotient by 100, and then add to 100 c. c. of 95 per cent. alcohol, distilled water sufficient to make the number obtained above, viz: to obtain 70 per cent. alcohol divide 95 by 70; then multiply the quotient 1.357 by 100, which gives 135.7. Therefore by adding 35.7 c. c. water to 100 c. c. of 95% alcohol, 135.7 c. c. of 70% alcohol will be obtained.

MULLER'S FLUID.

℞ Potassium bichromate, 2.5 parts.
Sodium sulphate (Glauber's salt), 1 part.
Water, 100 parts.

The specimen should be left in this fluid 1 to 6 weeks, and then washed in running water for 4 to 8 hours, then rinsed in distilled water, and then dehydrated by passing it through the lower percentage of alcohols to absolute, contained in dark colored bottles.

FLEMING'S SOLUTION, which is a fixing medium especially adapted for nuclear structures:

℞ Chromic acid (1 per cent. solution), 15 c. c.
Osmic acid (2 per cent. solution), 4 c. c.
Glacial acetic acid, 1 c. c.

Sometimes diluting with two to five times its bulk of water will give better results. Fresh specimens should remain in this fluid 1 to 2 days, then be washed in running water, then in distilled water and put through different strength alcohols to absolute.

PICRO-SULPHURIC ACID, which is a fixing medium especially adapted for embryos:

℞ Picric acid (saturated aqueous solution), 100 parts.
Sulphuric acid (concentrated), 1 part.

After standing for 24 hours, filter and add equal volume of distilled water.

Acetic-alcohol mixture (Carnoy).

℞ Glacial acetic acid, 1 part.
Absolute alcohol, 3 parts.

Small pieces of the specimen should be left in this fluid ½ to 1 hour as it fixes very rapidly. Then they should be placed in absolute alcohol, which should be renewed in 24 hours.

The above mixture may be modified by adding chloroform 3 parts to 1 of acetic acid and 6 of absolute alcohol.

Osmic acid is used as ½ to 1% solution. Small pieces should be placed in this fluid for 24 hours, then washed with running water for 24 hours, and then placed in 95% alcohol.

Platino-acetic-osmic acid solution of Hermann is useful for bringing out cell boundaries. It is to be used in the same way as Fleming's solution.

℞ Osmic acid, 2% aqueous solution, 4 parts.
Platinum chloride, 1% aqueous solution, 15 parts.
Glacial acetic acid, 1 part.

HARDENING.—Specimens after having been fixed in any of the fixing media should be dehydrated or hardened by passing them through 50%, 70%, 95% alcohol, allowing them to stay in each at least 24 hours, and then they should be placed into absolute alcohol for 24 hours. They are then ready for embedding.

EMBEDDING.

In order that specimens may be cut into sections of suitable thinness they should be permeated by and embedded in some substance which, when it has set, gives firmness to the specimens and is not injurious to the cutting edge of the knife used in sectioning. The substances generally used are two, paraffin and celloidin.

PARAFFIN METHOD.

The dehydrated specimen is placed into *chloroform* or turpentine or xylol 2 to 10 hours.

Then into a saturated *solution of paraffin, in chloroform* or in turpentine or in xylol, 2 to 4 hours.

Into melted *soft paraffin* 3 hours.

Hard paraffin should be slowly melted on a water bath and poured into a mold, into which the specimen is lifted from the soft paraffin (using a warm section-lifter) and arranged in any position desired. When the surface of the paraffin appears to possess a thin film upon its surface, cold water should be run around and then over the mold.

(A very efficient mold is formed by placing two right-angle-shaped pieces of metal (one-quarter inch deep) upon a glass plate so placed that they form a parallelogram. By adjusting the pieces of metal, molds of various sizes may be obtained.)

Celloidin method.

The dehydrated specimen is placed into a mixture of equal parts of absolute alcohol and ether 12-24 hours.

It is then transferred to a *thin solution of celloidin,* in equal parts of absolute alcohol and ether, 12-24 hours.

Then it is placed into a *thick solution of celloidin* (in ether and absolute alcohol, equal parts), 24 hours.

The surface of a cork (the size of the cork depending upon the size of the specimen) having been smeared with a thin layer of the thick celloidin solution, the specimen is lifted to the cork and arranged in the position desired, and upon it a few drops of the thick celloidin is placed. When the surface of the celloidin becomes converted into a film, the cork is placed into a vessel containing alcohol (80 per cent.), in which it is kept until needed for sectioning.

On account of the tendency of the cork, with specimen upon it, to float on the surface of the alcohol, the author has ceased using it, and has been using instead pieces of "fibre" that is used in electrical works for insulating purposes. The pieces sink to the bottom of the jar of alcohol, thereby keeping the specimen immersed. The surface of the pieces of "fibre" should be roughened, so as to cause better adhesion of the celloidin. Parloidin may be used instead of celloidin, in the same way.

SECTIONING.

Specimens may be cut into sections by means of a razor held in the hand or (which is more advisable) by means of a "microtome." If the specimen be embedded in paraffin, the paraffin should be carefully trimmed off to the end of the specimen at which the sectioning is to begin, the end being made rectangular in shape. The specimen is placed in the specimen-holder of the microtome (supposing that the microtome is to be used) and the knife should be so arranged that the cutting edge is at an angle with the specimen if single sections be desired, parallel with the specimen if serial sections be desired. As the sections are cut they should be kept from curling by means of a fine camel-hair brush, the brush being placed upon the edge of each section as it slides upon the knife.

If the specimen be embedded in celloidin, it should be placed into the specimen-holder of the microtome and continually kept flooded with alcohol (85 per cent.). The knife should be arranged at an angle and kept continually flooded also with alcohol (85 per cent.). The sections, as cut, should be placed into a vessel which contains alcohol (85 per cent.) or a mixture of equal parts of alcohol (95 per cent.), glycerin and ether. The sections should be kept in the vessel until needed for mounting.

In some instances when sections of a specimen are desired without previously embedding the specimen in paraffin or celloidin, the specimen is fixed and then covered with water, which is then frozen by means of a freezing apparatus. The freezing may be done by means of an "ether spray"; or by means of liquified carbon dioxide, which is allowed to assume the gaseous form beneath a metal plate upon which the specimen rests. In either case the specimen rests upon a metal plate so constructed that it can be held by the specimen-holder of the microtome.

The sections should be stained, for which purpose the following staining fluids may be used:

STAINING SOLUTIONS.

HAEMATOXYLIN.

Delafield's—

℞ Saturated solution of haematoxylin in absolute alcohol, 4 c. c.
Saturated solution of ammonia-alum in water, 150 c. c.

After allowing the mixture to stand for eight days, exposed to the sunlight, filter and add:

Glycerin, 25 c. c.
Absolute alcohol, 25 c. c.

To stain with this solution, add a small amount of it to an equal amount of water.

Ehrlich's—

℞ Haematoxylin crystals, 2 grms.
Absolute alcohol, 60 c. c.

After the crystals have been dissolved, add:

Water, 60 c. c., saturated with ammonium alum.
Glycerin, 60 c. c.
Glacial acetic acid, 3 c. c.

Haematoxylin and Red Oxide of Mercury—

Haematoxylin crystals saturated solution in 95% alcohol, 25 c. c.
Ammonia (concentrated solution) 500 c. c. red mercuric oxide 1.5 grams.

Mix in a flask and place the flask in a pan of water and heat gently to near boiling point. Remove flask and put it into cold water.

CARMINE.

Borax-Carmine—

℞ Borax, 4 grms.
Carmine, 3 grms.
Warm water, 93 c. c.

After the borax and carmine have been dissolved by the water, add:

Alcohol (70 per cent.), 100 c. c.

Decant as needed.

Sections should remain in this fluid 2 to 6 hours, then washed with acid alcohol (1% hydrochlorine acid to 100 c. c. 70% alcohol), then 95% alcohol.

Picro-carmine (Ranvier)—

To a saturated solution of picric acid add an ammoniacal solution of carmine until a precipitate appears. Evaporate slowly (on a water bath) to about one-fifth its volume, and filter. Evaporate the filtrate to dryness. The powder thus obtained should be dissolved in water as needed, the strength of the solution usually being 5 per cent.

Alum-carmine (Grenacher).

Ammonium alum, 5% solution, 100 c. c.

Carmine, 1 grm.

Boil for 15 minutes and allow to cool. Filter and add enough distilled water to make 100 c. c.

Cochineal solution (Czocor).

Powdered cochineal 7 grm. and exsiccated alum 7 grm. are placed in 100 c. c. and boiled down to one-half the volume, being stirred all the while. After cooling it should be filtered and to it a few drops of carbolic acid added. This fluid stains rapidly, but does not overstain. After staining with it, wash specimens in distilled water, then dehydrate, clarify and mount.

Van Giesen's *acid fuchsin* picric acid solution:

Acid fuchsin, 1% aqueous solution, 5 c. c.

Picric acid, saturated aqueous solution 100 c. c.

Dilute with equal quantity of water at time of using.

To stain with this solution, the specimen should be overstained with haematoxylin solution (about 5 minutes), and then be placed in this solution 2 to 3 minutes, then rinsed in water, dehydrated in 95% alcohol, clarified and mounted. This is an excellent connective tissue stain.

SAFRANIN is an important stain, its importance depending chiefly upon its power of staining the chromatin filaments of nuclei:

Safranin 3 parts.

Alcohol (70 per cent.), 100 parts.

The solution may be diluted with alcohol or made stronger by adding more safranin as desired.

EOSIN is generally used as a .2 to 2 per cent. solution of the water-soluble powder in water.

METHYL-GREEN—

Methyl-green, 1 grm.
Distilled water, 100 c. c.

After the methyl-green has dissolved, add 25 c. c. absolute alcohol.

SILVER NITRATE.—The fresh piece of tissue which is to be stained is rinsed in distilled water and then placed into a one-half to 1 per cent. solution of silver nitrate in distilled water for five to fifteen minutes. It is then rinsed again in distilled water and exposed (in distilled water) to the action of sunlight. When sufficiently stained it should be thoroughly rinsed in a normal solution of sodium chloride and mounted in glycerin; or in balsam after having been dehydrated. Sections of embedded specimens may be stained in the same manner, but before being mounted they should be dehydrated and clarified. This stain affects especially cement substance, and therefore useful for staining endothelium and fibrous connective tissue.

CHLORIDE OF GOLD.—Specimens may be stained with the chloride of gold (one-half to 1 per cent. solution in distilled water slightly acidulated with acetic acid) in the same manner as with silver nitrate.

WEIGERT'S HAEMATOXYLIN METHOD is especially adapted for staining portions of the central nervous system. The specimen, after having been hardened or fixed in Müller's fluid and embedded in celloidin, is immersed in a saturated solution of neutral cupric acetate which has been diluted with an equal volume of water, in which it is kept for about twenty-four hours at a temperature of 35° to 45° C. The following solutions having been prepared:

A—

Lithium carbonate (sat. aq. sol.), 1 part.
Water, 90 parts.

B—

Haematoxylin crystals, 1 part.
Absolute alcohol, 10 parts.

and the specimen having been cut into sections, the sections are placed into a mixture of *A* and *B* (equal quantities) for a length of time sufficient for them to be properly stained, usually one to four hours. After having been properly stained, the sections are hydrated, clarified and mounted.

For staining voluntary muscle to show nerve-endings the following method of Chr. Sihler is recommended. Small pieces of the muscle are first placed for eighteen hours in a solution containing:

Acetic acid, 1 volume.
Glycerin, 1 volume.
Chloral hydrate (1% solution), 6 volumes.

Then teased in pure glycerin. They are then placed in:

Haematoxylin (Ehrlich's), 1 volume.
Glycerin, 1 volume.
Chloral hydrate (1% colution), 6 volumes.

and allowed to remain 3 to 10 days. The pieces are then placed in the first solution until the color becomes differentiated.

SPECIAL METHODS FOR STAINING BLOOD.

THE EOSIN-METHYLENE BLUE METHOD—

Eosin powder, alcohol soluble, ½ grm.
Absolute methyl alcohol, 50 c. c.

In one wide mouth bottle.

Methelene blue powder (Grübler's), ½ grm.
Absolute methy alcohol, 50 c. c.

In another wide mouth bottle.

To stain.—With coverglass forceps lower the coverglass which has the film of blood on it into the eosin bottle for 30 seconds, then immediately lower it into the methylene blue bottle for 30 seconds, then immediately rinse in a beaker of distilled water for 30 seconds, and dry with bibulous paper, dehydrate and mount with balsam, or after drying examine with oil immersion lens.

EHRLICH'S *triacid or neutrophile stain:*

Saturated solution of *orange G.,* 13-14 c. c.
Saturated solution of *acid fuchsin,* 6-7 c. c.
Water, 15 c. c.
Alcohol, 15 c. c.
Saturated solution of *methyl green,* 12.5 c. c.
Alcohol, 10 c. c.
Glycerin, 10 c. c.

The blood having been obtained upon a clean slide or coverslip, should be gently heated until the blood is "fixed."

Place in stain 1 to 5 minutes.
Rinse in distilled water.

Dry with bibulous paper, and mount with balsam; or put on a drop of cedar oil and examine with $\frac{1}{12}$ objective.

The *nuclei* are stained *green;* the *eosinophile* and *neutrophile* granules, *red;* the *basophile* granules are usually not stained; the colored corpuscles appear pale yellow or red.

JENNER'S *stain:*

Equal quantities of a 1.2 per cent. aqueous solution of eosin and of 1 per cent. aqueous solution of methylene blue are thoroughly mixed and allowed to stand for 24 hours. The precipitate is filtered off, washed thoroughly with distilled water, dried in the air without heating. For use dissolve ½ grm. of the dry powder in 100 c. c. of pure methyl alcohol. Into this is placed the slide or cover-slip containing the smear of blood which has been allowed to dry without the aid of heat, and allowed to remain 1 to 3 minutes. It is then rinsed in distilled water until the film has a pale pink color (5 to 10 seconds.). Allow specimen to dry in the air and mount.

The *colored corpuscles* stain a *terra-cotta* color; the *nuclei* are *blue;* the *blood plaques purple;* the *neutrophile* and *eosinophile* granules *red;* the *basophile* granules and cell bodies *blue.*

WRIGHT'S *chromatin stain:*

To a 5 per cent. solution of *sodium bicarbonate* in distilled water, add 1 per cent. by weight of powdered *methylene blue.* The mixture, having been put into a flask, is steamed in an Arnold sterilizer for one hour from the time the temperature reaches 100° C. It is then taken from the sterilizer and allowed to cool. It is then poured gently into a dish or flask and to it is added 1 to 1000 aqueous solution of *eosin* until the blue color changes to purple and the mixture has a yellowish metallic looking scum on its surface (requiring about 500 c. c. of the eosin solution to 100 of the alkaline methylene blue). The precipitate formed is collected on a filter and allowed to dry without washing or heating. When dry a saturated solution in methyl alcohol is made (.3 grm. will saturate 100 c. c. methyl alcohol in a few minutes). After filtering, add to 80 c. c. of the filtrate, 20 c. c. of methyl alcohol. The stain thus prepared should be kept in tightly stoppered bottles.

The blood smeared slide or cover-slip is allowed to dry and is placed into the stain for one minute. The slide or cover-slip is then removed and upon it is dropped water until a metallic-like scum forms on the surface of the mixture, and a reddish tint develops at the margins. The preparation is then left for from 3 to 10 minutes. Then the specimen is washed with distilled water, until the thin portions of the film appear pale yellow or a faint pink. The specimen is then dried with bibulous paper and mounted with balsm or examined with cedar oil and $\frac{1}{12}$ objective.

The *colored corpuscles* should be *pink;* nuclei red or may be blue; cell bodies blue. The chromatin network of the nucleus and nucleoli stained with this stain can be distinctly seen.

Clarifying Reagents.

The embedding material surrounding and contained in the sections should be removed or clarified in order that it may not obscure the portions of the sections. The reagents which may be used are: benzole, xylol, turpentine, creosote, oil of cloves, oil of bergamot, or other essential oils.

Generally if the sections be embedded in paraffin, use xylol or turpentine; if embedded in celloidin, use creosote (which clarifies the celloidin) or oil of cloves (which dissolves the celloidin).

Mounting Reagents.

Sections or thin specimens may be mounted in glycerin, basalm or damar.

Glycerin is used as a mounting medium when the sections or specimens are to be mounted without having been previously embedded; when used, the cover-slip should be made adherent to the slide by means of some form of cement, as zinc white, gold size, etc.

Balsam is the generally used mounting medium, as a solution in xylol.

After the mounting medium has been placed upon the section the cover-slip should be placed on it, care being taken that no air be allowed to remain under the cover-slip. One end of the cover-slip should be placed at one edge of the section in contact with the balsam and the slip gradually lowered by means of a teasing needle.

After the sections have been mounted the slides should be placed in a horizontal position for several days, then cleaned with alcohol or xylol, labeled and stored away to be examined when desired.

INJECTING MEDIA.

Injecting media are used for the purpose of injecting capillary blood-vessels.

Carmine-gelatin—

I:

Liquor ammonia, 8 parts.

Carmine, 4 parts.

After being allowed to stand one-half to one hour, add:

Distilled water, 50 parts.

II:

Gelatin mass, prepared by adding to about ten parts of pure gelatin a sufficient amount of water to cover it, and allowing the mixture to stand until the water is absorbed by the gelatin.

Filter preparation I and place the filtrate in an evaporating dish on a water bath, and add to it, while hot, preparation II slowly, continually stirring the contents of the evaporating dish. Then add drop by drop a dilute solution of acetic acid until the preparation is slightly acid in reaction.

Prussian blue gelatin may be prepared in the same manner, using instead of preparation I a solution of Prussian blue (9 per cent.. solution in water).

Whichever medium is used it should be used before it has been allowed to set, and should be injected into the vessel going to the region to be injected. The injection should take place as soon after death of the animal as possible, or while the animal is under the influence of chloroform.

THE HAEMACYTOMETER consists of a glass slide which contains a quadrilateral rectangular depression of uniform depth, the floor of which is divided into squares by parallel lines crossing other parallel lines at right angles. Accompanying the slide there is at least one cover-slip, a graduated pipette and sometimes a puncturing needle.

The depth of the depression is usually one-tenth of a millimeter. The sides of the squares into which the floor of the depression is divided are one-twentieth of a millimeter long. Therefore each space, the base of which is represented by one of the previously-mentioned squares, has a capacity of one four-thousandths of a cubic millimeter ($\frac{1}{20}$ mm. $\times$ $\frac{1}{20}$ mm. $\times$ $\frac{1}{10}$ mm.).

The method for using the instrument is as follows:

With a puncturing needle which has been cleansed immediately before using, puncture the tip of a finger or the lobe of the ear, the surface used having been thoroughly cleansed. Place the point of the pipette into the oozing blood and draw (by suction) the blood into the pipette until it reaches the point marked .5 c. c. The point of the pipette should then be cleansed with a cloth which has been soaked in a solution of sodium sulphate (10 per cent.) and placed into a vessel containing sodium sulphate (10 per cent. aqueous solution); a dilute solution of acetic acid if only the colored corpuscles are to be counted; the sodium sulphate solution to which a few drops of a 1 per cent. solution of gentian violet has been added; or a dilute solution of acid methylene blue. Whichever solution is used, it is drawn into the pipette to the point marked 101 c. c. and the pipette is then gently shaken. It will readily be understood that the bulb of the pipette contains 100 c. c. of the mixture, of which .5 c. c. is blood, giving .5 per cent. solution of blood. About one-third of the contents is now driven from the pipette and then a drop is forced from the pipette into the depression on the slide. After the drop has been covered with a cover-slip the slide is placed upon the stage of the microscope. After sufficient time has elapsed (about ten minutes) for the corpuscles to settle on the floor of the depression, the specimen is examined. The corpuscles contained in a large number of areas, usually about fifty (the larger the number of areas counted the more reliable will be the result), are carefully counted.

The number of corpuscles divided by the number of areas counted gives the average number contained in one area, which, as stated above, has a capacity of $\frac{1}{4000}$ c. mm.

The average number of corpuscles of the diluted blood contained in $\frac{1}{4000}$ c. mm. multiplied by 4000 gives the average number of corpuscles contained in one cubic millimeter.

The average number of corpuscles of the diluted blood contained in a cubic millimeter multiplied by the quotient obtained by dividing 100 by the amount of blood originally drawn into the pipette (.5 c. c.) will give the average number of corpuscles contained in a cubic millimeter of blood.

(The student should carefully note the dimensions of the divisions of the depressions as etched on the slide, and if different from the dimensions mentioned in the foregoing description, which applies to the Zeiss haemacytometer, he should calculate accordingly.)

Method for staining cut sections with haematoxylin and eosin:

1. Receive the specimen in water.
2. Place it into haematoxylin stain for about 5 minutes.
3. Rinse in water.
4. Acid alcohol ½ to 3 minutes, depending upon the strength of the stain and of the acid alcohol, or until specimen turns to claret-red color.
5. Rinse in water.
6. Ammonia water ½ to 3 minutes, or until specimen turns to the desired blue color.
7. Rinse in water.
8. Eosin 2 to 5 minutes.
9. Rinse in water.
10. Alcohol 95 per cent. for 1½ minute.
11. Creosote 1 to 3 minutes.
12. Lift specimen on to the slide being careful not to get the specimen wrinkled or folded.
13. Press with bibulous paper in order to dry.
14. Put a drop of balsam upon the specimen, and upon that the cover-slip, and finally label.

[SEE TABLE ON PAGES 176 AND 177]

FRESH TISSUE.

	Formol.	Alcohol.	Muller's Fluid.	Picro-Sulphuric Acid.	Flemming's Solution.
Fixing	1—12 to 24 hours. 2—Graded Alcohols. 30 per cent., ½ hour. 50 " 1 " 60 " 2 " 70 " 12 " 80 " 12 " 95 " 12 " or transfer direct from formol to alcohol (95 per cent) for 24 to 36 hours.	1—Graded Alcohols. 30 per cent., ½ hour. 50 " 1 " 60 " 2 " 70 " 12 " 80 " 12 " 95 " 12 " or 1—Place the fresh tissue at once into alcohol (95 per cent.) for 24 to 48 hours.	1—1 to 6 weeks, changing the fluid at first daily, or when it becomes turbid. 2—Running water, 4 to 10 hours. 3—Graded alcohols.	1—5 to 24 hours. 2—Graded alcohols.	1—Small pieces of the tissue, 2 to 5 mm thick should be placed in about 4 c c. of the solution, 24 to 36 hours. 2—Wash in running water 1 to 3 hours. 3—Distilled water 5 minutes. 4—Graded alcohols.

Dehydrating.. **Absolute Alcohol, 4 to 24 Hours.**

	In Paraffin.	In Celloidin.*
Embedding..	Chloroform or turpentine or xylol 2 to 10 hours. Chloroform and paraffin, } 2 to 4 hours. Xylol and paraffin or Turpentine and paraffin Soft paraffin 3 hours. Hard paraffin (in a mold.)	Alcohol and ether 24 hours Thin solution of celloidin 12 to 24 hours. Thick solution of celloidin 12 to 24 hours. Place on a cork or fibre block and after the celloidin has become firm put into alcohol (80 per cent.) until needed.

*Parloidin may be used as a substitute for celloidin.

Sectioning.... **Cut Sections with a Microtome (or razor).**

Staining.....	HAEMATOXYLIN.	EOSIN.	SAFRANIN.	BORAX-CARMINE.	PICRO-CARMINE
	1—3 to 5 minutes.	1—1 to 5 minutes.	1—5 to 30 minutes.	1—1 to 3 minutes.	1—1 to 15 minutes.
	2—Rinse quickly, but thoroughly, in distilled water. If overstained, rinse in acidulated alcohol until excessive stain is removed. Acidulated alcohol: alcohol (70 per cent.) containing 1 per ct. nitric acid).	2—Rinse in distilled water.	2—Wash quickly in distilled water.	2—Rinse quickly in distilled water.	2—Rinse in 70 per cent. alcohol.
	3—Graded alcohols.	3—Distilled water, 5 minutes.	3—Alcohol 95 per. cent, 5 minutes.	3—If overstained, place into acidulated alcohol until excessive stain is removed.	3—Absolute alcohol, 1 to 2 minutes.
		4—Graded alcohol.	4—Absolute alcohol, 1 minute.		To prevent absolute alcohol from dissolving out all the yellow color from the specimen, put a small crystal of picric acid into the alcohol.

Dehydrating.. **Absolute Alcohol, 1 to 5 Minutes.**

Clarfying....	IF SECTION IS EMBEDDED IN PARAFFIN.	IF SECTION IS EMBEDDED IN CELLOIDIN.
	Turpentine, xylol, or oil of bergamot, 5 to 10 minutes.	Oil of cloves, creosote, or xylol, 5 to 10 minutes.

Mounting.—Put upon a slide, press with bibulous paper, put upon it a drop of balsam, then the cover-slip.

Labeling.—Lalel.

APPENDIX F.

When Double Staining.—With haematoxylin and eosin, overstain with the haematoxylin (5 minutes or more), rinse in water, than treat with acidulated alcohol until the specimen turns a claret-red, then rinse in water, then put in ammonia water (2 per cent,) until specimen turns blue, rinse again in water, dehydrate clarify and mount.

With haematoxylin and acid-fuchsin-picric acid stains, place specimen in haematoxylin for 3 to 5 minutes, then into the acid stain for 2 to 3 minutes, then rinse in water, dehydrate, clarify and mount.

INDEX.

A

B

C

D

E

G

H

I

J

K

M

N

O

P

R

U