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A QUIZ MANUAL

OF

HISTOLOGY,

General and Dental,

BY

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PREFACE.

An experience of some years in teaching Histology has led the writers to believe that a clear conception of the work by the young student is a matter of considerable difficulty, and that such a Manual as the present would be of value in giving him a better foundation for his subsequent study.

If this object can be attained the purpose of the book will be accomplished.

No claim for originality is made, either in the design or in the subject matter of the work except in the chapter on Dental Histology, which it is believed presents to the student for the first time a concise resume of all the recent available literature.

To avoid the rather cumbersome words "crown-wards" and "apex-wards," the words up and down, above and below, have been used with reference to the crown and the apex of the root and not to the position in the jaw; "up" meaning toward the apex; "down" meaning toward the crown; "above" meaning nearer the apex; "below," nearer the crown.

It is desired herewith to acknowledge obligations to the works of Piersol, Stohr, Schaefer and Stirling, as well as to many periodicals whose pages were freely consulted in the preparation of the work.

In addition it is desired to acknowledge the obligations due to Dr. G. V. Black, of the Northwestern University Dental School, and to Drs Weller Van Hook and F. X. Walls of the Medical Department of the University, for their kindness in reviewing the manuscript.

GENERAL HISTOLOGY.

What is animal Histology?

Animal Histology is the science which treats of the structural elements of the animal organism and their relations.

What are structural elements?

Cells or their products.

What is a cell?

A structural element which under suitable conditions is able to nourish itself, develop and reproduce.

What is a fibre?

An elongated, modified cell.

From what is the animal body developed?

From a single cell—the impregnated ovum—by repeated division.

When are cells alike in form?

In the embryonic state, before their development has begun, they are spherical and indistinguishable from each other.

What is meant by differentiation of cells?

As cells develop they change to accord with their future destiny, and this is called differentiation.

What is an elementary tissue?

A combination of similarly differentiated cells and their products.

Name the elemental tissues.

Epithelial, connective, muscular and nervous.

What is intercellular substance?

The product of cell action which is deposited between the cells.

What are the vegetative tissues?

The epithelial and connective tissues are called vegetative because they occur usually in vegetable as well as in animal organisms.

What are the essential parts of a cell?

The protoplasm and nucleus.

What is the protoplasm?

A soft, highly distensible semi-fluid substance which constitutes the major portion of the cell.

What are its chemical characteristics?

It is composed principally of albuminoid substances, but also contains much water and salts insoluble in water; it is alkaline in reaction, and contains a special nitrogenous proteid plastin.

What is the structure of protoplasm?

A reticulum (spongioplasm) which is embedded in an amorphous ground substance called the hyaloplasm.

What is the cell wall?

A membrane surrounding the cell; usually a specialization of the protoplasm or a transformation of the peripheral zone of the cell. It is not always present.

What is the nucleus?

A minute vesicular body, generally found near the center of the cell.

What is its form?

Generally round or oval, but it may be irregular in shape.

Of what is the nucleus composed?

Five proteids, which are usually grouped as chromatin and achromatin.

Chromatin or nuclein, Pyrenin or para nuclein,	chromatin.
Linin.	
Nuclear fluid or matrix, Amphipyrin,	achromatin.

Why are they so named?

The elements called chromatin (Greek *chroma*, color), are so called because they are easily stained with certain reagents, and achromatin because they are stained with difficulty.

What is the centrosome?

A minute corpuscle found near the nucleus from which fine threads extend to the chromatin cords and to the nuclear membrane.

How many nuclei do cells possess?

A cell usually has but one nucleus, but sometimes several nuclei are present. Non-nucleated cells, such as red blood corpuscles, originally possessed nuclei, but lost them in development.

What is the nuclear membrane?

The structureless membrane which surrounds the nucleus and corresponds to the cell wall.

What is the function of the nucleus?

The presence of the nucleus appears to be essential to the growth and nutrition of the protoplasm, but

undoubtedly its most important function is connected with the reproduction of the cell.

What is the nucleolus?

A small, highly refracting body found within the nucleus and probably of different chemical composition; its true value is not yet determined.

What is the form of a cell?

It may possess any shape, depending on the presence or absence of pressure and the kind of pressure when applied. They may be spherical, like embryonic cells, discoid, polyhedral, columnar, cylindrical, cubical, spindle-shaped, stellate, etc.

How large is a cell?

Cells differ greatly in size and are found to vary from 1-6000 in. in diameter up to an ostrich egg. The human red blood corpuscle measures about 1-3200 in., or from 7μ to 8μ in diameter.

What are the vital manifestations of cells?

The characteristics which distinguish living from inorganic units are:

Vegetable, { metabolism, growth, reproduction,

Animal, { irritability, motion.

What is metabolism?

The process whereby the cell assimilates those substances necessary for its nutrition and function.

How do cells grow?

As a result of metabolism, and equal growth may take place in all parts of the cell, but usually unequal

growth takes place and the original form of the cell is altered and it becomes flattened, branched, elongated, etc.

What is the process of reproduction?

Reproduction occurs by direct division—without karyokinesis—and by indirect division—with karyokinesis.

Describe direct or amitotic division.

In this process the nuclei of cells rich in protoplasm simply divide by constriction without definite grouping of nuclear substances; this is a rare and unimportant mode of multiplication.

What is mitotic division?

The process whereby the cellular division is preceded by certain changes in the nucleus.

Describe mitotic division.

Nucleus becomes larger, chromatin increases, fibrils contorted—close skein or spirem.

Chromatin fibrils further thicken, become less convoluted and form irregularly arranged loops—loose skein.

Fibrils separate at their peripheral turns and form loops, the closed ends of which are directed toward a common, clear center—the polar field.

Nuclear membrane disappears, achromatin elements form nuclear spindle with apices toward poles of the future nuclei and the equator occupying polar field, at right angles to the chromatin fibres—mother star, or aster.

The loops undergo longitudinal cleavage, splitting up into double the number of segments—cleavage.

Segments separate into two equal groups and pass

along the guiding lines of the spindle in opposite directions to the poles. The chromatin segments become crowded about the equator of the spindle during migration and form a compressed mass—equatorial plate.

Fibrils are grouped about the poles of the spindle and form two rosettes—daughter stars.

Cell protoplasm begins to divide and continues until separated into two bodies enveloping the new nuclei. Changes now appear as at first, but in inverse order; loose skein, close skein, completion of new nuclei, appearance of nuclear membranes, appearance of nucleoli. Daughter skeins.

What is the duration of cell division?

From one-half hour in man to five hours in amphibians.

Define irritability.

Irritability is the property of living matter whereby external influences are responded to by changes within the cell.

Describe the phenomena of motion.

Motion occurs more particularly in the form of ciliary motion in cells and in the contraction of fibres in muscles. Amoeboid activity has been observed in nearly all the cells of the animal body, and especially in leucocytes.

EPITHELIAL TISSUES.

Why is this tissue so named?

Because it is composed of epithelial cells and a relatively small amount of inter-cellular substance.

What is the shape of epithelial cells ?

Being soft and plastic, and yielding readily to pressure, the shape of the cells depends upon the amount and the kind of pressure to which they are subjected.

How are the cells nourished ?

Having no blood vessels, the nutrition of the tissue is maintained by absorption of the nutritive juices from the intercellular substance.

What of the nerve supply ?

Nerve supply is usually scanty but in certain regions, as the cornea and the fingers, high sensibility is found and the presence of nerve terminations among the epithelial elements is definitely established.

How is the epithelium regenerated ?

By karyokinesis.

What is the membrana propria ?

A modification of fibrous tissue, a basement membrane upon which epithelial cells usually rest.

What are the principal divisions of epithelium ?

Squamous,	simple: one layer. stratified: several layers.
Columnar,	simple. stratified.
Modified,	ciliated. goblet. pigmented.
Specialized,	glandular. neuro-epithelium.

Where are they found, respectively?

Piersol gives distribution as follows:

Simple squamous epithelium occurs in but few places:

Partially lining the tympanic cavity, including the mastoid cells; parts of the membranous labyrinth; the infundibula and alveoli of the lungs; the posterior surface of the anterior capsule of the crystalline lens; parts of the ducts of glands; the capsule of the Malpighian body and the descending limb of Henle's loop in the kidney; choroid plexuses and parts of brain-ventricles.

Stratified squamous epithelium occurs widely distributed, covering—

The skin and its extensions, as the external auditory canal, conjunctival sac, and cornea; the mouth, lower part of pharynx, and œsophagus; the epiglottis and upper part of larynx, together with the false and true vocal cords; the pelvis of kidney, ureter, bladder, beginning and end of male and entire female urethra.

Simple columnar epithelium occurs:

a. Non-ciliated, in—

The digestive tract, from the œsophageal opening of the stomach to anus, as well as in the larger ducts of the glands communicating with this tube; ducts of mammary glands; seminal vesicles and ejaculatory ducts; membranous and penile portions of urethra.

b. Ciliated, in—

Oviduct, uterus, and part of canal of cervix; greater part of brain-ventricles and canal of spinal cord.

Stratified columnar epithelium occurs:

a. Non-ciliated, in

Terminal part of the vas deferens; olfactory part of nasal fossae.

b. Ciliated, in—

The Eustachian tube and parts of tympanic cavity; lachrymal passages; respiratory part of nasal fossae, with communicating sinuses; ventricle of larynx, tra-

chea, and bronchii; epididymis and first part of vas deferens.

In general, where is stratified epithelium found?

Upon every part of the body where constant friction results in rapid desquamation of the cells.

In general, where are ciliae found?

Upon all surfaces or canals where motion is required to propel the products of gland activity toward an outlet.

Describe simple squamous epithelium.

It occurs as a simple layer of flattened, polyhedral, nucleated plates, and is rare in the human body—outer layer of retina, etc., and a few other places.

Describe stratified squamous epithelium.

An arrangement of several superimposed layers of cells, differing materially from each other in form, size, and appearance, according to the layer from which they are taken.

What is the appearance of cells taken from the deepest layer?

They are irregularly columnar, and being young, would be spherical if not compressed. They rest on the membrana propria and so irregularly that clefts are left, whereby nutrient juices and leucocytes can approach the cells.

What of the next layer?

They are irregularly polyhedral and are sometimes mutually connected by means of delicate processes which establish direct continuity between the cells.

What are prickle cells?

The cells of the middle layer which, when dissociated,

appear to possess spines where the processes were, and for this reason are named prickle cells.

Describe the cells of the upper surface.

As the cells approach the surface they become flattened and keratose and are finally cast off as dead scales.

What is the shape of columnar cells?

Seen from the side, they present an elongated appearance, the height considerably exceeding the breadth; and seen from above, they are hexagonal—in reality, therefore, they are prismatic.

Where is simple columnar epithelium found?

Throughout the intestine.

How are columnar cells disposed?

They rest in a single layer upon the membrana propria and their sides are joined with relative accuracy.

What is the marginal zone?

A peculiar appearance found on the free borders of columnar cells in some localities, which exhibits a narrow vertical striation and on the addition of water breaks up into a series of rods. The striæ are prolongations of processes of the protoplasm that penetrate the homogeneous zone.

Where is stratified columnar epithelium found?

This form is found only on the palpebral conjunctiva and in the main excretory ducts of some of the glands and a portion of the male urethra.

What is its appearance?

The outermost cells alone are distinctly columnar, the deeper layers spindle shaped, and the deepest mainly spherical.

What are ciliae ?

Specializations of the protoplasm of columnar cells in certain localities which appear as minute hair-like processes.

What is their function ?

By active and constant vibration they create a current which serves to propel mucous and other bodies along the membrane in the direction of the point of excretion.

What are goblet cells ?

Certain columnar cells distinguished by clear protoplasm and exceptional size whose peculiar elliptical shape results from the accumulation of mucous elaborated within their protoplasm.

Where are they found ?

On all surfaces covered by columnar epithelium; especially the intestine.

How do they act ?

When the distension becomes too great, the cells burst in the direction of least resistance and the surface of the membrane is bathed with the secretion.

What is pigmented epithelium ?

Cells whose protoplasm has been invaded by melanin, whereby the cell acquires a black or brown tint as found in the skin of certain races and in the retina of the eye.

What is glandular epithelium ?

Elements which are permanently modified to engage in the elaboration of secretion.

What is the appearance of glandular epithelium?

Varying in form from spherical to columnar and

polyhedral. Such cells are found more or less filled with particles of secretion.

Describe rod epithelium.

A peculiar striation found in certain cells—*i. e.*, ducts of salivary glands—and corresponding to the marginal zone. They are found only in secretory cells and have some relation to secretory activity.

What is neuro-epithelium?

The perceptive elements produced by high specialization of the epithelium of those areas toward which the terminations of the nerves of special sense are directed.

Describe the cell.

Two parts are present—an inner containing the nucleus and corresponding to the protoplasm of the cell, and an outer peripherally directed segment which sometimes terminates in stiff hair-like processes.

How does the cell functionate?

The outer segment receives the stimuli from external impressions, while the inner, centrally directed segment stands in close anatomical relation to the nerve fibres.

What is endothelium?

An aggregation of cells of the endothelial type which covers the free surface of those spaces not directly connecting with the air, such as the serous cavities.

Describe the endothelial cells.

These cells occur in a single layer of thin, irregularly polyhedral plates joined edge to edge.

What is the origin of endothelium?

Endothelium is a connective tissue structure arising from the mesoderm.

CONNECTIVE TISSUE.

What is the origin of connective tissue?

From the mesoblast.

How are the various kinds of connective tissue produced?

By differentiation and specialization of intercellular substance.

Wherein does connective tissue differ conspicuously from epithelium?

In the great predominance of the intercellular substance, in its many differentiations and functional importance.

How are connective tissues divided?

According to the nature of the intercellular substance; as, connective tissue, cartilage, and bone.

What are the cellular elements of connective tissue?

They are two: fixed or connective tissue cells proper and migratory or wandering cells.

Describe the fixed cell.

The fixed cell in its typical condition is a flattened, polygonal or stellate plate, and the protoplasm sometimes extends in several planes as thin, plate-like wings.

The nucleus occupies the thicker part of the body of the cell and processes extend into the protoplasm. It is limited by a distinct membrane and frequently contains a nucleolus.

What is its history?

Owing to its participation in the formation of intercellular tissue, the expanded cell soon becomes reduced to the inconspicuous spindle cell of adult areolar tissue

with only a thin envelope of protoplasm around the nucleus. Under favorable conditions it is capable of exhibiting amoeboid movements.

What are the plasma cells of Waldyer?

Cells of irregular form consisting of soft protoplasm and containing many vacuoles. They are found most constantly in young tissues.

What are pigment cells?

Fixed cells with melanin of extra-cellular origin in the protoplasm.

What is the Mastzellen or granular cell?

A cell characterized by an affinity for certain anilin dyes (dahlia) and the conspicuous granularity of the protoplasm. It is supposed to have some relation to the formation of adipose tissue.

What are wandering cells?

Small nucleated masses of active protoplasm (leucocytes) which have passed out of the vessels and wander through the surrounding tissue.

Describe mucous connective tissue.

This tissue is composed of the fixed cells and a large quantity of undifferentiated muciferous, intercellular substance together with a few bundles of fine fibrils—found only in the umbilical cord in the higher animals.

Describe areolar tissue.

It is composed of cells and an abundance of intercellular substance. The intercellular substance is differentiated into fine connective-tissue fibres (o. 6μ) united by cement into bundles of various sizes. The bundles are soft, flexible, extensible, characterized by longitudinal striation and a wavy course.

Describe elastic fibres.

These occur in varying quantities in the matrix of areolar tissue. They possess sharp, dark outlines, strong refractive power, and a conspicuous resistance to acids and alkalies. They usually occur as a network. When they predominate in connective-tissue bundles the tissue is called elastic tissue; fibrous tissue when fibrous bundles predominate.

What is their origin?

They arise from a transformation of the matrix.

What is adipose tissue?

A tissue composed of connective-tissue cells which contain fat globules.

Describe a "fat cell."

Fat globules in connective-tissue cells sometimes coalesce and give a spherical form to the cell. This is called a "fat cell." The protoplasm occupies a narrow and sometimes almost invisible peripheral zone in some part of which lies the flattened nucleus.

Describe reticular connective tissue.

It consists of a network of slender bundles of fibrillar connective tissue, upon which lie flattened nucleated cells, and when the meshes are filled with leucocytes, the tissue is known as lymphoid tissue.

Where is it found?

It occurs principally in lymph glands and is known as adenoid tissue.

CARTILAGE.

Describe the matrix.

The matrix of cartilage is the intercellular substance and is dense, easily cut and milk white or yellowish in color.

Describe the cells of cartilage.

Usually spherical or flattened on one side, they lie in spaces or lacunae of the matrix, which they fill completely.

What is the perichondrium?

An envelope of dense connective tissue covering the free surface of the cartilage.

Of what is it composed?

It is composed of two layers—an outer dense, fibro-elastic layer and an inner, much looser stratum.

How are they named?

Fibrous layer and chondro-genetic layer.

Why is the chondrogenetic layer so named?

Because it is intimately concerned with the production of new cartilage.

How are the varieties of cartilage named?

According as the matrix is free from admixture with fibrous tissue or is penetrated by the white fibrous and elastic fibres, three varieties are distinguished:

a. Hyaline cartilage,
b. Fibro cartilage,
c. Elastic cartilage.

Describe hyaline cartilage.

It is characterized by a faint bluish, pearly, transparent color and homogeneous matrix.

How are the cells arranged?

They occur in groups of two or more, and may or may not be separated by a thin hyaline partition.

How is this explained?

By the conditions and processes of growth—they are

the descendants of the original cell which has undergone mitosis, and are thus grouped together.

Where does hyaline cartilage occur?

In the respiratory organs, as the costal and articular cartilages, synchondroses, etc.

Describe elastic cartilage.

This has the same structural peculiarities as hyaline cartilage, but is distinguished by the networks of finer or coarser elastic fibres that penetrate the matrix, and its rather yellowish color.

How do the elastic fibres arise?

By a transformation of the matrix, and they appear in the vicinity of the cells as minute granules, which later are disposed in linear rows and fuse into fibres.

Where does this tissue occur?

It occurs as the cartilages of the external ear, of the epiglottis of the cartilages of Wrisburg and Santorini, and of the vocal processes of the arytenoid cartilages.

Describe fibro-cartilage.

The matrix contains an abundance of fibrous connective tissue in loose bundles extending in all directions.

How do the cells appear?

The cartilage cells are few in number and have thick capsules; they occur in small groups or rows at comparatively wide intervals.

BONE.

What is the origin of cartilage?

From the elements of the mesoderm.

Where does fibro-cartilage occur?

As the cartilages of the inter-vertebral discs, the public symphysis, the inferior maxillary and sterno-clavicular articulations.

What are the chief characteristics of the osseous matrix?

This tissue is distinguished by its hardness, solidity, and elasticity.

To what are these properties due?

They are the result of the intimate blending of organic and inorganic substances, and either can be removed without destroying the tissues.

How may this be determined?

By treatment with acids the inorganic substances are removed, the bone is decalcified and rendered flexible and easily cut like cartilage.

Also by cautious heating, the organic substances may be removed and the bone is calcined.

What is the composition of the matrix?

Calcium salts and connective tissue fibrils united by a small amount of cement substance in fine or coarse bundles so that a compact, or lamellar, and a spongy matrix are distinguished. It appears homogeneous or faintly striated.

What are lacunæ?

The numerous spindle-shaped spaces—15-27 μ long—found in the matrix.

What do they contain?

Nucleated flattened bodies—the "bone cells."

What are canaliculi?

Minute branched channels which radiate in all directions from the lacunæ.

What is their function?

They form an inter-communicating system of lymph spaces throughout the matrix and carry nutrient fluids and contain processes from the bone cells lying in the lacunæ.

What are osteoblasts?

Cells whose function consists in producing bone.

How do "bone cells" arise?

By incorporation of osteoblasts within the matrix.

What is meant by Haversian canal?

Channels from 22μ to 110μ wide, continuous with the central marrow cavity and of variable length, containing an extension of the bone marrow, and rich in blood vessels.

Of what does this extension consist?

A delicate connective tissue reticulum, rich in cells, blood vessels and lymphatics.

Where do the Haversian canals open?

On both the outer and inner surfaces.

What are lamellæ?

The plates or ribbons into which the bone is divided by the lacunæ and Haversian canals.

What is an Haversian system?

An Haversian canal and its concentrically disposed lamellæ.

What are interstitial or ground lamellæ?

The remains of the primary spongy network of periosteal bone.

What are the circumferential or fundamental lamellæ?

The superficial osseous strata that encircle the bone on both its outer and inner free surfaces.

What is the periosteum?

An envelope of vascular connective tissue that closely invests the outer surface of all bones except the articular facets.

Of what is it composed?

Of two layers respectively: the fibrous layer and osteogenetic layer.

What is the appearance of the fibrous layer?

A covering of dense fibrous connective tissue.

Describe the osteogenetic layer.

This is a loose stratum, rich in cells and blood vessels and contains within its meshes numerous round or spindle cells which later become osteoblasts.

Why is it so named?

From its intimate connection with the formation of bone.

What are Sharpey's fibres?

The transverse or perpendicular fibres that appear when the superficial lamellæ of decalcified bone are forcibly torn off.

What is their significance?

They represent periosteal fibres which have failed to ossify.

What is the marrow of bone?

Genetically, it is an extension of the osteogenetic layer of the periosteum found within the cavities of

bones and extending throughout the osseous tissue, by means of nutrient canals.

What is the color of marrow?

When young, it is red, but with age, owing to the disposition of fat, it becomes yellow.

What are the elements of red marrow?

A delicate connective tissue reticulum supporting a rich vascular distribution and the meshes of the tissue contain numerous soft connective tissue elements.

What are osteoclasts?

Cells especially concerned in the absorption of bone and are identical with the giant cells of myeloplaxes. (Robin.)

What is Dentine?

This tissue is analogous to bone since it is derived from embryonal connective tissue, but differs in the details of arrangement. *Vide* teeth.

What are Volkman's canals?

Canals embraced by the circumferential lamellæ which are not centers of systems like Haversian canals.

What is their function?

To carry the perforating vessels.

What is the ultimate fate of endochondral bone?

It is for the most part absorbed.

What change is first noticed in the production of endochondral bone?

The formation in the cartilage of centers of ossification, consisting of an increase in size of the embryonal cartilage cells and of the intercellular substance.

What is the second change?

Rearrangement of the enlarged cells into vertical rows around which calcification subsequently occurs.

What is the next change?

The osteogenetic tissue of the periosteum increases and sends processes into the solid cartilage toward the center of ossification. This is accompanied by the absorption of the cartilage until the focus of central calcification is reached, and here the primary marrow cavity is formed.

What is the fate of the cartilage cells?

They undergo degeneration and disappear.

What is the next process?

The periosteal ingrowth—vascularization of the cartilage—continues, the primary marrow cavity is enlarged and filled with blood vessels and young cells, while the intervening calcified matrix projects into the marrow space in irregular processes called trabeculæ.

What is the destiny of the young cells?

Some retain their original form and become marrow cells or they become fat cells or, most important of all, bone-forming cells, osteoblasts, which cover the trabeculæ and walls of the marrow cavity in a single layer and gradually form bone.

How is periosteal bone formed?

By the activity of the osteogenetic layer of the periosteum. The details of the conversion of osteoblasts into bone cells are the same in both cases.

What is the bone corpuscle?

The osteoblast, after it is completely surrounded by the young matrix, is thus named.

How is spongy converted into compact bone?

By the development of additional lamellæ within the meshes of the primary osseous network.

What is inter-membranous bone?

Bone formed from connective tissue instead of cartilage.

How is this accomplished?

Isolated bundles of connective tissue calcify, and on these osteoblasts derived from embryonal cells arrange themselves and produce bone.

What is endochondral bone?

Bone formed at the centers of ossification within the cartilage.

What is periosteal bone?

Bone formed directly from and beneath the periosteum constituting the permanent bones.

What are Howship's lacunæ?

Variously sized pits excavated by the osteoclasts and within which they lie.

Recapitulate the phases in development of a tubular, long bone?

Piersol summarizes as follows:

1. Solid embryonal cartilage.

2. Enlargement and rearrangement of cartilage-cells and lacunæ and calcification of matrix at center of ossification.

3. Penetration of periosteal tissue to the focus of calcification; vascularization of the cartilage.

4. Formation of medullary spaces by the breaking down of lacunæ surrounded by the zone of calcifying cartilage.

5. Covering of the surface of calcified cartilage trabeculæ by the layer of osteoblasts and the production of an enveloping sheath of true bone.

6. Resulting central network of endochondral bone, with gradual absorption of encased cartilage trabeculæ.

7. Absorption of the central spongy bone in shaft and formation of central marrow-cavity.

8. Formation, meanwhile, of peripheral periosteal network of spongy bone.

9. Conversion into compact bone by partial absorption of trabeculæ to form Haversian spaces; secondary deposit of concentric lamellæ within these spaces forming Haversian systems of compact bone.

10. Absorption of inner lamellæ of compact bone as the shaft increases in diameter by the deposition beneath the periosteum; production of enlarged medullary cavity.

11. Continual absorption of endochondral central bone until the latter is found alone in the epiphyses, where it continues to be produced at the expense of the intermediate cartilage during the entire future growth of the bone.

MUSCLE.

What is the chief functional characteristic of muscle?

Contractility.

Wherein does the contractility of muscle cells differ from protoplasmic contractility?

Protoplasm acts in all directions; muscle along definite lines and in limited directions only.

How is muscle divided for description?

Into two classes.

1. Non-striated, smooth or vegetative muscle.
2. Striated, striped or animal muscle.

How otherwise?

The smooth muscle being generally independent of the will is known as involuntary, while the striated muscle being subject to volition is called voluntary.

What are the structural elements?

Fibres which are really cells, extraordinarily elongated.

Describe the non-striated muscle cell.

This element consists of a contractile, spindle-shaped cylindrical or slightly flattened cell, composed of homogeneous protoplasm.

How large are the cells?

46 to 225μ long and 4 to 7μ wide.

What is the sheath?

A delicate homogeneous structure, resembling elastic tissue, which invests the contractile substance of the fibre.

Where is the nucleus?

The characteristic, rod-shaped nucleus lies near the center of the cell.

How are the cells disposed?

The individual cells are united into bundles or fasciculi, and these into strata or membranes.

Where does smooth muscle occur?

In all involuntary organs except the heart.

Where is the nerve supply obtained?

Principally from the sympathetic system.

Describe striated muscle.

This form developed from the original embryonic cell is composed of long, irregularly cylindrical fibres.

What are the component parts?

1. The sarcolemma.
2. The nucleus.
3. Muscle substance.

What is the sarcolemma?

A clear, homogeneous elastic sheath or closed sack investing each fibre and usually adheres tightly to the enclosed muscle substance.

What is the position of the nucleus?

Directly beneath the sarcolemma and usually parallel to the long axis of the fibre.

What is the shape of the nucleus?

Oval or fusiform.

What is the microscopic appearance of the fibre?

It presents alternately broad, dim and narrower, light, transverse striæ, owing to different refractive properties.

What is that difference?

The dark bands are doubly refractive or anisotropic, while the light bands are singly refractive or isotropic.

Of what are the dark striæ composed?

Of a series of minute prismatic elements placed side by side and separated from one another by a thin layer of a substance corresponding to and continuous with that forming the light zone.

How is the light zone divided?

By a delicate interrupted line or row of dark dots

known as the intermediate disc or the membrane of Krause.

What is the lateral disc?

That part of the light zone, between the intermediate disc and the dark bands, are thus named.

What are ultimate fibrillæ?

Fibres treated with chromic acid fall apart lengthwise into delicate fibrils, each of which exhibits the cross striæ. These fibrils are the contractile structural elements and are called ultimate fibrillæ.

How are the contractile fibrillæ arranged?

Grouped into bundles parallel to one another and held together by the sarcoplasm which surrounds them.

What are the bundles called?

Muscle bundles or sarcostyles.

What are Cohnheim's areas?

The dark polygonal areas shown by transverse section of each muscle fibre; it is enclosed by lighter lines and under high power exhibits minute punctuations.

What is the sarcolemma?

A structureless sheath representing a cell membrane which closely invests each fibre.

Describe the nucleus.

This is an oval body placed parallel to the long axis of the fibre upon the surface of the muscle substance, directly beneath the sarcolemma.

How are muscles joined to the skeleton?

By special connective tissue formations, tendons, fasciæ bursœ and tendon sheaths.

Of what is a striated muscle composed?

Striated muscle fibres disposed lengthwise in parallel bundles, and surrounded by a connective tissue sheath —the perimysium—which carries the nerves and lymph vessels.

What is the endomysium?

The connective tissue sheath surrounding each fibre and carrying blood vessels and nerve terminals.

What is the epimysium?

The connective tissue sheath surrounding a number of muscle bundles.

How are tendons composed?

They are composed of bundles of fibrous tissue and are characterized by the parallel course of the fibres.

How is the union of muscle with tendons effected?

By the extension of the endomysium, of the muscle fibre and the blending of the tissues.

What is the structure of fasciæ?

In part like tendons, but richly provided with elastic fibres.

Describe the tendon sheaths and bursœ.

Consisting of connective tissue in varying thickness, they are lined on the inner side with endothelial cells.

NERVOUS TISSUES.

What are the elements of nerve tissue in the embryonic state?

Spherical cells called neuroblasts.

How do they change in development?

They become elongated and pyriform and the narrow end grows out as a long, delicate process, often a

meter in length, and terminates in a free branched end.

What is the body of the cell called?

A ganglion cell or nerve cell.

What is the axis cylinder process?

The elongated delicate process which grows out of the neuroblast.

What are the collateral fibrils?

Delicate collateral processes given off from the axis cylinder process.

Where are the dendrites or protoplasmic processes?

Short processes which arise at other parts of the ganglion cell and divide dichotomously.

What is a neuron?

The nerve cell and axis cylinder together constitute a neuron.

What is a neuro-dendron?

The presence of a neuron together with dendrites and collateral fibrils constitutes a neuro-dendron.

What is the neurilemma?

The outer connective tissue envelope of the axis cylinder. It is a delicate, structureless membrane against the inner side of which lie the oval nuclei surrounded by a small amount of protoplasm.

What is the medullary sheath?

The inner connective tissue sheath of the axis cylinder lying just upon the axis cylinder and just below the neurilemma.

How are they disposed?

There are stretches where the axis cylinder lies uncovered, stretches where it is covered by both the

neurilemma and medullary sheath, and stretches where either alone is found.

Where are nerve cells found?

In the ganglia, in the organs of special sense, and along the course of cerebro spinal and sympathetic nerves, but principally in the central nervous system.

What of their size and shape?

Varying in size from 4μ to 135μ and more, they present spherical, spindle-shaped and irregularly stellate forms, the latter caused by the protoplasmic outlines.

How are the cells named?

According to the number of processes, as unipolar, bipolar, and multipolar.

What is the composition of ganglion cells?

They are composed of granular or finely striated protoplasm.

Describe the cell.

It has a characteristic vesicular nucleus, poor in chromatin, and enclosing a conspicuous nucleolus. There is no cell membrane, and the protoplasm sometimes contains yellowish grown pigment granules.

Describe the axis cylinder.

Usually single, it is the first outgrowth from the embryonic spherical cells, and it is characterized by its hyaline appearance and smooth outline. Its course is cellulifugal--it leads from the cell.

Describe the protoplasmic processes.

Usually multiple, they are a later outgrowth of the embryonal cell, are thicker, granular or finely striated and often varicose. Their course is cellulipetal—toward

the cell. They undergo repeated dichotomous division and terminate in an intricate network of fine fibrils.

What is a nerve cell of the first type?

A nerve cell having a long axis cylinder process, which becomes the axis cylinder of a medullated nerve fibre.

What is a ganglion cell of the second type?

A cell possessing only a short axis cylinder which divides and subdivides and terminates in the vicinity of the cell.

Describe the "first-type" cell.

The axis cylinder, after giving off a number of fine branched twigs—collateral fibrils—and running an extended course as the axis cylinder of a nerve fibre, undergoes rapid division and becomes a plexus of delicate fibrils.

How do the processes terminate?

In free endings without anastomosis.

What is meant by nervous network or nervous plexus?

The disposition of single nerve fibres to branch off from nerve fibre bundles and join other bundles. The transition of one nerve fibre into another never occurs.

NERVE FIBRES.

How are nerve fibres distinguished?

By the presence or absence of the medullary sheath into the medullated or white and the non-medullated or gray nerve fibres.

How might they be subdivided further?

By the presence or absence of the neurilemma.

Describe non-medullated fibres without neurilemma.

They consist of naked axis cylinders, and are found in the olfactory nerve, bound together by connective tissue.

What are Remak's fibres?

Fibres of the sympathetic nerve similar to the non-medullated fibres; they are transparent, cylindrical and grouped in bundles. They are from 3μ to 7μ wide, about 2μ thick and show faint longitudinal striation. There are other fibres which may or may not exhibit the same structure.

Describe non-medullated fibres with the neurilemma.

These consist of axis cylinders enveloped by neurolemma, and are of the same structure throughout. They occur in limited portions of the cerebro spinal nerve fibres.

Describe medullated nerve fibres.

None of these possess the medullary sheath throughout its length. They may be without a neurilemma and consist of axis cylinder and medullary sheath.

Where are these fibres found?

Only in the central nervous system.

Where are medullated fibres with a neurilemma found?

In the trunk and branches of the cerebro spinal nerves, and also in the sympathetic nerve.

Where does division of the medullated fibres occur?

1st, throughout the central nervous system, principally where the collateral fibrils diverge at right angles into the white substance. 2nd, in the peripheral nervous system, shortly before their ultimate distribution.

What is the significance of the axis cylinder?

It is the essential part of every nerve fibre, and occasionally has delicate longitudinal striation which indicates its fibrillar structure.

What do the fibrillæ represent?

Each represents a special conducting path and is cemented to adjacent fibrillæ.

What is neuroplasm?

The finely granular interstitial substance which cements fibrillæ together.

Of what is the medullary sheath composed?

Of a semi-fluid, highly refracting, fatty substance called myelin, which gives the appearance of glistening cylinders.

What are the Schmidt-Lantermann segments?

Small, conical segments into which the medullary sheath is divided by oblique clefts found at irregular intervals.

What are the nodes of Ranvier?

At regular intervals the medullary substance of the fibres is interrupted and the axis cylinder and neurilemma come in contact. These are called the nodes of Ranvier.

Where does the division of a medullated nerve fibre occur?

Always at the site of a node of Ranvier.

What are inter-nodal segments?

The parts of the fibre between the nodes are thus named. They are usually from 0.08 mm to 1 mm in length.

What is the neuroglia?

A peculiar form of connective tissue which secures the union of the nervous elements in the central nervous system.

How are the elements of nerve tissue united in the peripheral nervous system?

By connective tissue which contains the blood vessels.

PERIPHERAL NERVE ENDINGS.

TERMINATION OF SENSORY NERVES.

What changes occur in the sensory nerves in passing to ultimate distribution?

First the medullary substance is lost at some bifurcation corresponding to the node of Ranvier; after continuing for a variable distance the neurilemma ceases and the nuclei become more and more infrequent until they finally disappear, and the fibrillæ continue as naked cylinders (axis) which unite to form a widely meshed ground plexus.

What are the terminal plexuses?

This is the term applied to the network of primitive fibrillæ within the connective tissue of the organ supplied.

Where are they situated?

In some cases directly beneath the epithelium and represent the ultimate distribution of the fibrillæ, but in others fibrillæ emerge from the plexus, enter the epithelium and terminate in pointed or club-shaped free endings between the epithelial cells.

How are the most important forms of special sensory nerve endings grouped?

Tactile cells, tactile corpuscles and end bulbs.

Where are the tactile cells found?

In the deeper layers of the epidermis or the adjacent stratum of the corium, and may be either simple or compound.

What are simple tactile nerve cells?

Oval nucleated elements 5–12μ in size resembling ganglion cells.

What is the tactile meniscus or tactile disc?

A peculiar crescentic expansion upon which the tactile cells rest, and with which the nerve is connected.

What is a compound tactile cell?

A combination of two or more simple cells, associated to receive the nerve fibre.

Where are the tactile discs situated?

On the side of the cell which lies nearest to the central nervous system.

What are the tactile corpuscles of Meissner?

Tactile corpuscles of oval shape nearly 1-300 in. long by 1-800 in. thick, composed of one, two or more medullated nerve fibres which are invested with Henle's sheath—a single connective tissue lamella.

What changes do the fibres experience before entering the corpuscle?

They undergo numerous windings, and the sheath of Henle with the neurilemma become continuous with the fibrous envelope of the corpuscle.

How are the nerve fibres disposed of?

They soon lose their medullary sheath and break up into fibrillæ which pass in a spiral direction through the corpuscle, being connected here and there with terminal discs.

How are the tactile cells arranged?

They are greatly compressed, and usually of indefinite outline, the transversely placed nuclei and cell walls producing transverse markings.

Where are the corpuscles of Meissner found?

In the skin of all parts of the hand and foot, the volar surface of the forearm, the skin of the nipple, in the conjunctiva at the edge of lids, skin of lips, and tip of tongue.

Describe the end bulbs.

These are of cylindrical form and embrace both the simple and more highly specialized structures. They are described in three parts—the capsule, the inner bulb and the nerve fibre. In the simpler forms, the body is borne upon a stalk and contains the medullated fibre, and possibly a minute blood vessel enveloped in connective tissue.

What is the capsule?

A prolongation of the sheath of Henle forms a nucleated capsule.

What is the inner bulb?

A cylindrical mass of granular or faintly striated pale substance enclosed within the capsule within which the free axis cylinder lies, often terminating in a knob-like expansion. The medullary substance ends where the nerve fibre enters the inner bulb.

What are the corpuscles or Vater or the Pacinian bodies?

These are elliptical, semi-transparent bodies 2-3 mm long and half as broad, which are found along nerves supplying the skin of the hands and feet and some other places.

What are the component parts?

The capsule, the inner bulb and the axis cylinder.

Describe the capsule.

It is composed of 25–50 concentric connective tissue lamellæ, both white and elastic fibres, each of which possesses an outer transverse, an inner longitudinal layer of fibres and is lined by a single layer of endothelial cells.

What occupies the interstices between the lamellæ?

A clear, serous fluid, like lymph, most abundant between the outer lamellæ.

Describe the inner bulb.

This occupies the core of the corpuscle and is a light granular or faintly striated mass of homogeneous tissue, closely resembling protoplasm in which nuclei and fibrils are sometimes seen.

Where is the axis cylinder?

Within and corresponding to the axis of the inner bulb. It ends frequently as a slightly expanded terminal knob. The medullary substance surrounds the axis cylinder as far as the inner bulb and then disappears.

NERVE ENDINGS IN SMOOTH MUSCLE.

What nerve supplies the non-striated muscle?

The sympathetic system sends non-medullated nucleated fibres, enveloped by a thin perineurium.

What is the ground plexus?

The association of the fibres in small bundles containing ganglion cells at the nodal points.

What is the intermediate plexus?

The small branches given off from the ground plexus are thus called.

Describe the inter-muscular fibrillæ?

These are fine bundles of fibres that extend further into the contracting tissue. They pass between the muscle cells and probably terminate in pointed or slightly thickened free ends.

STRIATED MUSCLE.

What systems supply the voluntary muscles?

Both motor and sensory nerves.

How are the sensory nerves distributed?

As loose networks, the fibrillæ of which probably terminate between the individual muscle fibres.

Describe the intra-muscular plexus.

This is composed of the union of medullated fibres from the motor system into a network. From this network small bundles of nerve fibres spring and then divide so that a single medullated axis cylinder passes to each muscle fibre.

What is the telolemma?

At the point where the nerve pierces the sarcolemma

the medullary substance abruptly ends, while the neurilemma blended with the sarcolemma forms the perineurial sheath, or sheath investing the end organ. This sheath is the telolemma.

Describe the ultimate fibrillæ.

The axis cylinder beneath the muscle sheath continues upon the surface of the sarcous substance and later breaks up into fibrillæ which irregularly unite and end in thickened bulbous extremities.

What is the sole plate?

The flattened nucleated mass of soft, faintly granular protoplasm in which the nerve terminations are embedded. It is closely applied to the surface of the muscular substance.

What is the end plate?

It is composed of the sole plate together with the embedded nerve fibrillæ and constitutes the motor disc.

How many end plates do muscle fibres possess?

Usually but one; sometimes, however, there may be two or more, and also several nerve fibres may supply a single end plate.

TENDONS.

Describe the sensory end plates of tendon.

These consist of an intricate network of pale non-medullated fibres.

What is Golgi's corpuscle or tendon spindle?

These appear as sharply defined, greatly elongated elliptical masses, one end of which extends upon the tendon, while the other is usually continuous with the adjacent muscle fibres.

What is the tendon spindle composed of?

A connective tissue capsule which, embracing two or more primary bundles of the tendon, becomes united with the sheath of the tendon. The inner surface of the spindle is covered with endothelial plates.

How are the nerve fibres arranged?

Two, three or more medullated nerve fibres join the organ near its widest part, occasionally at one end. After repeated division as medullated fibres, the nerves spread out on the surface of the tendon as pale non-medullated fibres whose axis cylinders unite to form a richly but irregularly meshed figure. In addition to the network, the ultimate fibrillæ present numerous knobbed free ends.

BLOOD VESSELS.

What system supplies the blood vessels?

The sympathetic.

How are the fibres disposed?

In addition to the pale fibres a few non-medullated ones assist in the production of the irregular network surrounding the larger vessels. From this plexus fine branches are given off which ultimately end between the muscular bundles of the media and in the fibro-elastic tissue of the adventitia.

How are the capillaries supplied?

They are accompanied and partly surrounded by delicate non-medullated nerve fibres.

GLANDS.

What fibres supply the glands?

Both medullated and non-medullated fibres.

How are they arranged?

In bundles forming an inter-lobular plexus, rich in ganglion cells, which accompanies the larger excretory ducts and blood vessels. Thin bundles of pale fibres can be traced to the primary groups of acini where they break up into bundles of free axis cylinders passing between the acini. The termination within the acini is uncertain.

PERCEPTIVE APPARATUS.

How do the nerves of special sense terminate?

In highly specialized structures made up of neuro epithelium, such as the rod and cone cells of the retina, hair cells of internal ear, olfactory and gustatory cells.

How do these structures act?

The specialized epithelium receives the external stimuli while the nerve fibres provide for their transmission. No direct anatomical continuity between the cells and the fibres can be demonstrated.

THE CIRCULATORY SYSTEM.

What tissues compose the blood vessels?

Fibrous and elastic connective tissues and smooth muscle fibres in varying proportion.

What is the disposition of the elements?

Usually longitudinal in the inner and outer, and circular in the middle tunics.

What exceptions to this are found?

In the simple structure of the capillaries, and in the complicated structure of the heart.

THE HEART.

What three membranes compose the walls of the heart?

The endocardium, the powerful muscular layer and the pericardium.

Describe the endocardium.

The endocardium is a connective tissue membrane containing smooth muscle fibres and numerous elastic fibres.

Where are the elastic fibres most numerous?

In the auricles, where they form either a close meshed network or are blended into a fenestrated membrane, thus giving great elasticity.

What cells clothe the free surface of the endocardium?

A simple layer of irregularly polyhedral, epithelial cells—endothelium.

What is the arrangement of the muscle fibres?

The muscle fibres are surrounded by a delicate perimysium, and united by many lateral processes; the tissue of the auricles is entirely separate from that of the ventricles.

How are the muscle fibres arranged in the auricles?

In the auricles an outer transverse layer, common to both, can be distinguished, and in each is found an independent longitudinal layer. In addition numerous small bundles pursue independent courses in other directions. The fibres have no sarcolemma.

How are the muscle fibres disposed in the ventricles?

The bundles are intricately woven in all directions.

Why?

So that contraction can take place on all sides.

What are the annuli fibrosi?

Firm tendinous ligaments which lie between the auricles and the ventricles from which numerous muscle fibres have origin.

Describe the pericardium.

The pericardium is a connective tissue membrane investing the exterior of the heart, and by reflection forms the pericardial sac. It is clothed on its outer (visceral) and inner (parietal) surface by a single layer of endothelium, and has fibrous elastic connective tissue beneath.

How do the layers differ?

The parietal pericardium is distinctly thicker than the visceral.

Describe the valves of the heart.

They are composed of fibrous connective tissue continuous with that of the annuli fibrosi, and their surfaces are covered with the endocardium.

Where are the muscle fibres?

They are found only in the roots or attached to the edges of the valves.

How are the blood vessels arranged?

In the muscular walls of the heart they form typical capillary networks with elongated meshes.

Describe the lymphatic system.

The lymph vessels are numerous. They occupy the clefts between the muscle fibres and accompany the blood vessels.

Whence is the nerve supply derived?

Medullated fibres from the pneumogastric and non-medullated fibres from the cervical ganglia.

THE ARTERIES.

Name the tunics of the arteries.

Tunica intima.
Tunica media.
Tunica adventitia.

How are the elements disposed?

Longitudinally in the tunica intima and adventitia and transversely in the tunica media.

How are arteries classified?

For description into three divisions: small, medium and large.

What is meant by the small arteries?

The terminal branches just before their transformation into capillaries.

Describe the intima.

In small arteries it consists of long, spindle-shaped endothelial cells and a structureless membrane—the internal elastic membrane.

Describe the media.

This is composed of a single layer of circularly disposed unstriped muscle fibres.

Describe the adventitia.

Here are found longitudinally disposed bundles of connective tissue and elastic fibre.

What is meant by a medium artery?

All the unmentioned arteries of the body except the aorta and pulmonary artery.

What changes are found in the intima?

It has increased in thickness owing to the presence between the endothelium and internal elastic membrane of delicate connective tissue flattened corpuscles and elastic fibres.

Is this subendothelial layer always present?

It is absent in the cortiac, coeliac, exilliac, renal and mesenteric arteries as well as the uterine arteries of young individuals.

What changes are found in the media?

Wide meshed networks of elastic fibres and several layers of muscle fibres are found.

What is the proportion of the two tissues in the arteries?

Extremely variable—muscle preponderates in the cœliæ, femoral and radial, and elastic tissue in the carotid, axillary and common illiac.

What change takes place in the adventitia?

It becomes stouter; thick elastic fibres are found at the boundary of the media, and many times form a continuous layer known as the external elastic membrane. Occasionally new elements are found, as unstriped muscle fibres, but never in continuous layer.

Describe the endothelium of the large arteries.

The cells are broader and more polyhedral than in medium sized vessels.

Of what does the sub-epithelial layer consist?

Fibrous connective tissue, elastic network and flat-

tened stellate or spherical cells. The elastic network becomes closer meshed as it approaches the intima and finally passes into a fenestrated membrane.

Describe the media.

This is characterized by a preponderance of elastic tissue, circularly arranged.

Why does elastic tissue preponderate?

The vessel's proximity to the heart necessitates the presence of a tissue that will allow of expansion and contraction in unison with the heart pulsations.

Describe the adventitia.

It differs from that of medium sized arteries only in the absence of the external elastic membrane.

THE VEINS.

How many coats have veins?

As in the arteries, three coats may be distinguished —tunica intima, media and adventitia.

Describe the intima.

This consists of a single layer of endothelial cells, rather broader and more polyhedral than those lining arteries.

How is the subendothelium arranged?

In the large veins as distinct lamellæ, and contain numerous connective tissue corpuscles.

What structure lies outside the subendothelium?

The internal elastic membrane.

Describe the media.

Here will be found circular bundles of muscle cells and lamellæ of fibre elastic tissue in the larger veins. In some veins the media has almost no muscle fibre.

What are the component elements of adventitia?

When well developed it consists of intercrossing bundles of connective tissue, elastic fibres and longitudinal fibres of smooth muscle.

What are the valves of the veins?

Folds of the intima, covered on both surfaces by epithelial cells.

THE CAPILLARIES.

What are the capillaries?

Those minute vessels that establish communication between arteries and veins, and provide for the bodily nutrition.

What is the diameter of capillaries?

They average from 7μ to 10μ.

Of what do they consist?

A single layer of endothelial cells united by intercellular cement substance. The true capillary possesses no muscle cells.

What are vasa vasorum?

Small blood vessels of capillary size that supply nutrition to the walls of larger vessels.

Describe the development of capillaries.

A minute conical mass appears on the wall of a capillary; soon this unites with a similar offshoot from a neighboring point. Solid at first, they are hollowed out by an extension of the lumen of the capillary and the walls are differentiated to endothelial cells.

Whence is the nerve supply for blood vessels derived?

Principally from the sympathetic system.

What is the peri-vascular lymph space?

This name is applied to the lymph channels in the adventitia which occasionally unite and form a complete ensheathing sinus.

What is the carotid gland?

A pea-sized flattened ovoid mass lying at the bifurcation of the common carotid artery.

What is its structure?

A dense arterial network surrounded by granular polyhedral cells, and the whole enveloped in connective tissue.

What is the coccygeal gland?

A small body found in front of the apex of the coccyx in connection with the middle sacral artery.

What is its structure?

It is identical in structure with the carotid gland.

What is the function of these bodies?

They are rudimentary, and their nature and function is not known.

THE BLOOD.

What is the blood?

A mesodermic tissue possessing a fluid intercellular substance—the liquor sanguinis, in which float the cellular elements—the blood corpuscles.

What are the morphological constituents of the blood?

The white corpuscle, the red corpuscle and the blood platelets.

Where are the white corpuscles found?

In the blood, lymphatic vessels outside the blood ves-

sels, in bone marrow, adenoid tissue, fibrous connective tissue, and also between epithelial and gland cells.

What are the component parts of the leucocyte or white blood corpuscle?

The leucocyte consists of a protoplasm and nucleus and has no cell membrane nor definite form. When not engaged in amœboid activity it is spherical.

How do they reproduce?

Either by direct or indirect division.

How do they compare with red corpuscles?

They are larger but fewer in number, the proportion being about 350 red to one white corpuscle.

What is their function?

They exist as a source of reserve active protoplasm for the repair of destructive processes in both health and disease. They engage in the absorption of solid and fatty matters, and a certain part called phagocytes seem especially aggressive in their warfare upon foreign substances or obnoxious microbes.

THE RED CELL.

Give the morphology of red blood corpuscles.

They are soft, flexible, highly elastic elements and possess smooth, slippery surfaces. In man and other mammals they have the form of flat, circular discs, slightly concave on each surface.

What is the average diameter?

About 1-3200 in.

What are the constituent parts of the corpuscle?

The stroma and the hœmaglobin.

What is the stroma?

A transparent, colorless, homogeneous and plastic substance, extensible and pliable to a high degree.

What is the hœmaglobin?

The hœmaglobin fills the spaces of the stroma and imparts to the corpuscle its yellow or yellowish green color. It readily decomposes and crystallizes. One form of crystallization is hœmatin.

Wherein do the red cells of mammals differ from the colored corpuscles of other animals?

A nucleus and proper cell membrane are wanting.

Describe the blood platelets.

They have a diameter of about ¼ less than the red corpuscle and are colorless, round or oval discs, at times present in large numbers in the blood.

What is their function?

They seem to possess an active influence in the coagulation of the blood.

DEVELOPMENT OF BLOOD CORPUSCLES.

How do leucocytes originate.

The lymphatic and adenoid tissues are undoubtedly the principal sources of the leucocytes.

How do colored corpuscles arise?

From the earliest period of embryonic development, and during the whole of life, nucleated colored blood cells are found in certain situations. By mitosis they give rise to non-nucleated colored blood corpuscles which at first contain a nucleus. As centers for the formation of the blood in the embryo, the liver and

later, the spleen, in the adult exclusively, the bone marrow may be mentioned.

THE LYMPHATIC SYSTEM.

What is comprised in the lymphatic system?

The lymphatic tissue, the lymph channels and their contents, the lymph.

What is meant by lymph channels?

The irregular, interfascicular clefts between the bundles of fibrous tissue or by vessels with definite walls carrying lymph.

What is comprised in lymphatic tissue?

The single lymphatic nodule, the compound lymph gland and diffuse adenoid tissue.

What are lymphatic spaces?

Ill-defined clefts, universally present, of irregular form and size, which are bounded by the neighboring bundles of connective tissue and lined by an imperfect layer of endothelioid connective tissue cells.

What is the relation between these spaces and the lymphatic vessels?

It may be assumed that all interfascicular clefts are directly or indirectly connected with the lymphatics.

What are lymphatic capillaries?

Protoplasmic tubes of great delicacy composed of a single layer of endothelial plates and formed by the union of the lymphatic spaces at the margins of the fibrous tissue.

What is their function?

They carry the lymph from the organs to the adjacent lymphatic glands.

What is the shape of the lymphatic vessels?

The contour is irregular and presents numerous dilatations and constrictions that indicate the position of imperfect valves consisting of a fold of endothelium, often strengthened by a little elastic tissue.

What are perineurial lymphatic channels?

Many nerve trunks are enclosed by lymph channels into which lymph spaces of the surrounding tissue open. Similar channels enclosing blood vessels are called peri-vascular lymph sheaths.

Describe the walls of large lymphatic vessels.

In such vessels three coats can be recognized; an inner or endothelial, middle or muscular, and an outer or connective tissue.

What is the lymph?

A clear, straw-colored fluid containing cellular elements—the lymph corpuscles or leucocytes and granules of fat.

LYMPHATIC TISSUES.

How does lymphatic tissue usually occur?

As lymphatic nodules or glands; in some cases, however, groups of ill-defined diffuse lymphatic tissue occur, as in the pharynx, larynx, etc.

What does lymphatic tissue comprise?

Lymphatic, lymphoid or adenoid tissue is composed of two elements—the connective tissue reticulum and the small round cells contained in the reticulum. These cells being identical with the lymph corpuscles and leucocytes.

What is the reticulum?

Intertwining bundles of connective tissue along the fibrous trabeculæ of which, and especially at nodal points, flattened plate-like or stellate connective tissue cells are applied.

What is diffuse adenoid tissue?

This is the least specialized form of the lymphoid structures and is found in the mucosæ of the digestive and respiratory tracts.

Describe the single lymphatic nodules.

These consist of oval masses of adenoid tissue limited by a delicate capsule of fibrous lamellæ. They are numerous in the respiratory and digestive tracts.

What are the compound lymphatic follicles?

These are the lymphatic glands of gross anatomy and are formed by the partial fusion of a number of simple nodules.

What is the capsule?

A firm envelope enclosing the gland composed of fibrous connective tissue, and in the largest glands, some bundles of smooth muscle.

How is the lymph circulation conducted in the gland?

The afferent vessels conveying the lymph break up at the periphery of the nodule into branches which distribute the lymph—this in turn is collected and carried away.

What is the hilum?

At the point of entrance and exit of the larger blood vessels and efferent lymph channels, the capsule dips deeply into the gland and forms the hilum.

How is the tissue within the capsule divided?

Into a cortex or peripheral zone and medulla or central portion.

What are the trabeculæ?

Bundles of fibrous tissue extending from the inner surface of the capsule toward the hilum and dividing the cortex into imperfect spherical compartments which enclose masses of adenoid tissue called cortical follicles.

What is the germinal center?

A light, rounded area in the cortical follicles where karyokinetic figures can always be found.

What is the function of the cortical follicles?

They are centers for the formation of leucocytes which pass into the lymph sinuses.

What are medullary cords?

The continuation of the trabeculæ towards the center of the gland forms a number of elongated compartments that are thus named.

What are the lymph sinuses?

The spaces included between the trabeculæ and the dense adenoid tissue.

Where does the connective tissue reticulum arise?

From offshoots of the trabeculæ.

How are the blood vessels arranged?

In two groups, one of which enters at the periphery and supplies the capsule and larger trabeculæ, while the other enters at the hilum and is principally distributed to the lymphoid tissue.

THE SPLEEN.

What structures compose the spleen?

The capsule and the splenic pulp.

Describe the capsule.

The capsule is a dense felt work of fibrous tissue and a network of elastic fibres. The outer surface is firmly united to the peritoneum except where the peritoneum is reflected to stomach and diaphragm and at the hilum.

What are the trabeculæ?

Numerous cylindrical or band-like prolongations of the capsule which penetrate deeply into the interior from all sides and form a framework, in the spaces of which lies the splenic pulp.

What tissues comprise the pulp?

A delicate connective tissue reticulum and the cellular elements.

What are the cellular elements?

Partly leucocytes, partly larger nucleated cells, white and red blood cells and pigment granules.

How is the adenoid tissue distributed?

As a loose lymphoid tissue with intimately related vascular channels, and as spherical masses of dense adenoid tissue limited to certain points, and named Malpighian corpuscles.

Where are the Malpighian corpuscles usually situated?

In the forks of the smaller arteries, and in such a manner that the artery pierces them through the center or near the periphery.

What is their microscopic appearance?

In appearance they resemble simple nodules of adenoid tissue.

What is the history of the Malpighian corpuscle?

They are temporary structures continually disintegrating and redeveloping.

How is the arterial blood passed to venous channels?

Within the pulp the blood probably comes into direct contact with the lymphoid tissue and is collected by the venous spaces and passed on to the larger veins.

What is the origin of the lymphatic system?

The mesoderm.

THE THYMUS BODY.

What is the origin of the thymus body?

It is epithelial and derived from the endoderm.

What change takes place as the organ matures?

There is a rapid invasion of mesodermic tissues until the lymphoid type predominates, and the epithelial structures becomes mere rudiments.

Of what does it consist?

Usually of two lateral lobes, more or less closely united, composed of numbers of globules held together by inter-lobular areolar tissue and all enveloped within the fibrous capsule of the organ.

How are the lobules divided?

By septa arising from the capsule and penetrating the lobes.

What do the lobules consist of?

Adenoid tissue denser at the periphery than in the

center so that a dark cortical and lighter medullary substance can be distinguished.

What are Hassal's corpuscles?

Masses of altered embryonic epithelial cells, concentrically striated, found in the medullary substance.

What is the history of the thymus gland?

It reaches its highest development about the second year, and then undergoes retrogressive changes until by the twentieth it has lost its characteristic appearance and is replaced by fibrous connective tissue and fat.

MUCOUS MEMBRANES.

What is the structure of the mucous membrane?

Mucous membranes are composed of corium and epithelium. The epithelium covers the surface, and beneath it lies the corium.

Describe the epithelium.

This varies with its location, from squamous and stratified, to columnar and ciliated, but it is the most constant part of the mucous membrane. Where the cells are squamous and stratified, the mucous is derived from glands, but where they are columnar or ciliated, a large part of the mucous is secreted by the cells.

What is the corium composed of?

Connective tissue, either areolar or retiform.

What lies between the corium and epithelium?

Usually the basement membrane.

What is the Muscularis Mucosæ?

A delicate zone of involuntary muscle cells, which frequently occurs between the corium and the submucous tissue. It is a part of the mucous membrane.

PAPILLÆ AND VILLI.

Describe the papillæ.

These are little processes of the corium of a conical form, containing blood vessels and nerves and covered with epithelium. They vary in size and serve many purposes, of which the chief is probably to minister to the senses of taste and touch.

Describe the villi.

The villi are best observed in the small intestines. They contain blood vessels and lacteals and increase the absorbing surface.

GLANDS AND MUCOUS MEMBRANES.

What element is most important in the secretory process?

The nucleated cell.

How is the cell usually disposed?

The cell of polyhedral or columnar form is spread in a series over the secreting surface as an epithelium.

Upon what do the cells rest?

Generally upon a basement membrane or membrana propria, which appears as a delicate homogeneous line beneath the epithelium.

What is the object of the membrana propria?

It limits and defines the secreting surface and supports and connects the secreting cells on one side, while the other, in close relation to the blood vessels, is bathed in lymph.

How is the membrana propria formed?

Of flattened cells which may be united edge to edge

forming a complete limited membrane, or they may be branched and united by their processes.

How do the cells act?

They absorb substances existent in the blood, change or convert them into new compounds which they excrete.

How is excretion accomplished?

Either by exudation or bursting and destruction of the cell.

What two chief varieties of glands occur?

The tubular and saccular, each of which is further subdivided into simple and compound.

Describe the simple tubular glands.

These usually exist as perfectly straight cylindrical depressions, like the peptic glands; more often, however, the tubes are somewhat wavy and when very long are coiled up like the sweat glands.

Describe the compound tubular glands.

These vary from a simple bifurcation of the fundus to the intricacy of the tubules of the kindey or testicle.

Describe the simple saccular glands.

These do not occur in man, but in the lower types they are found as simple enclosures of glandular epithelium in a somewhat spherical shape.

Describe the compound saccular or racemose glands.

These are composed of a multitude of alveoli opening in clusters into the extremities of a branched tube called the duct; they are often filled, rather than lined, with secreting cells.

How are they arranged?

They have a distinctly lobular structure, arranged in groups around the commencing branches of the duct with which their cavities are continuous.

Differentiate between serous and mucous glands.

The cells of serous glands are distinctly granular, usually spherical, readily stained with carmine, and have conspicuous nuclei near the center.

Mucous glands are distended, very clear and transparent, slightly stained with carmine, and have the nuclei displaced to the outer edge of cells—frequently directly beneath the basement membrane.

Describe the fluid elaborated by serous glands.

It is thin and watery, appearing within the protoplasm of the cells as minute dark granules.

Differentiate between the serous cells at rest and after activity.

When at rest the cells are loaded with granules and appear larger, darker and more granular, while after active secretion the cells are exhausted and contain fewer granules and appear smaller, clearer and less granular.

What do the mucous glands secrete?

A clear, viscid, homogeneous substance or mucin, with an affinity for hœmatoxylin.

Differentiate between the mucous cell at rest and after activity.

During rest, the cell is loaded with mucoid secretion, the nuclei crowded to the periphery, the acinous cells appear clear with well-defined outlines and on the basement membrane side present a thin zone containing the nuclei and granular protoplasm.

After prolonged secretion the cells contain almost no mucous, the protoplasmic threads are more closely placed, the cell is smaller, darker and more granular.

What are the demilunes of Heidenhain?

Small crescentic groups of granular, deeply staining cells, often seen lying between the clearer elements and the basement membrane. They are supposed to be exhausted cells crowded to the periphery by the younger and more active cells.

What is the origin of glands?

The glands develop from a cylindrical ingrowth of epithelium into the subjacent mesodermic tissue.

THE THYROID BODY.

What is the thyroid body?

A compound tubular gland whose excretory canal, the thyro-glossal duct, in the early stages of the organ connects the tubules with the mucous surface.

What is the history of the gland?

Long before the gland matures the duct is obliterated, the acini become closed cavities and the organ is often classed as a ductless gland.

Of what does the adult gland consist?

Of numerous tubular acini united by inter-tubular areolar tissue into lobules, which, in turn, are joined into lobes by a general external fibrous envelope.

Describe the acini?

They are completely closed and lined with a single layer of cuboidal or low columnar epithelium resting on a basement membrane.

What is found in the acini?

Celloid substance, a viscid yellowish mass produced by the cells, detached epithelium, leucocytes, migrated plasma cells and sometimes red corpuscles.

SALIVARY GLANDS.

How are the accessory digestive glands grouped?

Those of the serous type, as the parotid gland and pancreas, those of the mucous type, as the sublingual, and the mixed or muco-serous, as the sub-maxillary.

Describe the parotid gland.

This is a compound sacular or racemose gland enveloped in a fibrous capsule from which septa penetrate the organ, dividing it into lobes which in turn are subdivided by fibrous partitions into many lobules, and these in turn are composed of ultimate saccules or acini.

Describe Stenson's duct.

This is the large excretory duct carried in the interlobular connective tissue. It is composed of a fibro-elastic tunica propria, lined by a simple low columnar epithelium, reinforced externally by fibrous tissue.

What are the salivary tubes?

These are the smaller ducts of the glands and the cylindrical epithelium becomes taller and shows a vertical radial striation in its outer zone.

What are the intermediate tubes?

These are the inter-lobular divisions of the ducts and the columnar cells are replaced by low, flattened cells which finally become continuous with the secreting cells of the acini.

Describe the acini.

They are limited by a basement membrane continued from the smaller ducts, and are almost completely filled with polyhedral, glandular epithelium, the intercellular clefts representing the beginning of the ducts.

Describe the sublingual gland.

This possesses the general arrangement of the parotid gland, but it possesses no intermediate division of the duct—the "mucous" tubes passing directly into the acini. The cells of both glands are large and clear when quiescent and smaller and more granular after functional activity. Demilunes of Heidenhain are frequently present.

Describe the duct of Bartholin.

This is the excretory duct and is composed mostly of fibro-elastic tunica propria lined with a single layer of low columnar cells and covered on the outside with a supplementary layer of fibrous tissue.

Describe the submaxillary gland.

This is a mixed gland and contains lobules of the serous type, and adjacent lobules of the mucous type.

Describe the duct of Wharton.

This is the excretory duct and resembles Stenson's duct.

Describe the vascular supply.

The larger arteries accompany the excretory ducts of all the glands into the inter-lobular septa where they send off branches between the lobules, and end in rich capillary networks enclosing the acini. The veins follow a similar plan.

Describe the disposition of the lymphatics.

They are represented by inter-fascicular clefts which, united with definite lymph vessels, empty into the large trunks which accompany blood vessels.

Describe the nerves of the salivary glands.

Both medullated and non-medullated fibres are found. The nerve fibres can be traced to the basement membrane of the acini, but the ultimate distribution is not known.

THE TEETH.

From the standpoint of comparative anatomy, with what structure in lower animals are the teeth analogous?

The dermal scales of such animals as the sharks and rays.

Is the tooth a part of the osseous system?

No; it is an independent organ held in position in the jaw by the alveo-dental periosteum or peridental membrane.

What are the tissues of which the teeth are composed?

(1) Enamel—The hardest structure in the body. It covers the exposed part of the tooth, or the crown, and gives the characteristic form to it. (2). Dentine — Forms the greater portion of the tooth, both root and crown. (3) Cementum—or crusta-petrosa — covers the dentine in the root portion and gives the attachment to the fibres of the peridental membrane.

What is the composition of the enamel?

Enamel is almost wholly made up of inorganic mat-

ter, containing 95 per cent to 97 per cent inorganic, 3 per cent to 5 per cent of organic matter. The inorganic matter is chiefly phosphates of calcium and magnesium, carbonates of calcium and magnesium and a small amount of flourides.

Describe the structure of the enamel?

The enamel is made up of irregular 4–6 sided prisms, the enamel prisms, closely placed and generally vertical to the surface of the dentine. They are not uniform in diameter but present slight varicosities causing the alternate light and dark striated appearance in longitudinal sections. The prisms are held together by a slight amount of inter-prismatic or cement-substance which is perfectly calcified. The prisms are not straight in their course but are more or less wavy, especially in the portion forming the cusps.

What is Nasmeth's membrane?

Nasmeth's membrane is a delicate but resistant cuticle composed of keratose epithelial plates, which cover the enamel at birth and for a short time after, but is soon worn away.

What is the composition of dentine?

Dentine is composed of 72 per cent inorganic, 28 per cent organic matter. Like bone, it is composed of an organic matrix into which inorganic salts are deposited. If treated with acids the organic matter is left, retaining the form of the tissue.

What are the dentinal tubules?

The dentinal tubules are minute canals which pass outward from the pulp cavity to the border of the enamel or cementum. They are wavy in their course, and in the outer portion of their course branch very

freely with each other. They are about 1.1 to 2.5 microns in diameter.

What are the inter-globular spaces and where are they found?

The inter-globular spaces are irregular spaces in the dentine where the tissue is imperfectly calcified.

What is the granular layer of Tomes?

The granular layer of Tomes is the layer of dentine just below the enamel or cementum. The appearance is caused by the enlarged ends of the dentinal tubules.

What fill the tubules in life?

In life the tubules are filled by processes from the odontoblasts.

What are the odontoblasts?

The odontoblasts are flask-shaped cells which lie next to the dentine on the surface of the pulp. From them protoplasmic processes pass outward through the dentinal tubules as far as the inner surface of the enamel or cementum. The odontoblasts are the cells which form the dentine.

What are the dentinal fibres?

The dentinal fibres are the protoplasmic processes of the odontoblasts which fill the dentinal tubules.

What is the difference between cementum and bone?

Cementum has no Haversian canals.

Describe the structure of the cementum.

Cementum is made up of successive layers resembling the lamellæ of bone. In it are irregular spaces, lacunæ, like those of bone, which communicate with

each other and with the ends of the dentinal tubules by the canaliculi. The cementum furnishes attachment for the fibres of the peridental membrane.

What is the dental pulp?

The dental pulp is the soft tissue filling the cavity within the dentine.

What is the structure of the pulp?

The pulp is composed of an embryonal connective tissue made up of a large amount of gelatinous intercellular substance in which round, stellate and spindle-shaped cells are scattered. The pulp is richly supplied with blood. The vessels enter the foramen at the apex of the root, pass down and break up into a rich plexus in the outer portion. At least one nerve enters at the apical foramen and forms a rich plexus of nerves just below the layer of odontoblasts.

DIGESTIVE TRACT.

THE TONGUE.

What composes the bulk of the tongue?

Variously disposed bundles of striated fibres from the lingualis and accessory muscles and over the unattached surfaces the mucous membrane is reflected.

How is the muscular tissue arranged?

In three planes:

1. Vertically, and slightly radially (genio-hypoglossus and vertical fibres from lingualis and hypoglossus).
2. Transversely (transverse fibres of lingualis.)
3. Longitudinally (Lingualis superior, inferior and styloglossus).

What is the septum lingualæ?

A vertical median partition dividing the muscular tissue into halves. The interfascicular spaces are filled by delicate connective tissue, fat and numerous small lingual glands. Branched, striated muscle fibres are common in the tongue.

Describe the mucous membrane.

That on the sides and inferior surfaces is thin and contains small papillæ and many mucous glands; on reaching the upper surface it becomes thicker and presents papillæ.

How are the papillæ named?

With reference to their shape, three kinds are distinguished; the filiform or conical, the fungiform and the circumvallate.

Describe the conical papillæ.

Occurring on all parts of the upper surface of the tongue, they consist of a conical or cylindrical elevation of the connective tissue of the mucosa, 5–2.5 mm in height covered with a thick layer of epithelium, the cells of which are partially removed by abrasion because of the exposed condition of the papillæ.

Describe the fungiform papillæ.

These are also found on all parts of the tongue, but they are fewer, broader and lower than the conical, appearing as isolated but distinct red points. The connective tissue stalks of these papillæ are composed of a dense network of fibrous tissue and bear secondary papillæ on their upper surface, the epithelium completely enveloping the connective tissue core.

Describe the circumvallate papillæ.

Usually eight or ten in number, they are placed in two rows forming ∧ at the posterior part of the dorsum of the tongue. Each consists of a large flattened fungiform papilla surrounded by a deep furrow and a secondary encircling ridge which suggested the name.

Where are the taste buds?

These lie within the epithelium, lining the sides of the deep circular furrow, and appear as inconspicuous oval bodies occupying nearly the whole thickness of the epithelium. Others are found in the folds in the vicinity of the circumvallate papillæ, on some fungiform papillæ and at the sides of the tongue.

What are the papillæ foliatæ?

These are parallel folds found just in front of the anterior pillars of the fauces and contain a number of taste buds.

Describe the taste buds.

Each taste bud consists of an enveloping layer of greatly elongated epithelial cells called cortical or tegmental cells, and these form a complete covering except at a small point corresponding to the superficial pole of the bud, and here a small canal, the taste pore, connects the interior of the bud with the surface of the mucous membrane.

What lies within the capsule of the taste bud?

A group of highly specialized elements, the gustatory cells.

Describe the gustatory cells.

They are neuro-epithelial elements, appearing as spindle, rod-like or forked cells, possessing an oval nucleus near the center. The outer ends of the cells are usually prolonged with fine pointed extremities and some of them terminate in stiff hair-like processes projecting within the taste pore almost to the free surface.

How are the inner ends of the gustatory cells arranged?

They are prolonged as slender, sometimes forked processes showing minute swellings or varicosities.

What glands are found in the submucous and interfascicular tissue?

Mucous and serous glands.

Where are they situated?

The mucous glands are found in the deeper layers of the submucous tissue and between the bundles of muscle fibre in the back part of the tongue. The serous glands are limited to the immediate neighborhood of the circumvallate and foliate papillæ.

Describe the adenoid tissue of the mucous membrane.

This occurs as diffuse masses and as circumscribed irregularly spherical lymph follicles 1 to 5 mm in diameter. The position of the follicles is frequently indicated by slight elevation of the mucosa in the center of which a minute pit leads to the lymphatic crypt. The epithelium lining the crypt is infiltrated with lymphoid cells, while the surrounding diffuse adenoid tissue contains several minute spherical masses of denser structure.

What are the salivary corpuscles?

Spherical, nucleated, granular bodies, a little larger than leucocytes, derived from the adenoid tissue of the mouth. They are really escaped lymphoid cells swollen by fluids.

Describe the blood supply of the tongue?

The vessels form a superficial network in the mucosa and send twigs to terminate in the summits of the papillæ. The acini of the glands and the lymph follicles are surrounded by capillaries.

Describe the nerves of the mucous membrane.

These are derived from the glosso-pharyngeal and lingual branch of the fifth, and end either beneath the epithelium in the usual manner or in close relation

with the organs of special sense—taste buds. Many microscopic ganglia occur along their course.

TONSILS.

What are the tonsils?

Compound lymphatic glands, consisting of from ten to eighteen lymph follicles embedded in diffuse adenoid tissue.

What is the capsule?

A fibrous structure separating the tonsils from the adjacent structures on the attached surface.

How is it covered on the oral surface?

By a reflection of the oral epithelium.

Describe the epithelium.

The epithelium covering the folds and depressions is completely infiltrated with lymphoid cells so that the boundary line between the epithelium and the adjacent adenoid tissue is often obscure.

Describe the mucous glands.

These are found in the vicinity of the tonsils, into the crypts of which they pour their secretion to mingle with the shed epithelium and lymphoid cells in the recesses.

Describe the blood vessels and lymphatics.

These occur in great numbers in the adenoid tissue, and also surrounding the organ and receiving radicles from the interior.

PHARYNX.

What tissues constitute the pharynx?

A fibrous tunic on the inside of which lies the mu-

cous and submucous tissue, and outside are the fibres of the constrictor and the muscles.

What differences distinguish the respiratory from the digestive portion of the sac?

The variations are mostly in the mucosa and depend especially upon the character of the epithelium.

Describe the epithelium of the upper portion of the pharynx.

The respiratory or upper division of the pharynx is clothed with stratified, ciliated, columnar epithelium, with numerous goblet cells.

What epithelium covers the lower portion of the tract?

Below the level of the soft palate, stratified squamous cells are found similar to those lining the oral cavity.

Describe the tunica propria.

This is the stroma of the mucosa and is formed of a felt work of fibrous tissue and variable qualities of elastic tissue.

Where are the papillæ?

The papillæ are found where squamous cells cover the sub-epithelial surface of the mucosa; they are not found beneath ciliated epithelium.

Where are the pharyngeal glands found?

In the deepest layers of the mucosa, especially around the orifices of the Eustachian tube.

How is the adenoid tissue distributed?

As lymph follicles existing singly or in groups in the upper part of the cavity.

What is the pharyngeal tonsil?

The aggregation of adenoid tissue found between the openings of the Eustachian tubes is so named.

Describe the submucous tissue.

This tissue unites the mucous membrane with the fibrous coat, whose dense felt work forms a structure frequently termed the pharyngeal aponeurosis. Its posterior part is thickened and forms the raphe to which the constrictor muscles are attached.

What fibres constitute the muscular coat?

Striated fibres of the constrictor.

Where is the areolar tissue?

This lies external to the muscular coat and attaches the pharynx to surrounding structures.

What structure carries the blood vessels, etc.?

The blood vessels, lymphatics and nerve trunks are supported by the submucosæ, and send off branches to the mucous membranes of the mouth.

What nerves supply the pharynx?

Branches from the cranial and sympathetic trunks form the pharyngeal plexus. Both medullated and non-medullated fibres are present, associated with minute ganglia.

ŒSOPHAGUS.

What structures comprise the œsophagus?

The mucous, submucous, muscular and fibrous coats.

Describe the mucous coat.

Stratified, squamous epithelium resting upon the connective tissue matrix, and the tunica propria, the inner

surface of which bears numerous papillæ. The deeper layers of the mucous are separated from the submucous coat by longitudinal bundles of involuntary muscle called the muscularis mucosæ, which first appear a little above the middle of the tube.

Describe the submucous coat.

This coat is composed of loose connective tissue and supports the larger blood vessels and nerves.

Where are the mucous glands?

Within the submucosa, and more numerous on the anterior surface and especially so at the cardial orifice. They are lined for the most part with columnar epithelium.

Describe the muscular coat.

This consists of two layers, an inner circular and an outer longitudinal layer, whose bundles are united by connective tissue septa.

What fibres are found in the œsophagus?

In the upper part striated, in the lower part smooth, and in the middle both kinds exist, the striated disappearing as the smooth increases and vice versa.

Describe the fibrous coat.

This coat envelopes the muscular coat, externally strengthening the tube and affording attachment to the surrounding areolar tissue connecting the œsophagus with neighboring organs. Considerable elastic tissue is found in this coat.

How are the blood vessels supported?

They penetrate the outer coats and ramify in the submucous tissue, sending branches to supply the other tissues.

How are the lymphatics and nerve fibrillæ disposed?

The lymphatics of the deeper layers of the mucosa terminate in the submucosa. The nerve fibrillæ pass from the submucous tunic into the mucosa and terminate beneath the epithelium.

STOMACH.

What coats compose the stomach?

The mucous, submucous, muscular and serous or fibrous.

Describe the mucous coat.

The mucous membrane is covered by a simple columnar epithelium, the squamous cells of the œsophagus abruptly terminating at the cardiac orifice.

What peculiarities distinguish the gastric mucous membrane?

The numerous goblet cells which replace the columnar elements of the epithelium, the conspicuous folds or rugæ on the inner surface and minute inequalities or pits which mark the openings of the gastric glands.

Describe the gastric glands.

The gastric glands are of two kinds, the peptic glands found in the middle and cardiac thirds, and the pyloric glands found in the pyloric third. Both varieties are limited to the mucosa extending in length the entire thickness of this coat.

How are gastric glands distributed?

Uniformly through all parts of the stomach in groups separated by delicate partitions of connective tissue.

Describe the peptic glands.

The peptic glands are slightly wavy, simple tubular

depressions in which a duct, neck and fundus are recognized.

How is the fundus of the gland disposed?

Generally it is tortuous or spiral, but exceptionally it is divided and sometimes its extremity is bent at right angles to the tube.

What cells line the glands?

Generally columnar epithelium from the mucous membrane passes with little change into the ducts, becoming imbricated and toward the neck shorter and more spherical in outline. At the neck or narrowest part of the tube the cells are more cuboidal and assume a columnar form as they approach the fundus.

What are the chief or central cells?

These bound the lumen of the peptic gland and form the bulk of the glandular epithelium. Each cell contains a spherical nucleus embedded within the granular protoplasm, the condition of which depends upon the state of functional activity.

What other cells exist in peptic glands?

The parietal or acid cells are situated in the periphery of the gland directly beneath the basement membrane and separated from the lumen by the intervening central cells.

What are intercellular clefts?

Minute lateral canals which occur in many places, affording direct communication between the parietal cells and the lumen of the tube.

Describe the parietal cells.

They are irregularly distributed from the fundus to the neck of the gland and most numerous in the vicin-

ity of the neck. The cells are larger than those in the lumen, polygonal in outline, and possess a pale granular protoplasm and a round or oval nucleus.

Describe the pyloric glands?

These glands possess long, wide ducts into which the several divisions of the body open, the tubular subdivisions are wavy and tortuous and the extremities are somewhat slightly expanded. The duct is lined by tall columnar epithelium which becomes broader toward neck and fundus.

What do the cells contain?

A fine granular protoplasm, and do not secrete mucous but a thin, albuminous fluid. Parietal or acid cells do not occur in pyloric glands.

What are the lenticular glands?

Patches of diffuse adenoid tissue that lie around and among the ends of the gastric follicles near the pylorus.

Describe the muscularis mucosæ.

This structure is found in the deepest layer of the tunica propria and is made up of an inner circular and an outer longitudinal layer of non-striped muscle.

Describe the submucosa.

This coat is comparatively thick and is composed of fibro elastic bundles of variable size, quite loosely interwoven. The rugæ of the stomach involve both the mucous and submucous coats, the submucous coat forming the connective tissue framework of the elevation over which the mucosa lies. The submucosa supports the larger blood vessels, lymphatics and nerves.

Describe the muscular coat.

This is composed of two sheets of involuntary mus-

cles arranged as an outer longitudinal and an inner circular layer, and near the cardiac end is an imperfect oblique layer.

How is the pyloric orifice arranged?

It is guarded by a fold of mucous membrane overlying the submucosa and reinforced by conspicuous ring-like thickenings of the circular layer, forming the gastro-duodenal valve.

Describe the serous coat.

This coat is composed of fibrous connective tissue and network of elastic fibres. A simple layer of endothelial plates covers the peritoneal surface.

Describe the blood supply of the stomach.

The large arteries penetrate the outer coat, divide within the mucosa and send branches to supply the mucous membrane, muscular and serous coats.

Describe the lymphatics of the stomach.

The large lymphatics accompany the blood vessels and form a plexus in the submucous tissue. A closer network in the deeper part of the mucosa sends radicles up between the glands to the end beneath the epithelium. The adenoid tissue is drained by peripheral lymphatics.

Describe the nerves of the stomach.

The nerves occupy a position between the circular and longitudinal muscular layers and form a plexus containing both pale and medullated fibres. At the nodal points ganglia are found and the whole forms the plexus of Auerbach.

What is the plexus of Meissner?

The intramuscular network continues, and after giv-

ing off lateral twigs forms a second ganglionic plexus in the submucosa called the plexus of Meissner.

INTESTINES.

What coats are found in the intestines?

The mucous, submucous, muscular and serous.

Upon what are the variations in the intestine dependent?

Upon modifications and specializations of the mucous membrane.

What are the villi?

Small cylindrical elevations projecting into the intestinal lumen and bathed in the juices of the canal.

What are the valvulæ conniventes?

Transverse or oblique folds of the mucosa extending partially around the tube, and are most marked in the duodenum and jejunum. They serve to increase the area of the mucous membrane and are beset with villi.

What cells cover the mucosa?

A simple layer of columnar epithelium resting on a basement membrane. The prismatic cells contain finely granular protoplasm. Oval nuclei are situated usually within the inner half of the cell.

Describe the basilar border.

This is a well-defined, continuous band investing the outer free ends of the cells and exhibits a fine vertical striation.

Where are the goblet cells?

These are very numerous, but especially so in the large intestines. In carmine preparations they appear

as clear oval breaks in the epithelial outline. Migratory leucocytes are also found in the intercellular clefts.

What is the endothelium of Debove?

Flattened connective tissue plates forming a membrana propria upon which the epithelium rests.

Describe the villi.

Derived entirely from the mucosa, the epithelium extends over the projecting portion of the tunica propria to invest entirely the finger-like processes.

Where are the lacteals?

The lacteal occupies the center of each villus and ends blindly near the apex of the villus.

Describe the tissue surrounding the lacteal.

It consists of a fibrous reticulum holding lymphoid cells within its meshes and resembles adenoid tissue. Numerous bundles of delicate smooth muscle fibres also surround the lacteal and extend from their origin in the muscularis mucosæ toward the apex of the villus.

How are the blood vessels distributed?

They form a capillary network around the central lacteal and extending through the greater part of the villus connect the afferent arteriole and efferent veins.

How are the lacteals affected by digestive activity?

When at rest, the lacteals contain lymph, but during digestive activity they appear milky on account of the emulsion formed by the absorbed oil.

Where do the villi end?

At the ileo-cæcal valve, and are not present in the large intestine.

What glands are found in the intestinal walls?

The glands of Lieberkuhn and Brunner, and the solitary and agminated lymph glands.

Where are the crypts or glands of Lieberkuhn?

They form an almost continuous layer of simple tubular depressions throughout the large and small intestines, lying between the bases of the villi in the small intestine.

Describe the crypts of Lieberkuhn.

They occupy nearly the whole depth of the mucosa, and the columnar cells of the free surface pass directly into the tubules to become the spherical secreting cells, many of them being converted into goblet cells. In the large intestines they increase in size, becoming longer and possessing wider mouths.

What are the glands of Brunner?

They are higher specializations of the pyloric glands of the stomach. In passing from the stomach to the intestines they undergo repeated division and at the same time sink lower and lower into the mucosa, until they finally reach a position in the submucosa of the duodenum.

Describe the structure of Brunner's glands.

They appear as groups of short, wide, tubular acini, disposed about long slender ducts which pass from the submucous tissue through the mucosa to open on the intestinal surface between the orifices of the follicles in the depressions between the bases of the villi. Owing to their rapid branching they resemble racemose glands rather than the compound tubular glands to which they belong. The secretion is serous, not mucous.

Describe the solitary glands.

These are isolated lymph follicles scattered through the entire intestine. They lie primarily within the mucosa but frequently, also, within the submucous coat. The adenoid tissue is denser at the periphery than toward the center.

Describe the agminated glands or Peyer's patches.

These are large, oval groups of closely associated lymph follicles, held together by diffuse adenoid tissue. They are usually found in the lower two-thirds of the small intestine, and reach their highest development in the ileum. They appear first within the mucosa, but later encroach largely on the submucosa.

Describe the muscularis mucosæ.

This occupies the deepest part of the mucosa and marks the outer boundary of the mucous layer. It is composed of longitudinal fibres and occasionally circular fibres of smooth muscle.

Describe the submucosa.

This consists of loosely united bundles of fibro elastic tissue and supports the large vascular and lymphatic trunks.

Describe the muscular layer.

This is composed of a relatively thick inner circular layer and an outer longitudinal layer separated by a thin layer of connective tissue. In the lower part of the rectum the circular layer becomes thicker to form the internal sphincter.

Describe the blood vessels of the intestine.

These follow the general arrangement of those of the stomach. Many branches pass from the network of the submucosa to be distributed to the deep and su-

perficial parts of the mucosa; the tubular glands are surrounded by capillary networks, and beneath the epithelium wider capillaries encircle the mouths of the follicles. These capillaries all connect with venules that empty into the large veins of the submucosa. For the villi, special branches pass directly to the bases, expand into networks which pass around the lacteals as far as the apex and then descend as straight veins, receiving in their course the superficial capillaries that encircle the glandular ducts. In Brunner's gland the capillaries are distributed to the acini.

Describe the lymphatic supply.

The lymphatics arising within the mucosa as blind canals descend to join the larger trunks in the submucosa where the channels freely communicate with one another.

Describe the nerves of the intestines.

These are disposed in a manner almost identical with those of the stomach. The plexus of Auerbach and the plexus of Meissner are both present.

THE LIVER.

How is the liver developed?

According to the type of a compound tubular gland, but in the mammalian adult this type is lost in the fusion of the tubes to form cells.

How is the fibrous tissue arranged?

It envelopes the exterior and is prolonged into the interior through the transverse fissure together with the blood vessels and bile ducts.

What is the capsule of Glisson?

The prolongation of the capsule of fibrous tissue surrounding and separating the lobules.

How are the blood vessels disposed?

The inter-lobular vessels are a continuation of those passing through the transverse fissure and are situated between the surfaces of the lobules. They are the portal vein and hepatic artery.

Describe the portal vein.

The portal vein gives off numerous branches which enter the lobule at the periphery and break up into a freely inter-communicating inter-lobular capillary network, the meshes of which are somewhat elongated and trapezoidal in form, with the smaller end directed toward the center of the lobule. A convergence to the inter-lobular vein in the center.

What structures occupy the meshes of the capillary network?

Liver cells, bile capillaries and some delicate areolar tissue.

Describe the liver cells.

These possess a somewhat polyhedral form—a fine granular protoplasm, no cell membrane and one or more nuclei. Pigment granules and oil drops are usually present. Almost all cells are bounded on at least one side by a capillary which does not come in direct contact with the cell but possesses a delicate intervening peri-vascular lymph channel.

What is the general arrangement of hepatic tissue?

In anastomosing cords of cells formed in close networks.

Where are the bile canaliculi?

They border the cells on all sides except on that side where the capillary lies.

Describe the bile capillaries.

These are narrow clefts found between the cells of the same diameter throughout the lobule; at the periphery the intercellular channels pass into the larger inter-lobular bile ducts, and the character of the cell changes from the liver cell to the low epithelium of the bile duct. The basement membrane becomes the connective tissue holding together the cords of the liver cells.

Describe the hepatic duct.

This is formed by the union of the inter-lobular bile vessels, and while the smaller ducts have no wall except columnar epithelium, the larger vessels possess a fibrous adventitia and an inner mucous membrane.

Describe the mucous membrane.

In addition to the columnar epithelium, it comprises a tunica propria of elastic fibres and some involuntary muscle disposed in circular and longitudinal bundles. Small mucous glands are also found in the larger canals. The columnar epithelium distinguishes the inter-lobular ducts from blood vessels of the same size.

How are the veins disposed?

The blood brought by the portal vein passes into the lobule at the periphery by numerous branches which unite to form the intra-lobular capillary network. This empties into the centrally placed vein which discharges into the sub-lobular veins—branches of the hepatic vein.

Describe the nerves of the liver.

The main trunks enter at the transverse fissure. The

fibres are mostly non-medullated and accompany the hepatic artery to the periphery of the lobule. The ultimate distribution is not known.

Describe the gall bladder.

The walls are composed of a mucous membrane with some involuntary muscle and an outer fibrous coat. The mucosa is disposed in folds or rugæ, which interlace and give a reticulated appearance to the mucous membrane.

Describe the lymphatics.

These are both superficial and deep. The superficial lymphatics accompany the branches of the arteries supplying the capsule. The deep lymphatics accompany the inter-lobular blood vessels.

THE PANCREAS.

How is the pancreas divided?

By connective tissue septa into lobes and lobules; the lobules in turn are composed of acini.

What structures compose the pancreatic duct?

Fibrous connective tissue lined with a single layer of columnar epithelium.

Describe the pancreatic duct.

The branches of the main duct divide at once into the long, intermediate tubules. The walls of the main duct and the larger branches contain minute mucous glands. The columnar cells from the main duct gradually diminish in height and finally pass over into the flattened cells placed parallel to the long axis of the intermediate tubules which are very long and narrow. Near the acini they divide and terminate abruptly.

Describe the epithelium of the acini.

The cells are short, cylindrical or conical cells, characterized by highly refracting granules—"zymogen granules"—which occupy the zone next the lumen and are thus distinguished from all granular cells. The clear, peripheral zone contains the nucleus.

What are the bodies of Langerhans?

Certain round or oval areas which appear lighter or less dense than the ordinary tissue, and are composed of groups of small, imperfect acini, among which ramify rich capillary networks.

How are the blood vessels distributed?

Similar to those of the salivary glands.

How are the nerves disposed?

The nerve trunks are confined to the connective tissue between the divisions of the gland. The ultimate termination of the fibres is undetermined.

THE URINARY ORGANS.

THE KIDNEY.

What is the kidney?

A highly developed compound tubular gland composed of pyramidal lobules, whose function consists in the secretion of urine.

What is seen in longitudinal section?

Two regions are appreciable; a peripheral granular zone, the cortex embracing the outer third, and the radially striated medulla occupying the remaining two-thirds.

What are the papillæ?

A number of eminences at the inner surface of the medulla next the pelvis at whose apices open the large terminal uriniferous tubules.

What constitutes the lobules of the kidney?

The pyramidal mass of dividing and subdividing tubules, the base of which corresponds to the surface of the organ and its apex to the renal papiliæ; this division disappears in the adult human organ.

What are the Malpighian pyramids?

Striated conical structures which occupy the medulla to the number of from eight to twenty. The apices correspond to the papillæ and their bases to the line of juncture betwen the cortex and medulla.

What produces the light and dark striæ in the pyramids?

The uriniferous tubules and the blood vessels respectively.

What constitute the columns of Bertini?

The masses of the organ extending between the sides of the Malpighian pyramids as far as the pelvis. They contain large blood vessels.

What constitute the medullary rays or pyramids of Ferrein?

Slender tapering bundles of parallel tubules extending from the Malpighian pyramids into the cortex.

How is the cortex subdivided by the penetration of the rays?

Into the medullary rays and the labyrinths.

Why is the labyrinth so called?

On account of the great tortuosity of the component uriniferous tubules.

What are the dark red points irregularly placed throughout the labyrinth?

Malpighian bodies.

Of what do they consist?

The glomerulus or Malpighian tuft and the capsule of Bowman.

How are the blood vessels of the glomeruli arranged?

The afferent artery breaks up into numerous capillaries united by delicate connective tissue into groups. The efferent collects the blood escaping from the convoluted capillaries.

How is the connective tissue distributed about the kidney?

The blood vessels of the labyrinth and the secreting parenchyma of the organ are enveloped in connective tissue, which also forms a fibrous investment of the organ.

Where do the blood vessels lie as regards the capsule?

On the outside, the capsular wall being pushed in before the developing tuft.

How is the reflected portion of the capsule disposed?

It closely invests the convoluted capillaries and dips in between the vascular lobules of the glomerulus.

Where do all uriniferous tubules arise?

In the dilated capsule of Bowman in the labyrinth.

Where is the neck?

At the pole of the Malpighian body, opposite the vascular stalk, and is the beginning of the tubule.

What portion of the tubule succeeds the neck?

The proximal convoluted tubule characterized by its large size and tortuous course.

Where is the spiral portion?

This succeeds the proximal convoluted tubule; beginning about at the junction of cortex and medulla, it passes into the medullary ray as a slightly wavy tube of markedly diminished size.

Describe the next portion.

This is the narrowest portion of the tubule and it extends into the medulla as far as the papillary zone, being known as the descending limb of Henle's loop.

What is the next portion named?

Henle's loop. Just before this is reached the tube increases a little in size; the tube, after passing the loop, continues of same size through the ascending limb and passes once more to the labyrinth, where it continues a short way as the irregular tubule.

What portion succeeds the irregular tubule?

The distal convoluted tubule, which then passes into the arched collecting tubule to enter the medullary ray for the third time as the straight collecting tube.

What are the tubes of Bellini?

The excretory ducts, visible to the naked eye, on the free surface of the papillæ, resulting from the frequent union of small canals

Describe the cells lining the capsule.

They are a large, flattened epithelial cell, in single layer resembling endothelial plates seen in ordinary specimens as delicate spindle nuclei in profile.

Describe the cells of the neck.

They are low epithelial cells of the cuboid type.

What cells clothe the proximal convoluted tubule?

Low columnar or cuboidal cells. The granularity and transparency vary with the stage of secretion. The outer zone of epithelium next the basement membrane presents the vertical striation of red epithelium. The epithelium of the spiral tubule presents few changes.

What changes are found in the cells of the descending limb of the loop?

The change in the diameter causes the low columnar cells to be replaced by flattened transparent plates,

whose nuclei being thicker than the cell body encroach upon the lumen of the tube and give it a wavy appearance.

Describe the cells of the loop and the ascending limb.

They are polyhedral with flattened nuclei and faint striations.

What distinguishes the irregular tubule?

The uncertain lumen and distinctly striated epithelium.

How are the cells of the distal convoluted tubule arranged?

Similar to the proximal, the epithelium being granular, indistinctly separated into individual cells and presenting a striated outer zone.

What cells line the arched collecting tubule and the straight collecting tubule?

Low cuboidal transparent cells which pass into distinct columnar cells for the remainder of the tubule.

Describe the cells of the tubes of Bellini.

These present a beautiful example of the simple columnar epithelium in the tall, transparent and clearly defined cells with which they are lined. These are the largest epithelial elements in the kidney.

What is the course of the renal artery?

Entering at the hilum, it passes through the sinus within the submucous tissue, where several small twigs are given off. Before entering the glandular tissue the renal artery forms several large branches which pass by oblique channels through the columns of Bertini to a point at the junction of the cortex and medulla cor-

responding to the bases of Malpighian pyramids. Here they bend and form horizontal arches, from which spring the ascending inter-lobular cortical arteries and the arteriæ rectæ of the medulla.

How are the cortical branches distributed?

Passing toward the free surface, they give off short curved lateral twigs to supply the afferent vessels of the glomeruli; here they divide into lobules of convoluted capillaries, which in turn join to form the efferent vessels, and these soon break up into the capillary networks which surround the labyrinth and medullary ray. At this point the networks are taken up by the inter-lobular veins that accompany the arteries and pass to the pelvis, where they aid in forming the renal veins.

What are the venæ stellatæ?

The vessels that collect the blood from the peripheral zone of the cortex converge at certain points called venæ stellatæ, and afterwards pass into the labyrinth and follow the inter-lobular vessels.

What are the arteriæ rectæ?

These arteries supplying the medulla enter as straight vessels which divide and form rich networks reaching to the papillæ, where the excretory ducts are surrounded by capillaries.

What are the venæ rectæ?

Veins which accompany the corresponding arteries and empty into the large veins at the juncture of the cortex and medulla.

Describe the course of the large venous trunks.

They pass obliquely through the medulla along the arteries and join their fellows in the pelvis to form the renal veins.

URETERS.

What coats compose the ureter?

The ureters, calices and pelvis of the kidney are composed of three coats, the mucous membrane, the muscular and fibrous coats.

Describe the tunica propria of the mucous membrane.

This consists of delicate, connective tissue fibres which, richly interspersed with cellular elements, pass without sharp demarcation into the submucosa.

What epithelium covers the tunica propria?

The so-called "transitional;" that is, a stratified, scaly epithelium, composed of but few layers, of which the uppermost is cylindrical or cubical.

Describe the muscular coat.

This consists of an inner longitudinal and outer circular layer of smooth muscle fibre. The lower half of the ureter has an additional layer of longitudinal muscle bundles.

How is the fibrous coat arranged?

In loosely united connective tissue bundles.

THE BLADDER.

How many coats has the bladder?

The bladder also has three coats, the mucous, muscular and fibrous.

What form of epithelium lines the bladder?

The epithelium of the bladder resembles that of the ureter and pelvis of the kidney in every particular. A distinction from these is impossible.

Describe the muscular coat.

This consists of strata of smooth muscle fibres; an inner and outer longitudinal layer which enclose between them the circular layer interlaced in such a manner that their outlines are indistinct.

Describe the muscular layers at base of bladder.

Here the inner longitudinal layer is augmented and the circular layer forms the not always distinct internal vesical sphincter.

What nerves supply the bladder?

Medullated and non-medullated fibres from the sympathetic system.

Describe the blood vessels of the bladder.

The muscular and mucous coats are furnished with a rich supply of capillary networks.

THE URETHRA.

Describe the female urethra.

It is composed of a mucous and muscular coat. The tunica propria consists of delicate fibrous tissue with many connective tissue cells, and is beset with papillæ, which are especially well developed near the meatus. The epithelium varies from stratified scaly to simple columnar. A few simple tubular glands are present.

The muscular coat consists of an inner longitudinal and an outer circular coat of smooth fibres separated by a compact layer of fibrous tissue.

Describe the male urethra.

This structure is also composed of a mucous coat and a muscular coat. In the prostatic portion, the epithelium resembles that of the bladder; in the membra-

nous portion it gradually becomes stratified columnar, which in the spongy portion is changed to simple columnar, while in the fossa navicularis it is transformed to stratified squamous. The tunica propria is rich in elastic fibres and covered with papillæ, which are best developed in the fossa navicularis. Isolated branched tubular glands occur throughout the urethra. In the prostatic portion the muscular coat consists of an inner longitudinal and an outer circular layer of smooth fibres which gradually disappear in the spongy portion. The mucous membrane has a rich vascular supply.

MALE REPRODUCTIVE ORGANS.

PENIS.

What structures compose the penis?

The two corpora cavernosa and the corpus spongiosum, all being enveloped by fascia and skin.

Describe the corpus cavernosum.

It is composed of a fibrous sheath, the tunica albuginea, and of erectile tissue. The tunica albuginea is a stout connective tissue membrane 1 mm thick in which an outer longitudinal and an inner circular layer can be distinguished; the bundles intermingle with many elastic fibres. The erectile tissue consists of connective tissue trabeculæ with some smooth muscle fibres which form a network, the spaces of which are lined with a single layer of flat epithelial cells and filled with blood. The arteries in part open into capillaries, and in part directly into the deep cortical plexus.

Describe the disposition of the capillaries.

They form a network beneath the tunica albuginea, called the superficial cortical plexus, which is connected with a many layered net of wide venous channels, known as the deep cortical plexus which lies in the upper part of the erectile tissue and passes gradually into the venous spaces of the latter.

What are the helicine arteries?

Small branches within slender trabeculæ which pro-

ject as loops in the cavernous spaces and appear to terminate in blind ends. The helicine arteries are supposed to furnish compensatory receptacles for the blood during extreme erection.

How are the veins disposed?

They arise mostly from the deep cortical plexus and partly from the deeper portions of the erectile tissue, and penetrating the tunica albuginea empty into the dorsal veins of the penis.

Describe the corpus spongiosum.

The central portion is a venus network formed by the conspicuously developed veins of the urethral submucosa, while the peripheral portion resembles the structure of the corpora cavernosa, excepting that there is no direct communication of the arteries with the venous spaces. The tunica albuginea consist of circularly arranged bundles of fibrous tissue.

Describe the glans.

It consists of greatly convoluted veins held together by strong connective tissue, which supports the blood vessels.

TESTICLE.

What is the testicle?

A compound tubular gland enveloped in a fibrous capsule, the tunica albuginea.

What is the corpus Highmori, or mediastinum?

A mass formed by the thickening of the capsule on the upper posterior aspect of the testicle.

How is the testicle subdivided?

By a number of septa passing from the mediastinum

by divergent paths to the tunica albuginea on the opposite side. The divisions are named pyramidal lobes, and have the base directed toward the capsule and the apex toward the corpus Highmori.

Describe the tunica albuginea.

This structure consists of dense fibrous connective tissue with its free surface covered by a single layer of flat epithelial cells, and on its inner surface it lies in contact with a layer of loose connective tissue, called the tunica vasculosa, which connects with the interlobular septa.

Where is the rete testis?

This network of freely anastomosing tubules is enclosed by the dense fibrous tissue of the corpus Highmori.

What is the interstitial connective tissue?

Prolongations of connective tissue from the septa to surround the seminiferous tubules. It is rich in cellular elements.

How are the seminiferous tubules disposed?

In three portions, the convoluted tubules, the straight tubules, and the rete testis.

Describe the convoluted tubules.

These are round winding canals whose origin is not yet determined. It is probable that they are united at the periphery with one another, and form a network from which numerous tubules turn aside and pass with many windings to the corpus Highmori. The walls are composed of several layers of flattened endothelioid connective tissue plates on a thin basement membrane, on the inside of which lies a lining of stratified epithelial cells.

Describe the cells next the basement membrane.

These cells are of two kinds, the sustentacular cells or Sertoli's columns, which are not directly concerned in the production of the seminal filaments, and the spermatogenic cells which increase by mitosis and grow to be large cells that occupy a second layer just back of the first. These are called mother cells, and in turn give rise to four daughter cells, lying still nearer to the center of the tubule.

Describe the spermatoblasts.

This name is applied to the daughter cells, and from them the spermatozoa are directly derived. The nucleus of each spermatoblast develops into the head of a spermatozoon, a small portion of the protoplasm forming the caudal filament. The middle piece reacts like paranuclein, and probably is derived from the centrosome.

Describe the straight tubules.

The tubuli recti begin where the secreting portion of the convoluted tubules end, and a reduction in size occurs as well as in number. The walls consist of a membrana propria and a simple layer of low columnar cells.

Describe the rete testis.

These canals are lined with a simple stratum of cubical or flat epithelial cells.

Describe the vasa efferentia.

These emerge from the upper end of the rete testis and form the coni vasculosi by their progressively increasing convolutions, and ultimately form the globus major of the epididymis. The lining cells are simple cylindrical epithelial elements, alternating with clusters

of cubical cells without ciliæ. A fibrous membrana propria and a tunic of non-striped muscle, consisting of several circular strata, complete the walls

Describe the epididymis.

This structure possesses a stratified ciliated epithelium, and its convolutions are supported and held together by a loose vascular connective tissue.

Describe the vas deferens.

This consists of either a two-layered columnar epithelium, or a transitional epithelium, of a layer of connective tissue divided into a tunica propria and submucosa, and of an inner circular and outer longitudinal layer of smooth muscle fibres.

Describe the ampulla.

This is the terminal expansion of the duct, and the walls are somewhat thinner. Branched tubular glands are formed in the mucous membrane, and the columnar cells contain many pigment granules. The seminal vesicles possess the same structure.

Describe the ejaculatory duct.

This consists of a simple columnar epithelium and a thin inner circular and outer longitudinal layer of smooth muscle.

Describe the arteries of the testicle.

They are branches of the spermatic coming partly from the mediastinum and partly from the tunica vasculosa, and break up into capillary networks which surround the seminiferous tubules. The veins follow the course of the arteries.

SEMEN.

What is the semen?

The secretion of the testicles, consisting almost entirely of spermatozoa, in which a head and tail can be distinguished.

Describe a spermatozoon.

The head is 3–5 m. long by 2–3 m. broad, and seen from the side appears flattened and somewhat pyriform, with the narrow end directed forward; from above the surface is oval with a rounded anterior end.

How is the tail disposed?

It exhibits a delicate filament called the axial fibre, which is composed of delicate fibrils. It is described in three divisions, the middle piece lying next the head, the main piece and the end piece.

Describe the movements of the spermatozoon.

The spermatozoa are distinguished by their extraordinary vitality. The vibratile movements are executed by the tail, which drives the head before it. The movements occur generally after the dilution of the secretion normally effected by admixture of the fluids of the ampulla, the seminal vesicles, of the prostate and Cowper's glands. The motion may continue for 24 to 48 hours after death, and longer still in the secretions of the female generative tract.

THE PROSTATE BODY.

Describe the prostate gland.

It consists mostly of smooth muscle fibres; the lesser part is glandular tissue composed of thirty to fifty simple branched tubular glands, and is characterized by

the wide intervals between the tubules which open by two large and a number of smaller ducts into the urethra.

Describe the cells of the tubules.

The cells are low columnar elements which line the tubules in a simple layer; in the larger ducts transitional epithelium is formed, like that in the prostatic portion of the urethra.

What are the prostatic crystals ?

Round, stratified masses of secretion, up to 0. 7 mm in size, occurring in the tubules of elderly persons.

The plain muscle fibres are increased toward the urethra and form a strong circular layer called the internal vesical sphincter. The outside of the gland also shows smooth muscle fibres which extend to the bundles of striated muscle forming the external vesical sphincter.

Describe the glands of Cowper.

These also are compound tubular glands, whose wide tubules are covered with a simple layer of clear columnar cells, and the excretory duct is lined with two or three strata of cubical cells.

FEMALE REPRODUCTIVE ORGANS.

OVARY.

How is the ovary divided for description?

Into a cortex and medulla.

What cells cover the free surface of the cortex?

Low columnar cells called the germinal epithelium.

What is included in the cortex?

The outer third of the organ, containing the Graafian follicles and the ova.

What is comprised in the medulla?

The inner two-thirds of the organ containing the blood vessels.

What is the ovarian stroma?

A peculiar kind of connective tissue characterized by its many spindle cells. It is found throughout the organ, but is more conspicuous as it nears the periphery.

What is the tunica albuginea?

A condensation of the cortical stroma recognized as a distinct layer directly beneath the germinal epithelium.

Describe the immature Graafian follicle.

The most immature follicle consists of an ovum surrounded by a single layer of flattened cells, and outside

of these lie the cells of the stroma, with no intervening membrane. Others more advanced are present, with two or more rows of polygonal cells.

What is the origin of the cells surrounding the ovum?

They arise from the germinal epithelium as cylindrical masses which penetrate the stroma and proliferate, thereby forming numerous elements within the follicle.

Describe the mature Graafian follicle.

These appear as clear vesicles 4–8 mm in diameter and differentiated from the surrounding tissue by a condensation of stroma forming a sheath—the theca folliculi.

Describe the theca folliculi.

It is composed of two layers, an outer, the tunica fibrosa, comprised of fibrous connective tissue and coarser blood vessels, and an inner tunic propria, rich in cells and capillaries.

Describe the membrana granulosa.

Consisting of many layers of small polyhedral cells, it is the product of the single row of cells originally surrounding the ovum.

What is the discus proligerus?

This term is applied to a thickening of the membrana granulosa which continues as a zone of cells surrounding the ovum The cells lying next to the ovum are placed vertically to its surface, forming a radical zone called the corona radiata.

What is the liquor folliculi?

An albuminous fluid filling the interior of the follicle and derived as exudate from the blood vessels of the

theca, and partially from the destruction of the central cells of follicle.

Where is the ovum?

This is a spherical body about 2 mm in diameter, lying within the discus proligerus and surrounded by a distinct membrane—the zona pellucida.

Describe zona pellucida.

This structure is derived from the cells of the discus proligerus and forms a protecting membrane presenting a delicate radial striation.

What is the vitiline membrane?

Lying next to the zona pellucida, it limits the protoplasm of the ovum and forms a true but inconspicuous cell wall.

Describe the protoplasm of the ovum.

Composed of albuminous matter, it is modified by the presence of numerous fatty particles.

Describe the germinal vesicle.

This structure corresponds to the nucleus of the ovum, and is situated eccentrically, limited by a distinct membrane, and contains the nucleolus or germinal spot. It is within the germinal vesicle that the important changes of cell division are inaugurated. The chromatin threads form a loose network throughout the vesicle, the inner spaces being filled with a substance representing the nuclear juice. Sometimes the follicle contains more than one ovum.

Describe the medulla.

This is characterized by the looseness of its structure and the size of its vessels. The stroma of the medulla contains more fibrous tissue, fewer spindle cells and

some involuntary muscle separating and surrounding the vessels, which are largely venous.

What are interstitial cells?

These are polygonal epithelial cells and represent the remains of the cylindrical cell masses which grow into the tissue of the primitive ovary from the Wolffian body. They are found in groups between the bundles of stroma in the cortex and medulla.

Describe the corpus luteum.

This is produced by changes in the ruptured and partly collapsed follicle, which becomes filled with blood after the escape of the ovum. Gradually a mass of polyhedral cells forms and capillaries from the follicular vessels extend into the mass, which afterwards shrinks and is later invaded by the peripheral cells. It follows the discharge of every mature ovum, and when pregnancy occurs it becomes exceptionally large and retains its distinctive character much longer.

Describe the blood vessels of the ovary.

They enter at the hilus, penetrate to the medulla and give off twigs to supply cortex and Graafian vesicles.

What nerves supply the ovary?

Both cerebro spinal and sympathetic systems send fibres to the ovary, and both pale and medullated fibres are present.

PAROVARIUM.

Where is the parovarium?

It lies transversely within the broad ligament between the ovary and oviduct.

Of what does it consist?

A group of tubular structures whose vertical tubules

converge somewhat at their ovarian ends, and their opposite ends are connected with a longitudinal head tube of larger caliber which extends downward into the broad ligament.

What cells line the tubules?

Low columnar epithelial cells.

What is the origin of the parovarium?

It represents the remains of parts of the Wolffian body—the transverse tubules corresponding to the tubules of the body, while the head tube is identical with the upper part of the Wolffian duct—when this tube persists for any great part of its original length it is called Gartner's duct.

What is the stalked hydatid of Morgagni?

This is a pedunculated vesicle, representing the remains of the duct of the pronephros and is found in both sexes. Its dilated sac and stalk when pervious are lined with low columnar or cuboidal epithelium.

FALLOPIAN TUBE.

What coats comprise the Fallopian tubes?

The mucous, muscular and serous.

How is the mucous membrane arranged?

In numerous longitudinal folds that give the transverse section a stellate appearance. There are no glands in the mucous membrane of the oviduct.

What composes the mucous coat?

A fibro-elastic tunica propria containing numerous connective tissue cells and a layer of ciliated, simple columnar epithelium, the ciliary wave being directed toward the uterus.

What lies outside the tunica propria?

An extremely thin muscularis mucosæ, consisting of longitudinal bunches of smooth muscle.

Describe the submucosa.

This is only represented by a thin layer of fibrillar connective tissue.

Describe the muscular coat.

This consists of an inner circular and an outer, very thin, longitudinal layer of smooth muscle.

Describe the serous coat.

This coat is formed by the peritoneum and a considerable layer of loose bundles of connective tissue.

Describe the blood vessels.

They form a narrow meshed and abundant capillary network. The larger veins run along the bases of the longitudinal folds of the mucosa.

THE UTERUS.

What coats are found in the uterus?

Mucous, muscular and serous.

Describe the muscular coat.

Although composed of smooth fibres that interlace in all directions, three layers are distinguished: an inner layer having mostly a longitudinal direction, a middle layer having in general a circular direction, called the stratum vasculare (on account of the numerous arteries and veins), and an outer layer (stratum supra-vasculare) formed partly of circular bundles and partly of longitudinal bundles.

Describe the muscle fibres.

They are elongated spindle cells, or blunted and frayed at the ends and sometimes forked. They vary from 60—600μ in length. The nucleus, sometimes multiple, is usually oval and lies in a granular substance.

How is the mucosa divided for description?

As follows:

The virgin mucosa resting.
The mucosa menstruating.
The mucosa of the gravid uterus.

Describe the virgin mucosa resting.

After puberty it has a thickness of from 1–2 mm and is covered by a single layer of ciliated columnar cells, the ciliary wave being directed toward the cervix. The tunica propria is formed of fine fibrous tissue resembling embryonic connective tissue and consisting of elongated cells with oval nuclei. The cells send out branched processes in all directions, which unite with those of neighboring cells, and form a cellular network, the meshes of which are occupied by leucocytes and lymph. The tunica propria supports the simple or forked gland tubules which not infrequently extend to the muscularis. The glands are invaginations of epithelium, and consist of a simple layer of ciliated epithelium resting on a delicate basement membrane composed of anastomosing connective tissue cells. The arteries run in a spiral course from the muscularis to the surface of the mucous membrane, where they break up into capillaries and form a close network. The veins leading from the capillaries form a plexus in the deeper layers of the mucosa. In the cervix, the mucous membrane is thicker, and its upper two-thirds is cov-

ered with a single layer of tall ciliated cells. Near these stratified squamous cells appear.

Where are the mucous crypts?

Mucous follicles occur also in the membrana of the cervix and some few scattered tubular glands.

What changes are noted during the period of menstruation?

Thickening of mucosa and structural changes, menstruation, regeneration.

Describe the initial phase.

This is characterized by considerable thickening of the mucosa, the surface becomes irregular, the mouths of the glands open in deep depressions, the blood vessels become enormously enlarged. The thickening of the mucosa depends somewhat on actual increase of tissue from the proliferation of connective tissue cells and leucocytes and by growth of gland tubules. This condition of the mucosa is called decidua menstrualis. Then follows disintegration of the upper layer of the mucosa and infiltration of blood into the subepithelial tissues; the enlarged blood vessels become exposed and rupture, causing hemorrhages into the uterine cavity, and the flow into the vagina which constitutes the external signs of menstruation. The surface now being devoid of epithelium consists of connective tissue and exposed blood vessels.

Describe the stage of regeneration.

The hyperæmia disappears rapidly, the effused blood is partly absorbed and partly cast off, a cellular network grows upward and restores the lost tunica propria while the epithelial covering of the mucosa is regenerated from the gland cells.

How does the mucous membrane appear at different depths?

The superficial zone is compact, and the deep zone shows numerous cavities produced by the lower divisions of the gland tubules which have become widened and tortuous. Later on the channels of the glands appear compressed and straightened, owing to the distension of the uterus. Between the glands are many blood vessels, spindle cells and multi-nucleated giant cells. The epithelium of the glands is soon lost and the gland lumina become adherent and are obliterated.

How is the decidua gravitatis divided for description?

The mucosa of the gravid uterus is considered under three heads.

The decidua serotina, when the ovum finds attachment.

The decidua vera, which comprises all the mucosa attached to the uterus not comprised in the above.

The decidua reflexa, or that portion of the mucosa that encapsules the ovum (it disappears about the fifth month).

The decidua vera and serotina develop throughout the pregnancy much as the menstrual decidua, but the progressive alterations assume vastly greater proportions.

Describe the decidual cells.

These are flattened spherical oval or branched cells of conspicuous size, which occur in large numbers in the mucosa of the gravid uterus. Usually they possess but one nucleus, but sometimes multiple nuclei are present. Late in pregnancy they assume a brownish

color. They are found more numerously in the upper compact zone of the serotina. The decidual cells are said to arise from connective tissue elements.

Describe the chorion and amnion.

These fœtal membranes are seen in cross sections of the decidua vera loosely united by mucous connective tissue. The chorion consists of an epithelial and a connective tissue layer, of which the first is turned toward the uterine wall, and the latter toward the amnion. In the amnion the epithelial layer of cubical cells is turned toward the cavity of the uterus, and the connective tissue layer faces the chorion.

Describe the lymph vessels.

They form a wide meshed network in the mucosa, provided with blind branches, and send small twigs through the muscularis to connect with a close subserous network of larger channels.

Describe the nerves of the uterus.

They are both medullated and non-medullated, and branching in the muscularis they form a dense plexus here and in the mucosa.

VAGINA AND GENITALS.

What coats are formed in the vagina?

Mucous, muscular and fibrous coats.

Describe the mucous membrane.

It is composed of stratified scaly epithelium and a tunica propria beset with papillæ which are built up of small interlacing bundles of connective tissue mingled with elastic fibres and leucocytes. The mucosa rests on a submucosa consisting of loose bundles of tissue

and robust elastic fibres. There are no glands in the mucosa of the vagina.

Describe the muscular coat.

This is composed of an inner circular and an outer longitudinal layer of smooth muscle fibres.

Describe the fibrous coat.

This is composed of dense connective tissue mingled with elastic fibres.

Describe the blood and lymph vessels.

These are arranged in parallel horizontal networks in the submucosa and tunica propria. The venous channels lie between the bundles of the muscular coat. The nerves form a plexus with many small ganglia in the outer fibrous coat.

What characterizes the mucosa of the external geniatalia?

It possesses numerous glands, and on the labia minora sebaceous glands without hair follicles are found. The labia majora possess the same structure as the skin.

RESPIRATORY SYSTEM.

What is comprehended in the respiratory tract?

The system of air passages, such as the nasal fossæ, pharynx, larynx, trachea and bronchial tubes, and the special organs of respiration, the lungs.

THE LARYNX.

What is the structure of the larynx?

A cartilaginous framework formed by the thyroid, cricoid, arytenoid, and the other smaller cartilages of Wrisberg and Santorini, united by ligamentous membranes and fibrous tissue and lined by mucous membranes; on the outside the cartilages are covered by fibrous and mucous structures.

What constitutes the mucous membrane?

An epithelium, a tunica propria and a submucosa.

What is the character of the epithelium?

That covering the epiglottis and the laryngeal cavity as far as the false vocal cords is stratified, squamous—at the lower edge of the false vocal membranes it becomes stratified ciliated columnar and extends throughout the laryngeal ventricle. On the true vocal cords, the epithelium is again stratified, squamous and beyond this the bronchial type continues—stratified ciliated columnar.

What elements compose the tunica propria?

Fibrous connective tissue with a rich network of elastic fibres, and the superficial part is beset with papillæ.

Describe the true vocal cords.

The vocal cords are folds of the mucosa, composed principally of longitudinal bundles of elastic fibres, some fibrous tissue, covered by stratified squamous epithelium and externally reinforced by fasciculi of the thyro-arytenoidous muscle. They have no mucous glands.

Describe the epiglottis.

The epiglottis is composed principally of yellow elastic cartilage. Numerous taste-buds, similar to those on the tongue, lie embedded in the posterior surface and leucocytes are numerous so that the mucosa assumes the aspect of diffuse adenoid tissue. The minute glands lie embedded in the pits and openings in its plate of cartilage.

Describe the submucosa.

This is a loose tissue that serves to unite the mucous membrane with the firmer surrounding structures; in places mucous follicles are found lined with columnar cells.

What cartilages are hyaline?

The thyroid, cricoid and arytenoid.

What cartilages are yellow elastic?

The epiglottis, the apex and processus vocales of the arytenoid and the cartilages of Wrisberg and Santorini.

What are the cartilagines trilicæ?

Little nodules embedded in the lateral thyro-hyoid

ligaments and are composed sometimes of fibrous and sometimes of yellow elastic cartilage.

How do the blood vessels terminate?

Within the mucosa in capillary networks beneath the epithelium and in the papillæ by vascular loops.

How are the lymphatics arranged?

As a superficial network within the mucosa and a deeper set within the submucous tissue, the largest being found on the anterior surface of the epiglottis.

What kind of nerves supply the larynx?

Principally medullated fibres, although pale fibres are sometimes present.

THE TRACHEA.

What is the general structure of the trachea?

A fibrous tube, lined with mucous membrane and kept patulous by incomplete cartilaginous rings.

Describe the epithelium of the mucous membrane.

The epithelium is of the stratified ciliated columnar variety, and among the elements lie goblet cells. The current established by the ciliæ tends to expel mucous or other substances.

Wherein is the tunica propria conspicuous?

For its large amount of elastic tissue.

How is it distributed?

In two zones: an inner loose, fibrous layer containing a small amount of elastic fibres, vascular loops, nerve fibres and lymphoid cells, and an outer layer, next to the submucosa, composed of a close network of longitudinal elastic fibres.

How is the submucosa arranged?

This is a loose structure and connects the mucosa with the fibrous sheath and supports the glands, lymphatics, nerve trunks, and larger blood vessels.

Describe the tracheal glands.

These are racemose glands occupying the submucous layer and connecting with the surfaces by long, excretory ducts. They are lined with low columnar epithelium, while the acini contain cuboidal cells.

Where is the fibrous coat?

External to the submucosa, and forms an investment in which the cartilaginous rings are embedded.

Describe the rings of cartilage.

These are masses of hyaline cartilage of horse-shoe shape, embracing about three-fourths of the tracheal tube.

How is the remaining space bridged?

By the fibrous tunic and a layer of transversely disposed bundles of non-striped muscle which extend along the inner side of the cartilages to whose perichondrium they are attached.

How are they otherwise distributed?

Across the intervals between the rings, thus forming a continuous layer that serves to contract the tube Longitudinal muscular bands are also present.

Describe the blood supply.

The larger blood vessels pass to the submucosa, from which smaller twigs are given off to supply the mucous membrane and partially the fibrous and cartilaginous structures.

How do the vessels terminate?

In a network within the mucosa beneath the epithelium. The acini of mucous glands are surrounded by capillaries.

Describe the lymphatics.

Lymphatics are numerous within the mucous and submucous coats. Lymphoid tissue in the form of solitary follicles also occurs.

Describe the nerves.

Both the medullated and non-medullated fibres occur. The larger trunks pass into the submucosa and send out minute fibrillæ.

THE BRONCHI.

How do the bronchi differ from the trachea?

The large bronchi have almost exactly the structure of the trachea, but the smaller tubes are modified to conform to the gradual reduction in size.

How is the epithelium modified?

It is reduced to a single layer of ciliated columnar cells

How is the mucosa affected?

At first it is not greatly diminished, as the loss in elastic tissue is compensated for by the appearance of an additional layer of smooth muscle between the mucosa and submucosa.

Describe the muscular layer.

It corresponds to a muscularis mucosæ, and forms a complete investment, especially conspicuous when the cartilaginous plates diminish.

How do the ring cartilages disappear?

At first reduced in size, they are broken up and finally replaced by irregular short plates which, becoming smaller and more infrequent, disappear entirely in the smaller bronchioles.

What is the smallest bronchiole named?

When the bronchiole does not exceed one millimeter in diameter, it is called a terminal bronchus.

How does a terminal bronchus end?

In slightly larger alveolar passages, the walls of which are studded with air sacs, from which extend blind, irregular spaces called infundibula, which are surrounded by air sacs communicating with the general cavity, but not with each other.

What cells line the terminal bronchioles?

Ciliated epithelium.

What cells line the alveolar ducts?

Cuboidal cells which rapidly assume a flat polygonal type.

Describe the walls of a terminal bronchus.

Outside the single layer of epithelium is the mucosa containing longitudinal elastic fibres and thin irregular annular bundles of smooth muscle. The mucous glands and cartilaginous plates are absent.

Describe the walls of the alveolar ducts.

These show still further reduction, the fibrous coat is greatly thinned, and the mucous coat becomes a delicate tunica propria of fibro-elastic tissue wherein some smooth muscle fibres remain.

Describe an infundibulum.

It is lined with large flat endothelial plates between which smaller polygonal cells appear.

THE LUNGS.

How do the lungs resemble racemose glands?

In plan of development the bronchial tubes correspond to excretory ducts and the pulmonary parenchyma to glandular tissue.

What structures comprise the pulmonary parenchyma?

Groups of air sacs, enclosed by connective tissue, form lobules, which in turn are united into lobes, and all are connected by alveolar tissue.

Describe the air sacs or alveoli.

These correspond to the acini of racemose glands, and are placed closely side by side, the mutual pressure making them polyhedral. They open into the common passages of the alveolar ducts and infundibula, and around the opening, the elastic tissue of the infundibulum is arranged as a ring from which the electric fibres pass in all directions over the sac to form its framework.

What does the wall of the air sac comprise?

The epithelium, connective tissue framework and capillary network.

Describe the epithelial lining.

This is composed of a single layer of large plates similar to endothelium, among which small polygonal cells lie scattered.

What is the order of appearance of these cells?

The small cells only are present in the embryonal condition, but after inflation has occurred the large cells appear.

What are stomata?

Minute openings frequently found at the junction of the angles between the cells and connecting with the lymphatics.

What is the framework of the air sac composed of?

Principally of elastic fibres from the annular bundle surrounding the mouth of the sac, some fibrous tissue and a few connective tissue cells.

How is the framework arranged?

It completely surrounds the alveolus and constitutes the septum between adjoining air sacs, and acts as a support for the capillary vessels and the investing epithelium.

Describe the capillary network.

This is remarkable for the closeness of its meshes. The smaller twigs extend among the groups of infundibula, embracing the opening into the air sacs with more or less complete rings from which pass the capillaries enveloping the air sacs with network on all sides.

How are they disposed between the alveoli?

Between the alveoli only a single layer of capillary vessels is present, and they encroach alternately upon the adjacent air sacs as projecting arches or loops.

How are the alveoli of different infundibula separated?

By distinct connective tissue partitions which increase in thickness as the included pulmonary sub-

stance becomes larger, until they become the fibrous envelope ensheathing the lobes.

How are the lymphatics arranged?

In two sets, one of which arises in the connective tissue septa, and the other in connection with the bronchial mucous membranes.

What nerves supply the lungs?

The cerebro-spinal and sympathetic systems both contribute fibres to the lungs.

THE PLEURA.

What tissues compose the pleura?

An endothelium, covering a connective tissue matrix, and a subpleural tissue.

Describe the endothelium.

It comprises a single layer of large, thin, irregular polyhedral connective tissue plates, between the junctures of which minute stomata are frequently found.

Describe the connective tissue matrix.

This consists of fine bundles of fibrous connective tissue, intermingled with elastic fibres.

How are the lymphatics disposed?

The inter-communicating lymph channels form a plexus of considerable richness within the fibrous lamellæ.

Describe the subpleural tissue.

Where developed as a layer of some thickness, it is composed of loosely disposed areolar tissue containing many elastic fibres.

SKIN AND APPENDAGES.

What elementary structures compose the skin?

A superficial epithelial layer, the epidermis, derived from the ectoderm, and a deeper connective tissue layer —the corium—derived from the mesoderm.

What cells compose the epidermis?

Highly developed squamous epithelium, which forms an accurately fitting protective covering over the entire body surface.

How are the cells arranged?

In irregular layers, dependent upon the cuticular development.

What layers can be distinguished in well developed skin?

The stratum Malpighii, stratum granulosum, stratum lucidum and stratum corneum.

Describe the stratum Malpighii.

This contains the most recent and most actively growing elements, the deepest of which possess a distinctly columnar character. They are bounded below by a thin basement membrane.

What are the prickle cells?

The next layer of cells have fine intercellular clefts or channels bridged across by intercommunicating fi-

bres that suggest the name. There are several layers of the prickle cells.

Describe the stratum granulosum.

The cells of the prickle layer gradually become flattened and compressed and filled with granular particles called eleidin, which has an affinity for carmine; this constitutes the granular layer.

What is the next layer called?

The next layer appears as an ill-defined narrow zone of cells which as yet is incompletely transformed into horny substance and is known as stratum lucidum.

Describe the corneous layer.

The corneous layer is composed of thin, dry, compressed plates which contain keratin and from which the nuclei have disappeared.

Describe the pigment granules.

When present these granules are especially numerous in the deeper layers of the stratum Malpighii, where it is conveyed by the wandering cells.

What is the corium?

The true skin consists of a felt work of white fibrous connective tissue bundles in which elastic fibres and smooth muscles are mixed in varying amounts.

What two layers constitute the corium?

The stratum papillare and stratum reticulare.

Describe the papillæ.

The elevations consist of closely arranged bundles of fibro-elastic tissue and support vascular loops and a rich terminal nerve supply. They vary in size, number and disposition in various parts of the body, being most

numerous and best developed on the flexer surfaces of hands and feet.

What purpose do the papillæ serve?

They greatly extend the sensory surface and form the principal organs of tactile sensibility.

How are the papillæ disposed?

Upon the hands and feet they are distributed in characteristically arranged rows, which form elaborate and individually distinct ridges on the skin, which remain unchanged through life.

What is the shape and size of the papillæ?

They have a conical figure, rounded or blunt at the top, and sometimes cleft into two or more points, when they are called compound papillæ. On the palm, sole and nipple they are mostly compound, and measure from 1-200 to 1-100 of an inch in height; sometimes they are less than 1-800 of an inch in height.

Describe the subcutaneous stratum or stratum reticulare.

This is a framework of loosely disposed fibro-elastic bundles continued from those of the deeper layers of the corium without interruption.

What is the panniculus adiposus?

A compact layer composed of interfascicular spaces which are filled with adipose tissue.

What are the cellular elements of the subcutaneous tissue?

The usual connective tissue cells, fusiform and plate like elements, leucocytes, and fat cells. The latter are sometimes absent.

What is included under appendages of the skin?

The nails, hair and cutaneous glands.

Of what does the nail consist?

Of a large exposed body which ends anteriorly in a free edge and extends posteriorly as the root some distance beneath the overhanging upper margin of the groove or nail fold receiving the root. The borders of the nails are covered by the nail walls.

What is the appearance of the nail root?

It is usually light in color and somewhat opaque; on the thumb it extends beyond the nail fold as a pale, projecting convex area called the lunula.

Upon what does the nail rest?

Upon a highly vascular and sensitive "nail-bed," the posterior portion of which, covered by the root of the nail, is called the matrix.

How does growth of the nail take place?

From the matrix alone, each newly formed increment pushing before it the already formed parts at the rate of about 1 mm per week The transformation of the cells into horny plates takes place only on the matrix.

What is comprised in the nail-bed?

The corium and that part of the epidermis corresponding to the stratum Malpighii.

What are the longitudinal ridges?

Minute elevations which occupy the surface of the corium, except posteriorly over the matrix. They are lowest behind and gradually increase in height toward the front of the nail, abruptly terminating when the nail parts from its bed.

Where does the epithelial portion of the nail bed arise?

From cells belonging to the stratum Malpighii.

What is the substance of the nail?

Intimately united lamellæ of horny epithelial cells possessing a nucleus and closely resembling the elements of the stratum lucidum.

THE HAIR.

Whence do the hairs arise?

Entirely from the epidermis and are, therefore, of ectodermic origin.

How are hairs divided for description?

Into the root and the shaft.

How does the root terminate?

In a bulbous expansion, the hair bulb, which at its lowest point is indented to receive the connective tissue papillæ.

What is the follicle?

A pocket of modified integument in which the bulb is embraced; the corium and epidermis contribute respectively the fibrous and epithelial root sheaths.

Of what does the hair consist?

Entirely of epithelial cells disposed in three distinct strata called the cuticle, the cortical substance, and the medulla or pith.

Describe the cuticle.

It is composed of a single layer of thin, horny imbricated scales enveloping the entire surface of the hair. Owing to the imbricated arrangement only the free

projecting edges are visible, and this gives the oblique transverse markings so distinctive of the surface view of hair.

Describe the cortical substance.

This constitutes by far the greater part of the hair, and is composed of elongated, horny epithelial cells, with attenuated nuclei, and are so intimately united that the boundaries of the elements are usually indistinguishable.

What changes are found in the cells on the root?

They are broader and less horny, and around the papilla the cells of the cortical substance become continuous with the extension of the stratum mucosum.

Describe the medulla?

This occupies the central part of the shaft and sometimes extends from near the bulb to the extremity of the hair.

What composes the medulla?

Irregular cuboidal or spherical cells 15–20μ in diameter, filled with dark granules which are really minute air vesicles. By reflected light the pith appears silvery white, while by transmitted light it is opaque.

Upon what does the color of the hair depend?

Upon the presence of pigment granules, diffuse pigment and air.

How is the pigment distributed?

In dark hair the granular pigment, occurring as colored particles, lies within the elements of the cortical substance and often between the cells. The cortex sometimes also contains diffuse soluble coloring matter in combination with the cell protoplasm.

Describe the hair follicles.

They are tubular or flask shaped depressions in the skin which tightly embrace the hair shaft.

What is the purpose of the follicle?

It supplies the tissue from which the hair is formed, and affords the necessary attachment and support to the hair after development.

How does the follicle develop?

By an ingrowth of the epidermis into the subjacent connective tissue. The hair appearing as the result of the differentiation of the cells in the most dependent part of the epidermal plug.

What coats comprise this hair follicle?

Below the sebaceous glands the follicle consists of the fibrous coat and stratum mucosum only, but above the glands the stratum corneum is added.

Describe the fibrous coat.

This consists of three layers—the outer of longitudinally placed bundles of connective tissue rich in cells, the middle of circular connective tissue, and the inner a clear, homogeneous zone, the hyaline membrane separating the epithelium from the fibrous tissue.

How is the epithelial layer disposed?

In two well marked strata, the outer root sheath and the inner root sheath.

Describe the outer root sheath.

This is a direct continuation of the stratum mucosum of the adjacent skin, and its structure corresponds with that layer of the epidermis.

How are the cells disposed?

A layer of columnar cells lies in contact with the

glossy membrane, while the succeeding layers are squamous epithelium.

Describe the inner root sheath.

This is composed of two layers, the first of which, Henle's layer, consists of a single or double row of epithelial cells without nuclei, while the inner or Huxley's layer is formed of nucleated cells and is lined by a delicate membrane, the cuticle of the root sheath, which exhibits the same structure as the cuticle of the hair.

Describe the base of the hair follicle.

This presents a deep invagination for the reception of the hair papillæ containing the pigment cells and the blood vessels.

GLANDS OF THE SKIN.

What glands are found in the skin?

The sebaceous and sudoriparous glands.

Describe the sebaceous glands.

These are either branched or unbranched simple saccular glands, and consist of short excretory ducts and acini.

Describe the cells of the gland.

The duct is lined by stratified epithelium, consisting at first of low cuboidal cells followed by spherical or polyhedral elements.

What is the sebum?

A semi-fluid substance consisting of oil droplets and the debris of broken down cells which the glands secrete.

Where are the sebaceous glands found?

They are always located in the papillary layer of the skin, and are of universal occurrence.

What are the sweat glands?

Modified, simple tubular glands, extending from the free surface of the skin to the deepest part of the reticular layer of the corium. They are divided for description into two parts, the excretory duct and the coil.

Describe the excretory duct.

The duct runs a straight or sinuous course through the corium, enters the epidermis between two papillæ, passes in a spiral through the corneous layer, and opens on the surface of the skin by a rounded orifice, the sweat pore just visibe to the naked eye. The walls consist of longitudinal bundles of fibrous tissue, lined within by several layers of cubical and epithelial cells.

Describe the coil.

This is a greatly convoluted simple canal lined with a simple layer of cuboid cells containing granules of pigment and fat surrounded by a delicate membrana propria. Sometimes longitudinal fibres of smooth muscle occur between the membrana propria and the gland cells.

Describe the secretion.

Usually an oily, fluid substance, under the influence of altered innervation it becomes the watery liquid called sweat.

What glands are described with the sweat glands?

The ceruminous glands of the ear. The glands of Moll of the eyelid must be regarded as modified sudoriparous glands, as they closely correspond in structure.

CENTRAL NERVOUS SYSTEM.

What constitutes the central nervous system?

The spinal cord and the brain.

Of what does the spinal cord consist?

Of white and gray substance.

How is the white substance disposed?

It encircles the gray matter and is partially divided by a deep anterior cleft, the anterior median fissure and a posterior septum, into a right and left half.

How is each half subdivided?

By the furrows marking the exit of the anterior and posterior roots of the spinal nerves into a large lateral column, an anterior column and a posterior column.

What arrangement is peculiar to the upper thoracic and lower cervical region?

Here two divisions can be distinguished in the posterior column, of which the median portion is named the Column of Goll and the lateral portion the Column of Burdoch.

How are the anterior columns united?

By the white commissure at the bottom of the anterior median fissure.

Describe the gray substance.

This appears in cross sections in the form of an H

and consists of two lateral columns connected by a horizontal bridge, the gray commissure.

How are the columns divided?

Into anterior, posterior and lateral cornua.

How are the spinal nerve roots arranged?

The anterior roots emerge from the front boundary of the anterior cornua, and the posterior roots enter at the postero-median side of the posterior cornua.

What is the reticular process?

A net-like mass of gray substance found laterally at the base of the posterior cornua.

Where is the column of Clark?

On the median side of the posterior cornua, near the gray commissure.

Where is the substantia gelatinosa?

This covers the posterior horn and immediately surrounds the central canal.

Where is the central canal?

In the midst of the gray commissure.

Where is the substantia gelatinosa Rolandi?

This is the mass that caps the posterior horn and just posterior to this is the zona spongiosa, on the dorsal edge of which lies the zona terminalis—an area of cross-sectioned thin nerve fibres.

How large is the central canal?

From 0.5 mm to 1 mm in diameter, but not infrequently it is impervious.

How is the gray commissure divided with regard to the canal?

The portions in front and behind the canal are named

respectively the anterior and posterior gray commissures.

What are septula medullaria?

Processes of gray matter of variable size that radiate into the white substance.

What is the conus medullaris?

This is the end of the cord and consists almost wholly of gray matter.

What is the minute structure of the gray substance?

It consists of multipolar ganglion cells which, with their ramifying and axis cylinder processes, form a dense network—the "nerve-felt," which is penetrated by nerve fibres proceeding in part from the white columns and in part from the posterior roots, and the whole is supported by a framework of neuroglia.

How are the nerve cells divided?

In accordance with the relations of their axis cylinder processes into motor cells and column cells.

Describe the motor cells.

These lie in groups in the anterior horn, an antero-median and postero-lateral, separate in the cervical and lumbar enlargements, but in the uppermost cervical and in the thoracic regions united in a single cluster. The cells possess a large cell body and long protoplasmic processes, dendrites extending far into the surrounding substance. The nerve or axis cylinder process emerges from the summit of the anterior cornu, makes an oblique descent through the white substance, at the same time receiving a medullary sheath, and becomes the axis cylinder of a medullated nerve fibre. Occasionally the axis cylinder process gives off a few lateral twigs before leaving the gray matter. It leaves

the spinal cord as a part of the anterior root fibre bundle. All anterior root fibres arise from motor cells of the anterior horn and on the same, not opposite, side.

Describe the column cells.

These constitute the chief mass of the nerve cells of the gray substance, and lay partly scattered, partly grouped, in the lateral horn and dorsal nucleus. The majority are smaller than the motor nerve cells and possess fewer and less branched, but far reaching dendrites.

How are the processes distributed?

The axis cylinder process, after sending out many collateral fibrils in the gray substance, enters the white substance; the anterior or lateral columns, rarely the posterior, either on the same or on the opposite side.

What are commissure cells?

When the process enters the white substance on the opposite side, the cells are termed commissure cells because the axis cylinder passes through the anterior gray commissure before entering the white substance. The commissure cells occupy an area embracing the central canal in an arch on the ventral side.

Describe the "stem fibres."

After arriving in the white substance, the axis cylinder process of the majority of the column cells divides into a vertical ascending and descending "stem fibre" which lies parallel to the longitudinal axis of the spinal cord and sends off twigs—collateral fibres—which return to the gray substance, where they terminate in tufts of free fibrils; the stem fibres themselves finally terminate like the collateral fibres.

How are the collateral fibres distributed?

The collateral fibres that enter into the anterior columns are tolerably strong and penetrate the anterior cornua singly or in bundles, where they weave a net around the large motor cells. They are especially strong in the antero-lateral curve of the anterior horn. The collateral fibrils coming from the lateral columns which go chiefly to the substantia gelatinosa centralis and only those ventral to the substantia gelatinosa Rolandi are well developed; the latter pass to the opposite side and form the dorsal or posterior commissure.

How are the nerve processes of the column cells covered?

In the adult, they are enveloped in a medullary sheath.

What direction do the processes take coming from Clark's column?

These do not divide in the white substance, but turn cranial ward and proceed to the cerebellum; and the axis cylinder processes of other column cells, when arrived in the white substance, turn without dividing either upward or downward.

What are Deiter's cells?

Nerve cells of the first type, such as motor and column cells.

What are interior cells?

A cell whose nerve process rapidly divides, but remains in the gray substance; they occur in the posterior columns and are nerve cells of the second type.

Where do the nerve fibres arise?

The fibres that enter the anterior and lateral columns

arise in part from the medullated, collateral fibres and the ends of the nerve processes of the column cells; in part from the axis cylinder processes that come from the brain, such as the medullated fibres of the posterior roots which originate in the centripetal processes of the cells of the spinal ganglia.

How do they enter the spinal cord?

The posterior root fibres enter the spinal cord in two groups; a lateral, which runs in the zona terminalis, and a median that runs in the posterior columns. The fibres do not enter the gray substance directly, but each first divides in Y shape into an ascending and descending "stem fibre," from which numerous collateral fibres diverge at right angles and enter the gray substance.

How do the fibrils terminate?

After entering the gray substance, they distribute themselves with their tufts of terminal fibrils over nearly every point; one set, terminating mostly in the summit of the posterior horn, have their origin in the lateral root fibre group, and form a very fine fibred dense plexus, that lies partly in the substantia gelatinosa Rolandi. The second set terminates in Clark's column, and originates in the median root fibre group, as does a third set which passes through the middle of the substantia gelatinosa Rolandi ventralward into the anterior cornu, and there radiates fan-shape and surrounds the motor cells in a network of fibrils forming the reflex bundle. This and the collateral fibres of Clark's column sink into the gray substance forming a curve with the concavity lateralward, and from a mass easily seen.

How do the "stem fibres" terminate?

After a long course they turn into the gray substance and end like the collateral fibrils in five branches.

What is the white substance composed of?

Entirely of medullated nerve fibres, which are without the sheath of Schwann. They differ greatly in thickness. The majority nerve fibres run parallel with the long axis of the spinal cord. Sometimes the fibres take an oblique direction; these are especially numerous in front of the gray commissure, where they cross and form the white commissure.

How is the supporting framework of the spinal cord constructed?

In two ways:

1. Fibrous connective tissue extensions of the pia which penetrate the white substance as vessel sheaths, and grows thinner as it approaches the gray matter.

2. The neuroglia, which consists mostly of nucleated elements, the glia cells, and possibly a small amount of homogeneous ground substance.

How many kinds of glia cells are there?

Two—the ependymal cells and Deiter's cells.

Describe the ependymal cells.

They line the lumen of the central canal in a single layer; when young they possess ciliæ. Their cylindrical bodies are prolonged in an extended process which in the fœtus reaches the surface of the spinal cord and terminates in a simple or branched end.

Describe Deiter's cells.

At first they lie in the gray substance, but later retire

into the white substance and undergo many changes in shape.

Describe the substantia gelatinosa Rolandi.

In addition to the ganglion cells and nerve fibres traversing it, it is mostly a granular substance, a transformation of the numerous delicates processes of Deiter's cells.

THE BRAIN.

What structures compose the brain?

White and gray matter.

How does the gray matter occur?

In four situations:

1. Cerebral cortex, covering the outer surface of the hemispheres.
2. Corpora striata, optic thalaini, corpora quadrigemina; all limited masses in the cerebral ganglia.
3. Lining of the ventricles.
4. Cerebellar cortex, covering the surface of the cerebellum. Other masses of gray matter also occur and have numerous connections with one another by means of fibre tracts.

CEREBRUM.

Into how many sections can the cerebral cortex be divided?

Into four zones, but not sharply differentiated.

Describe the molecular layer.

This is the most superficial, and in ordinary preparations appears finely granular, and contains an interlacement of medullated fibres called tangential fibres from their horizontal position.

What forms the reticulum?

Partly the dendrites of the pyramidal cells, and partly the processes of the glia cells.

What are the cells of Cajal?

Irregularly shaped bodies found in the molecular zone, which have processes running parallel with the surface, from which lateral twigs ascend. Their function is not determined.

Describe the zone of the small pyramidal cells.

This is characterized by ganglion cells of pyramidal form. The apex of the pyramid is prolonged into a long, ramifying protoplasmic process which sends out lateral twigs and enters the molecular zone, terminating in many branches. Smaller dendrites spring from the sides and inferior surface of the cell.

How is the axis cylinder process disposed?

This proceeds from the base, and after giving off branched collateral fibres, passes as a rule to the white substance to become the axis cylinder of one, or by division, two nerve fibres. Sometimes it runs to the molecular layer and divides, entering the web formed by the tangential fibres. The nerve processes and the collateral fibres are enveloped in a medullary sheath.

Describe the zone of large pyramidal cells.

This is distinguished by the larger size of its cells. The large axis cylinder process, after sending several collateral fibrils into the gray substance, always goes to the white substance.

Describe the layer of polymorphous nerve cells.

Here the elements are mostly oval or polygonal; an apical dendrite is absent, but the nerve process, after

sending off a number of lateral twigs, enters the white substance, where it passes into one or two nerve fibres.

Where are second type ganglion cells found?

In the last three zones. The axis cylinder process is either confined to the gray matter in the vicinity of the cells, or extends to the molecular zone and terminates in many branches.

How are the medullated fibres arranged?

In the last two zones the thick, radiating bundles split up into single fibres near the zone of small pyramidal cells.

How are the radiating bundles formed?

By the descending medullated nerve processes of the large and small pyramidal cells and by thick medullated nerve fibres of unknown source that ascend from the white substance toward the cortex, where they divide and subdivide into "super-radial" and the tangential interlacement, and finally end in branches.

What are the stripes of Germari or Baillarger?

This name is given to a set of medullated collateral fibrils of the nerve processes of pyramidal cells which become condensed toward the super-radial reticulum.

What is the inter-radial reticulum?

A name given to a set of medullated nerve fibres running transversely to the radiating bundles.

What is the substantia reticularis alba?

A modification of the cerebral cortex in the hippocampal and uncinate convolutions, where the tangential fibres are very numerous and form a net-like extended white layer.

CEREBRAL GANGLIA.

What constitutes the cerebral ganglia?

The gray substance consists of ganglion cells of variable size, medullated nerve fibres and neuroglia.

GRAY SUBSTANCE OF VENTRICLES.

How far does the ventricular gray substance extend?

From the floor of the fourth ventricle, through the aqueduct of Sylvius into the third ventricle, to the tuber cenerum and the infundibulum.

What is its composition?

The gray substance of the ventricles is the origin of the cranial nerves, and is composed of neuroglia, nerve fibres and multipolar ganglion cells. In some locations the cells are distinguished by their size—nucleus of hypoglossal nerve—or by their peculiar form—spherical ganglion cells in upper pair of the corpora quadrigemina.

CEREBELLUM.

What layers compose the cerebellum?

From within outward, the granule layer, the layer of the cells of Purkinji—microscopic—and the molecular layer.

Describe the granule layer.

This is characterized by its rusty color and consists of numerous layers of small cells which exhibit a large nucleus and almost no protoplasm.

Name the ganglion cells.

Two kinds are found, both of second type, small and large granule cells.

Describe the small ganglion cells.

They are multipolar, with short protoplasmic processes and a delicate nerve process without medullary sheath which passes vertically into the molecular layer, where it divides into longitudinal T branches running parallel to the surface and terminating in free unbranched ends. These are the principal elements of the granule layer.

Describe the large granule cells.

These are less numerous, but are more than twice as large as the small granule cells, and of directly opposite distribution—the protoplasmic processes extend to the molecular layer and the nerve process divides and ends in a rich ramification penetrating within the granule layer.

What nerve fibres are found in the granule layer?

Medullated nerve fibres partially fill the intervals between the nerve cells. They are derived from the medullary tracts, and some end in the molecular zone.

Describe the cells of Purkinji.

These are large multipolar ganglion cells forming the middle stratum. The bodies are slightly pear-shaped and send two large protoplasmic processes into the molecular layer, where they ramify in planes transverse to the long axis of the convolution.

From the opposite pole of the cell the axis cylinder process proceeds. This soon becomes medullated, and passing through the granule layer enters the white substance of the cerebellum. Collateral fibrils are thrown out in the granule layer and some run back between the Purkinji cells.

What cells compose the molecular layer?

Large and small cortical cells, both multipolar ganglion cells.

Describe the large cortical cells.

They lie in the lower half of the molecular layer and the protoplasmic processes extend mostly toward the surface. Their longer nerve process runs near the inner margin of the molecular layer transversely to the axis of the convolution, and sends toward the surface a few collateral fibres. In the deeper portions at intervals the terminal branches form a basket-like network around the bodies of Purkinji's cells and often embrace also the beginning of the axis cylinder process.

Describe the small cortical cells.

These lie nearer to the surface, but the nerve process has been little investigated.

Describe the neuroglia of the cerebellum.

This consists of two kinds of cells; one of which, lying at the boundary of the granule layer, has a small body, and sends a few short processes inward and many long processes in a straight course to the surface, where they end in a triangular expansion, and form relatively thick peripheral glia layer. The others, stellate in form, resemble the mossy cells of the cerebral cortex and occur in all strata.

How are the cerebellar elements united?

By contact; not by direct connection.

Describe the white substance.

Excepting the connective tissue, it consists of medullated nerve fibres without a neurilemma.

What is the pituitary body composed of?

A small posterior lobe and an anterior larger lobe

Describe the small posterior lobe.

This really belongs to the brain and consists mostly of connective tissue, blood vessels and cells which closely resemble multipolar ganglion cells.

Describe the anterior lobe.

Derived as a diverticulum from the primary oral cavity, it contains tubular acini embedded in loose vascular connective tissue, the majority of which are solid and filled with pale or dark cubical epithelial cells. A few of the acini are sometimes hollow and occasionally they contain celloid substance.

Describe the pineal body.

This is derived from a diverticulum of the primitive brain vesicle, and consists of epithelial cells, some of which have delicate processes and of connective tissue envelope, from which septa extend into the interior.

What is the "brain sand?"

Rounded concretions of variable size, with uneven surfaces, found in the interior of the pineal body.

They are composed of an organic basis and calcium and magnesium phosphate.

THE MEMBRANES.

What tissues envelop the brain and cord?

The dura mater and pia mater.

Describe the dura of the spinal cord.

It consists of compact connective tissue and numerous elastic fibres, flat connective tissue cells and plasma

cells. The inner surface is covered with simple flat epithelial cells (endothelium).

Describe the dura of the brain.

This consists of two lamellæ, an inner corresponding to the dura of the cord and like it in structure, and an outer corresponding to the periosteum of the vertebral canal. Its component elements are like the inner lamellæ except that the outer fibre bundles are arranged transversely to the inner, and it is rich in blood vessels.

Describe the pia mater.

This is a two-layered sack. The outer, or arachnoid, is covered on its free surface with endothelium, and is not closely attached to the dura. The inner closely invests the surface of the brain and cord, and sends blood vessels into their substance. The arachnoid and the pia are joined by many trabeculæ.

What are the villi of the arachnoid?

Evaginations of the arachnoid especially found near the superior longitudinal sinus, that push the attenuated dura before them into the venous sinus. The pia consists of delicate connective tissue bundles and plate-like cells which cover the inner surface.

What are the telæ choroideæ and plexus thoroideæ?

These are vascular villous projections on the margin of a fold of the pia, that hang like a fringe within the ventricles; they are composed of connective tissue and blood vessels united into tufts or globules, and covered with simple cubical epithelium—ciliated in the newborn.

Describe the blood vessels of the central nervous system.

They form a narrow meshed capillary network in the gray and a wide meshed network in the white substance, and possess a so-called adventitial sheath.

SUPRA RENAL BODY.

Why is this organ described with the nervous system?

On account of its early history, the profusion of its nerve elements and the results of pathological processes.

Name the constituent parts of the organ.

The capsule, the cortex, and the medulla.

Describe the capsule.

It is composed of fibrous connective tissue of considerable thickness, and from this envelope many connective tissue septa penetrate deeply into the soft cellular substance and break it up into cylindrical masses.

Describe the cortex.

This consists of aggregations of irregularly rounded or polygonal cells whose granular protoplasm sometimes contains fat particles in addition to clear nuclei.

How is the cortex divided?

In three divisions, known as the zona glomerulosa, zona fasciculata, and zona reticularis.

Describe the zona glomerulosa.

This is characterized by the grouping of the cells into round or oval masses just beneath the capsule.

Describe the zona fascicularis.

Here the cells are grouped in cylindrical form.

Describe the zona reticularis.

Here the cells are scattered in irregular anastomosing cords and the cells are pigmented.

Describe the medulla.

The medulla contains granular and sometimes deeply pigmented polygonal cells arranged as cords and irregular network in a framework of highly vascular connective tissue.

Where are the ganglion cells?

These occupy the medulla in great numbers, along with a rich network of non-medullated nerve fibres and conspicuous venous channels.

Describe the blood vessels.

They divide within the capsule and send many small twigs along the fibrous septa to form capillary networks around the cell groups of both cortex and medulla. The veins unite to form trunks passing out at the hilus.

Describe the nerves.

The nerves are remarkable both for number and size, and accompanying the arteries to the medulla, they there form an intricate plexus composed mostly of non-medullated fibres.

DENTAL HISTOLOGY.

Define dental histology.

Dental histology is the study of the microscopic structure of the teeth and the tissues of the mouth. It is that part of general histology which treats of the tissues of special interest to the dentist; and it has to do not only with cells and their arrangement, but also with the results of cell life in formed material, such as dentine and enamel.

Of how many tissues are the teeth made up?

Four.

Name the dental tissues. What part of the tooth is formed by each?

Enamel: covering the crown or exposed portion of the tooth.

Cementum: covering the root portion of the tooth.

Dentine: making up the mass of the tooth.

Pulp: or soft tissue filling the central cavity in the dentine.

From the standpoint of comparative anatomy, with what structures are the teeth analogous?

The dermal scales of such animals as the sharks and rays.

Are the teeth a part of the osseous system?

No.

To what structures in the body are they allied?

To such structures as the nails and the hair.

From the development, what is the analogy between the teeth and the hair?

The tooth is developed from a papilla of connective tissue covered by an epithelial structure. The hair is an epithelial structure, supported on a connective tissue papilla.

ENAMEL.

How much organic matter is found in the enamel of the tooth?

Not more than 5 per cent. Dr. Williams' recent work seems to show that in normal perfect enamel there is no organic matter whatever.

What is the chemical composition of the enamel of the teeth?

(American System of Dentistry.)

Water and organic matter	3.6
Calcium phosphate and fluoride	86.9
Magnesium phosphate	1.5
Calcium carbonate	8.0

What is the difference between the action of enamel, dentine and bone when treated with acid?

When treated with acid, bone and dentine have the inorganic salts dissolved out of them, and leave the organic matter which retains the structure of the original tissue. When enamel is treated with acid no trace of structure is left.

Compare enamel with other calcified tissues.

Enamel differs from all other calcified tissues. Both bone and dentine are made up of a formed substance, which yields gelatine on boiling, and which was the result of cell activity, being analogous to the intercellular substance of cartilage, into which the inorganic salts

have been deposited. When treated with acid this matrix of formed substance is left, maintaining the form of the tissue after all the salts have been removed

Enamel has no such matrix of organic matter in the adult tissue. Probably it normally contains no organic matter and never has more than 5 per cent. The matrix of formed substance, which gives the structure to the tissue in development, is perfectly transformed into inorganic matter in the adult tissue.

Of what structural elements is the enamel made up?

The enamel rods or prisms, sometimes called the enamel fibres; and the inter-prismatic or cementing substance, which is also perfectly calcified.

Describe in a general way the enamel rods.

The enamel rods are prismatic, usually five or six sided, and pointed at each end, passing out perpendicularly from the surface of the dentine.

What is the diameter of an enamel rod?

From 3.4 to 4.5 microns.

Name the layers or portions of the enamel at the time of eruption.

The portion made up of the rods arranged parallel with each other, making the body of the enamel.

The narceous layer of Sudduth.

Nasmyth's membrane.

What is the narceous layer of Sudduth?

The granular layer which covers the outer ends of the enamel rods giving to the outer surface of the tooth its smooth polished surface, is called by Dr. Sudduth the narceous layer, and is considered analogous to the similar layer in the shells of mollusks.

What is Nasmyth's membrane?

Nasmyth's membrane is the layer of horny scales which cover the crown of the tooth at the time of its eruption. Also called "the cuticula dentis."

What is Nasmyth's membrane a remnant of?

Nasmyth's membrane is the remains of the inner tunic of the enamel organ. The columnar cells become flattened and horny and cover the tooth as a membrane at the time of eruption. The layer is very soon worn off.

Describe the appearance of a section of enamel, cut across the rods.

The section has very much the appearance of a tile floor. The cross sections of the rods appearing as irregular five- or six-sided areas separated by the cementing substance.

Describe minutely the enamel rods and their relation to each other.

The enamel rods are long, usually five- or six-sided prisms pointed at both ends. Some of them pass from the surface to the dentine, but many others are shorter and end in points between the converging rods These rods are from 3.4 to 4.5 microns in diameter. They are not even in their outline, but present alternate expansions and contractions which are more marked in some specimens than in others. The rods lie parallel with each other, the enlargements in one rod lying opposite the enlargements in the ones next to it. The rods may be likened to rods of clay made by rolling up clay balls and pressing them together. In development the rods are formed in such a way, the sperules of calcoglobulin are formed in rows; these are surrounded with a cement-

ing substance and both become perfectly calcified by substitution, organic matter being removed and inorganic substituted for it.

What is meant by the striation of enamel?

The appearance of alternate light and dark bands similar in appearance to the striation of voluntary muscle. These striations appear even in low magnification and are caused by the variations in size of the rods.

What is meant by the stratification of enamel?

Stratification is the appearance, common to almost all enamel, of bands of brown or dark pigment. These bands are not parallel with the outline of the enamel, but are more curved; they mark lines of increment and are not caused by a difference in the form of the rods in that portion, but by a deposit of pigment with the lime salts in that part, and mark the rhythmic or intermittent formation of enamel.

Describe the direction of the rods in different parts of the tooth.

While the direction of the rods is outward, perpendicularly from the surface of the dentine, this is only a general statement; only in a few places are they straight and pass directly outward. The rods are more or less wavy in their course, and over the cusps are very much twisted and interwound. As you pass down the sides of the crown and approach the gingival margin, the enamel becomes very thin and the rods very short, and their direction is at more than a right angle to the axis of the tooth.

What principles of operating are based on the directions of the rods?

The beveling of the margins of cavities, especially at

the gingival margin. If the seat of the cavity is carried out at right angles to the axis of the tooth, the inner ends of the rods will be cut off and the outer ends left without support from the dentine; these unsupported ends are sure to be broken off in packing the filling, and leave a defective place. On the buccal and lingual margins of compound cavities in molars and bicuspids, the rods follow the direction of a radius and the enamel margins must be trimmed to this line so as to have the proper strength.

When enamel is attacked by acids, what is first acted upon?

The inter-prismatic or cementing substance. This is seen when ground sections of enamel are treated with acid, as well as when the tooth is attacked by caries.

DENTINE.

By what other names is the dentine known?

The ivory. It is dentine that makes up the mass of the tusks of elephants and walruses, etc., and that dentine is commercially known as ivory.

Tooth bone.

What cavity does the dentine inclose?

The dentine incloses a cavity in its center known as the pulp chamber.

What fills this cavity in life?

The pulp or soft tissue containing blood vessels and nerves which nourish the tooth. It is commonly though incorrectly called the nerve.

How do the blood vessels and nerves reach the pulp chamber?

The blood vessels enter at the apical foramin, and pass down through the root canal occupying the central portion of the tissue in these fine canals. The canals are surrounded by dentine to the apical foramin, or very nearly, for a short distance at the end of the root the canalway passes through cementum, where the end of the root is made up only of cementum.

What proportion of organic matter in dentine?

Twenty-eight per cent.

What proportion of inorganic matter in dentine?

Seventy-two per cent.

What two kinds of organic matter in dentine?

The organic matrix, into which the salts are deposited and which gives the structure to the tissue, and the remains of the fibrils which fill the tubuli. Only that forming the matrix strictly belongs to the dentine.

Give the chemical composition of the dentine.

The following are two analyses given in the American System:

Organic matter	27.61	20.42
Fat	.40	.54
Phosphate and fluoride of calcium	66.72	67.54
Carbonate of calcium	3.36	7.97
Phosphate of magnesium	1.08	2.49
Other salts	.83	1.00

Describe the effect of acids on the dentine.

When the dentine is treated with acid, even very dilute, the inorganic salts are dissolved out of the organic matrix, leaving the organic matter in the form that was characteristic of the calcified tissue. When treated in this way the entire tooth is attacked evenly, softening the entire surface first and penetrating deeper and deeper till the entire tooth is decalcified. This action is to be contrasted with the decalcification of caries.

What are the dentinal tubuli?

The dentinal tubuli are minute canals passing from the pulp chamber to the outer surface of the dentine, just under the enamel or cementum.

What do they contain in life?

In life they are filled by the dentinal fibrils.

Give another name for the dentinal fibril.

The fibres of Tomes.

From what do these fibres come?

These fibres are prolongations from the odontoblasts.

Do the dentinal fibrils penetrate between the enamel rods?

There is a difference of opinion on this point, but the best authority is that they do not.

What is the diameter of the dentinal tubule?

From 1.1 to 2.3 microns.

Describe in detail the structure of the dentinal tubule.

The dentinal tubuli pass outward from the pulp chamber to the outer surface of the dentine, just beneath the cementum or enamel. In the crown portion their course presents a characteristic "f" or "s" shaped curve, so that the tubule opens from the pulp chamber at right angles to the surface of the dentine and ends under the enamel at right angles to the line of union.

In passing outward from the pulp chamber the tubule at first presents few or no branches, but in the outer portion the branches become very numerous, appearing as little rootlets given off at an acute angle and anastomosing very freely with each other. Just under the enamel or the cementum they end in enlargements which are often at right angles to the course of the tubule.

What is the sheath of Neumann?

The sheath of Neumann is a layer of partially calcified matrix surrounding the dentinal fibril, and lining the dentinal tubule. They are the most indestructible part of the dentine, resisting the action of acids and subsequent prolonged boiling in strong alkalies. Their exact nature is a matter of dispute.

What is the granular layer of Tomes?

The granular layer of Tomes is the layer of dentine just beneath the enamel or cementum. As the name indicates, it is granular in appearance, showing round or irregular spaces.

What causes the appearance?

The dental tubuli end in bulbous or irregular enlargements which are filled with living protoplasm, and which cause the granular appearance of the layer of dentine just beneath the enamel and cementum, known as the granular layer of Tomes.

Where do the tubuli branch most freely?

In the root portion of the tooth and in the outer portion of their course.

What are the two kinds of curves in the dentinal tubule?

The tubule presents two distinct curves in its course, a double curve in the general direction of the tubule so that at its opening into the pulp chamber it is about perpendicular to the inner surface of the dentine, and at its outer end it is about perpendicular to the line of union between the enamel and dentine. Besides this curve in its general direction the tubule presents a great many wavy curves throughout its course which do not affect its general direction; as many as 200 of these wavy curves have been counted in the length of a single tubule.

Do the tubuli communicate with the canaliculi of the cementum?

There is more or less difference of opinion on this point, but they probably do.

What are the incremental lines of Salter?

The incremental lines of Salter are lines appearing in sections of dried teeth. They run in a direction parallel with the line between the enamel and the dentine, and are probably caused by the shrinkage of the tooth in drying.

What are the inter-globular spaces?

The inter-globular spaces are portions of the dentine where the matrix has not been calcified, thus leaving irregular shaped spaces, filled only with organic matter. They are not empty spaces, but are points of imperfect development. Sometimes they are very extensive.

What are they filled with?

With uncalcified matrix of the dentine. The tubuli pass through them.

Is dentine formed after the tooth is erupted?

Yes. The formation of dentine goes on normally through life, consequently the pulp chamber in young teeth is larger than in old ones. The formation of secondary dentine may be caused by any irritation acting on the pulp, as advancing decay, exposure to heat or cold, etc., etc.

What is the characteristic of secondary dentine?

The structure is less perfect. The tubuli are always crooked and irregular, and not like the tubuli of the body of the tooth.

Is dentine ever reformed after absorption?

No.

When dentine on the surface of a root is removed by absorption, how is the breach refilled?

By the formation of cementum.

CEMENTUM.

Where is the cementum found?

Covering the surface of the roots of the teeth.

What is the cementum sometimes called, especially in the older books and in medical books?

"Crusta Petrosa."

What tissue of the body does it resemble?

Bone.

What is the difference between bone and cementum?

Cementum contains no Haversian canals.

Do you ever find Haversian canals in cementum?

No.

Is there a difference of opinion on this point?

Yes.

What is probably the true nature of what some observers have called Haversian canals in the cementum?

They are places where blood vessels have been embedded in the cementum, forming a canal around them, but these canals have no concentric arrangement of the lamellæ of cementum around them, such as is necessary for the formation of a Haversian system in bone. These canals are simply foramina. Instead of having an apical foramen simply, the tooth has one or more foramina on the side of the root.

These lateral foramina are probably formed in this way. When the dentine is being formed the dental papilla is a cone-shaped structure, the blood vessels entering at the base. As the dentine is formed the papilla is covered in more and more and the blood vessels which entered at the base from all directions are cut off, leaving only those at the center to supply the pulp. Sometimes one of the vessels, instead of being cut off or deflected, persists and is embedded in the dentine, and later when the dentine is covered with cementum the vessel is inclosed in it.

Describe the structure of the cementum.

The cementum is very thin at the neck of the tooth, where it slightly overlaps the enamel; passing down the root it becomes thicker and thicker, often forming quite a portion of the end of the root. It is formed in regular layers one upon the other, like the lamellæ of bone. Between these layers are found small spaces or lacunæ, like the lacunæ of bone, in which the cement corpuscles are found These spaces communicate with each other by minute canals, the canaliculi, which also probably communicate with the dentinal tubuli. In the thin portion of the cementum near the neck of the tooth the lacunæ and also the canaliculi are scarce or entirely absent, but in the thicker portions, around the apex and at the bifurcation of the roots of molars, they are very numerous.

The cementum is filled with the fibres of the peridental membrane which have been embedded in it and then calcified. The size and number of these fibres vary in different animals.

What is the function of the cementum?

The function of the cementum is to furnish the at-

tachment for the fibres of the peridental membrane.

Do you ever have a root without any cementum?

No.

In what portion of the cementum are the lacunæ most numerous?

In the thick portions, at the apex of the root and between the bifurcations of roots.

Where are they usually absent or scanty?

Along the sides of the roots toward the neck of the tooth where the cementum is thin.

Does the observation of the cementum give any judgment as to the age of the tooth?

An observation of the cementum can give only a general idea of the age of the tooth, that is, the length of time the tooth has been erupted, but it may give a very accurate idea as to relative times in the tooth's life history. For instance, if absorption has occurred on the root at one time and hypertrifies at another, you are able to tell which occurred first and something about the time between the two.

Upon what fact is the judgment based?

The cementum is formed in successive layers, so that the layers record the growth of the tissue in the same way as the rings in the wood of a tree record the growth of the tree. A single layer is not necessarily continuous all over the surface of the tooth, but in any given area a layer which lies above has been formed more recently than any layer which lies beneath it.

How do absorptions on the surface of the root leave a permanent record in the tissue?

The cavity formed by the absorption is not filled by

a local formation of cementum confined to the depression, but the next layer of cementum which is formed over the surface of the root dips down into the concavity made by the absorption, and is thicker in that portion so that by the time several layers have been formed the concavity is obliterated.

How are the fibres of the peridental membrane attached to the tooth?

The cementum is built up around them and they are calcified with the cementum matrix.

What other structure in the body do they resemble?

Sharpey's fibres in the attached portions of the periosteum.

By what is the surface of the cementum covered?

The entire surface of the cementum is normally covered by the peridental membrane. When the cementum is uncovered it is by an abnormal recession of the peridental membrane and gum.

What is exostosis?

Exostosis is the formation of an excessive amount of cementum on the root of a tooth. The formation may be confined to a small area or may involve almost the entire root. The hypertrify is usually caused by a thickening of each of the layers of cementum in that portion of the tissue, but there may be as well a greater number of layers in that portion.

PULP.

Where is the pulp found?

Filling the cavity of the dentine.

What is it commonly though improperly called?

The nerve.

Of what kind of tissue is the pulp made up?

The pulp is chiefly made up of embryonal connective tissue richly supplied with blood vessels and nerves.

What is the characteristic of an embryonal connective tissue?

An embryonal connective tissue is one in which the cells are widely scattered in a gelatinous intercellular substance. As a rule, the cells are embryonal in character in that they are capable, under special conditions, of undergoing special development.

Name the four kinds of cells found in the pulp.

Spindle cells.
Round cells.
Stellate cells.
Odontoblasts.

Name the three portions of the pulp in reference to the arrangement of the cells.

The outer surface of the pulp, next to the dentine, is covered by the layer of the odontoblasts.

Just beneath the odontoblasts is a layer in which the cells are very few and widely scattered.

Just beyond this layer the cells are rather more numerous than in the body of the pulp.

And the body of the pulp in which the cells are scattered through the matrix.

Describe the cells of the pulp.

In thin section the cells are seen widely separated. Most of the cells are stellate or spindle shaped. Each cell has a round nucleus about which is a small amount of protoplasm which is prolonged out into the intercellular substance in fine filaments that are not always well seen. The round cells are more numerous in some sections than in others, and it is not always possible to tell whether the cell is spherical or whether the round outline is simply due to cutting a spindle cell across at right angles to its long axis.

If the section is thick the cells seem to be close together, but that is because they lie one above the other.

Where are the odontoblasts found?

The odontoblasts are found covering the outer surface of the pulp next to the dentine.

What is the "Membrana Eboris?"

The membrana eboris is the name given to the layer of odontoblasts by the older writers.

Describe an odontoblast.

The odontoblasts are flask-shaped or club-shaped cells, each with a large oval nucleus. The cells form a single or a double layer on the outer surface of the pulp. The nucleus is found in the enlarged end of the cell away from the dentine; the other end of the cell is

prolonged into a long protoplasmic process which passes into the dentinal tubule and is called the fibre of Tomes or the dentinal fibril. It penetrates the entire thickness of the dentine, and ends next the enamel or cementum in an enlargement in the granular layer of Tomes. In some cases two fibrils can be traced from one cell into two tubuli. The odontoblasts lie very close together, with little or no intercellular substance between them. The fibres branch and divide in their course as the dentinal tubuli do, and these branches communicate with each other very freely in the outer part of their course, putting one odontoblast in communication with a considerable area of the dentine on the outer surface.

What is the function of the odontoblasts?

The formation of dentine.

What embryonal structure is the pulp a remnant of?

The dental papilla.

What are the functions of the pulp?

The pulp has a sensory function and a vital function. The sensory function is the recognition of temperature or rather of changes of temperature and of other causes of irritation. This is peculiar to the pulp; it is not shown by the peridental membrane.

The vital function is the formation of dentine.

What differential diagnosis is based on the sensory function of the pulp?

The differentiation between a tooth with a live pulp and a tooth with a dead one. If the pulp is dead and the tooth be touched with cold water or with a hot instrument no sensation will be experienced, but if the

pulp is alive it will manifest it by a sharp twinge of pain.

The recognition of the cause and initial locality of an alveolar abscess can sometimes be accomplished only in this way.

Is the pulp a specially vascular tissue?

Yes.

What is the characteristic of the blood vessel walls?

All the blood vessels of the pulp have very thin walls. The arteries have usually only a single layer of muscle fibres, and many of the veins, even of considerable size, have but a single layer of endothelial cells in their walls.

Describe the blood supply of the pulp.

One artery, sometimes two or three, enter the pulp at the apical foramen; they pass down the center giving off lateral branches which pass out to the periphery of the pulp, where they break up into a very rich capillary plexus beneath the odontoblasts. From this plexus the blood is collected in the veins which pass up through the central portion and one or more leave the pulp through the apical foramen. An injected specimen shows the vessels very well, the small veins and capillaries making a fine network throughout the tissue, and the large vessels with more direct course occupying the central portion of the organ.

To what pathological condition does the structure of the blood vessel walls make the pulp specially liable?

The thinness of the blood vessel walls, and the fact that they lie in a tissue largely made up of gelatinous

intercellular substance, makes the pulp specially liable to hyperæmia and inflammation.

Describe the condition and the consequent effects.

A chemical irritant acting through a carious cavity or sudden thermal changes affect the muscular wall of the arteries causing them to relax, thus allowing more blood to enter the organ and over-filling the veins and capillaries with blood. This may be simply a passing flush, as when something cold is brought against a tooth in eating, causing a sudden twinge of pain which passes off at once, or if the irritant is constant in its action the condition is maintained.

If a tooth is extracted in a paroxysm of hyperæmia and examined under the microscope, if it is simply a passing flush the blood vessels are found large, distended and filled with blood; but if the pulp has been in that condition for some time, many of the blood vessels will be found to show a pouching of the walls or a varicose condition.

A hyperæmia of the pulp usually passes on to inflammation or returns to the normal condition. In rare cases there may be death of the pulp and complete infarction following a very acute hyperæmia in this way; the attack is very acute, the relaxation of the arteries is so complete and the arterial pressure so high as to compress the veins at the apical foramen, and check the escape of the blood from the pulp The circulation is stopped and the pressure ruptures the thin walls of the vessels and a hemorrhagic infarct results.

When suppuration occurs, what course does it follow?

When suppuration occurs it follows the course of the large veins passing down the center of the pulp.

What is the general course of the nerves in the pulp?

One medullated nerve fibre enters the pulp at the apical foramen and its branches follow, in general, the course of the blood vessels.

Where is the terminal plexus found?

The terminal plexus of nerves is found in the clear layer just beneath the layer of odontoblasts.

Have nerves ever been demonstrated penetrating the dentinal tubuli?

No.

To what degenerative changes is the pulp specially liable?

Calcification and deposits of calcoglobulin.

PERIDENTAL MEMBRANE.

What is the peridental membrane?

The peridental membrane comprises that tissue which intervenes between the root of the tooth and the bony wall of the alveolus.

By what other names is it known?

Alveolo-dental periosteum, or pericementum.

Give one reason why it may be considered the most important of the dental tissues.

The usefulness of the tooth depends upon the health of the peridental membrane. Though the tooth be perfect in every other respect, if the peridental membrane is in an abnormal condition it will not tolerate use in mastication, for the inflamed membrane will not bear the force brought against it.

What are the three functions of the membrane, and define each?

A physical function; to hold the tooth in its position in the jaw.

A vital function; the formation of cementum.

A sensory function; the sense of touch, as distinguished from temperature sense.

Why is it not proper to call the membrane "periosteum?"

"The membrane not only fills the space between the tooth and the alveolar wall, but surrounds the tooth

above the margin of the alveolus and supports the gum about the neck of the tooth. The fibres of the membrane are larger, stronger and more numerous than those of the periosteum in any of its attached portions. The tissue contains structures of a glandular nature never found in the periosteum, and its functions are not analogous to those of the periosteum in any position."

What are the structural elements of the membrane?

Fibres.
Fibroblasts.
Cementoblasts.
Osteoblasts.
Osteoclasts.
Glands.

To which is the physical function due?

The fibres.

What kinds of fibrous tissue do you find in the membrane?

The mass of the membrane is made up of white fibrous tissue. The tissue is divided into two classes—1. The principal fibres. Those which spring from the cementum of the root and are attached to the bone of the alveolus or the surrounding tissue, thus performing the physical function of holding the tooth in its alveolus. 2. The indifferent or inter-fibrous tissue. The tissue made up of fibres and cells which fill the spaces between the principal fibres and surround and accompany the blood vessels and nerves.

Is there any elastic tissue in the membrane?

No. When the white fibres are dissolved by reagents, no elastic fibres are left as in tissues containing both.

Define the principal fibres.

Principal fibres is the name Dr. Black has given to the large fibres of the membrane which are attached at one end to the cementum and at the other to the bone of the alveolus or the tissue of the gum. They are made up of fasciculi of smaller fibres. The fasciculi break up into their component small fibres in the central portion of the membrane, and are reunited to be attached to the bone so that the fibres are continuous from tooth to bone.

Define the indifferent fibrous tissue.

The indifferent fibrous tissue is made up of small fibres accompanied by fibroblasts. These fibres fill the spaces between the principal fibres, and in these places the direction of the fibres is often different from that of the principal fibres. About the blood vessels and nerves the indifferent fibrous tissue is arranged in a concentric way, surrounding and accompanying the vessels and nerves.

Into what parts is the membrane divided for study and reference?

1. Gingival. 2. Alveolar. 3. Apical.

1. The gingival portion surrounds the neck of the tooth below the border of the alveolus and supports the gingivus.

2. The alveolar portion is that between the border of the alveolus and the apex of the root.

3. The apical portion of the membrane surrounds the apex of the root.

Describe the arrangement of the principal fibres in the gingival portion of the membrane.

On the labial and lingual sides of the root the fibres

spring from the cementum in large bundles and pass out, breaking up somewhat into smaller fibres and are lost in their attachment to the fibrous mat of the gum. Toward the mesial and distal sides the fibres bend around laterally and pass directly from tooth to tooth. They spring from the cementum of one tooth as large fibres, break up into smaller fibres which are deflected from their direct course to pass around fibres which are parallel with the áxis of the tooth, and are finally reunited into large fibres and attached to the cementum of the adjoining tooth.

Describe the arrangement of the fibres in the alveolar portion of the membrane.

In the alveolar portion of the membrane the fibres pass from the cementum to the bone of the alveolar wall. In the lower part (near the gingival border) the fibres are large and do not break up into smaller fibres as much, in passing across to the bone, as in most parts of the membrane; in many cases you are able to follow an individual fibre from the cementum to the bone without losing its identity at all.

In the lower part of the alveolar portion just at its border the fibres pass obliquely from the cementum to the bone, being inclined toward the apex of the root. Just beyond the border of the alveolus, and for a short distance along the root, the fibres pass directly from the cementum at right angles to the axis of the tooth. In this position the single fibres are larger, and more often pass from the cementum to the bone without dividing than in any other part of the membrane.

Farther toward the apex the fibres again become oblique, but they are inclined in the opposite direction, and the inclination increases more and more toward the apex. In passing from the cementum to the bone

the fibres run toward the margin of the alveolus, away from the apex of the root.

Many of the fibres springing from the cementum near the apex are large, and as they pass out across the membrane break up into fan-shaped fasciculi to be attached to the wall of the alveolus.

Describe the arrangement of the principal fibres in the apical portion of the membrane.

In the apical portion the principal fibres are large and break up into fan-shaped fasciculi, which spread out in all directions to be attached to the bone. The spaces between the fibres are large and are occupied in the young largely by embryonal tissue; the amount of indifferent fibrous tissue increases as age advances.

In the young, the tissue in this portion resembles that of the pulp or the dental papilla.

What is the dental ligament?

In the gingival portion of the membrane many fibres springing from the cementum pass out, first decussating with, then blending with fibres springing from the bone and bend down into the gingivus, thus forming a strong band of fibres which support the gingivus and hold it against the neck of the tooth.

Discuss the arrangement of the principal fibres with reference to the physical function of the membrane.

The arrangement of the principal fibres is the best that could be devised for holding the tooth in its position in the jaw. At the alveolar margin the fibres are inclined toward the apex of the root holding the tooth into the alveolus. Just below the margin of the alveolus the fibres are specially large and pass out at right angles to the axis of the tooth, supporting it against

the lateral strain of mastication. Farther down in the alveolar portion the fibres are arranged so as to swing the tooth in its socket, supporting it against the force of occlusion.

What are the cellular elements of the membrane?

Fibroblasts.
Osteoblasts.
Osteoclasts.
Cementoblasts.
Glands.

Describe the fibroblasts and their arrangement.

The fibroblasts are spindle shaped cells which lie between the fibres and accompany them. They are much more numerous in the young than in the old.

Describe the osteoblasts of the membrane.

The osteoblasts of the membrane are exactly like those of the periosteum in its attached portions. They are cuboidal cells with granular protoplasm and a large round nucleus. They lie between the fibres on the surface of the bone, with the formation of which they are immediately concerned. They present fine protoplasmic processes extending into the matrix of the bone.

What are the osteoclasts?

Osteoclasts are large or giant cells with many nuclei which have the power of dissolving calcified tissue.

Describe an osteoclast and contrast it with an osteoblast.

The osteoclasts are large, two or three times as large as an osteoblast; they always have several nuclei and are found lying in depressions which they have scooped

for themselves in the surface of the bone or cementum with which they lie in contact.

By what other name are the osteoclasts in the peridental membrane sometimes called?

Cementoclasts.

Why does the word seem unnecessary?

The cells are morphologically the same. There is no difference in appearance or structure between what are called osteoclasts and cementoclasts, and their origin is probably the same; in one case the cell is acting on bone, in the other it is acting on cementum. Osteoclasts may be defined as cells which destroy calcified tissue of any kind; the word cementoclast defines them in reference to their location; that is, a cementoclast is an osteoclast which is destroying cementum.

What are the cementoblasts?

Cementoblasts are cells which form cementum.

Describe a single cementoblast.

The cementoblasts are flattened in form and never resemble the osteoblasts, which are always cuboidal. They cover the entire surface of the root between the fibres, and their outline is notched so as to fit in between and around the fibres. Each cell is made up of granular protoplasm, with a single large, round or oval nucleus. Protoplasmic processes penetrating the cementum have not been demonstrated, though it is probable that they exist.

Describe the formation of the cementum by the cementoblasts.

The cementoblasts cover the entire surface of the root. They form the matrix in regular lamellæ and

then superintend the deposit of lime salts into the matrix.

Occasionally one of the cementoblasts is embedded in the formed matrix and becomes one of the cement corpuscles. The cementoblasts cover the surface of the root, lying between the fibres; as they build up cementum, they include the fibres in the formed cementum and the salts are deposited in the fibres as well as the matrix. In this way the fibres are firmly fastened to the tooth.

Describe the absorptions which occur in the cementum.

When an absorption occurs in the cementum the first thing which happens is the cutting off of the fibres at that point by the osteoclasts; they then attack the cementum, scooping out a hollow in it in which they lie close against the surface attacked. The surface is not softened to any depth, but if the osteoclasts are removed from an absorption surface it is found to be smooth and polished. It is necessary for the cells to be in absolute contact with the surface destroyed.

What may be the cause of an absorption?

Absorptions are very often found on the root and are probably due to many causes, some of which are very obscure. At about the time the tooth reaches full occlusion they are almost always found and are probably caused by the movements necessary to bring the cusps into full occlusion with the opposing tooth.

After an absorption, how is the contour of the tooth restored?

After the absorption has ceased the next layer of cementum to be formed over the surface of the root

dips down into the cavity formed, and in that portion the layer is thicker than on the rest of the root surface, so that after a few layers have been formed the contour of the root is restored.

How are the movements of the tooth, either natural or artificial, accomplished ?

The movements of the tooth and alveolus, such as are necessary in the correction of irregularities of the teeth, are accomplished by a combined or co-ordinated action of the osteoblasts and osteoclasts. The osteoclasts cut off the attachments of the fibres and remove the bone of the alveolar wall in the direction of the pressure which is put on the tooth; then the osteoblasts build in new bone, forming a new alveolus and reattaching the fibres so that the tooth becomes solid again. The fibres are never all cut off at one time; while they are being cut off at one point and the bone absorbed, they are being attached at another by bone being built around them.

The natural movements of the tooth in development from childhood to maturity are accomplished in the same manner.

Describe the movements of the anterior superior teeth in the development from childhood to maturity.

After eruption is complete the entire tooth and alveolus is moved downward and forward with the development of the bones of the face, causing the lengthening of the face characteristic of this period. The movement is accomplished by the same means as the artificial movements in regulating. Bone is built up around the margin of the alveolus and the alveolus is filled up from the bottom, increasing the height of

the alveolar process. In the same time the distance between the tooth and the bone of the alveolus which was great at the time of eruption, to allow the passage of the crown of the tooth, is reduced by the formation of bone all around the wall of the alveolus.

Where are the glands of the membrane found?

The glands of the membrane are found between the fibres close to the cementum.

Describe the arrangement of these structures.

The glands form a network around the root extending almost to the apex. This network is quite close in the gingival portion and becomes more open as you approach the apex. As many as 200 have been counted in a cross section of a central incisor, through the gingival portion.

Describe the cells of these structures.

The cells are epithelial in character with granular protoplasm, which takes the stain strongly; each has a large distinct nucleus. They are arranged in threads like tubular glands. In cross sections they show five or six or more cells, arranged in a circle or whorl, and they are inclosed in a very delicate membrane. The threads are not straight, but wind in and out between the fibres, giving an appearance similar to that of a tubular gland. No lumen or duct has ever been demonstrated.

Describe the blood supply of the peridental membrane.

Four or five blood vessels enter the membrane at the apical space and pass downward, supplying the tissue with a fairly rich capillary plexus. As these vessels pass down through the membrane they receive lateral

branches which enter the membrane through the Haversian canals which open on the sides of the alveolus. These lateral branches are sufficient to maintain the size of the vessels, in spite of the capillary plexus which they supply. At the gingival border they receive branches which enter over the margin of the alveolus. There is, therefore, a double or triple source for the blood supply of the membrane. Vessels entering at the apical space, at the margin of the alveolus and through the Haversian canals in the sides of the alveolus.

What is the importance of this arrangement of the blood supply?

When the vessels entering at the apical space are obliterated by suppuration involving that portion of the membrane, the nourishment of the entire membrane is not cut off, but the gingival and alveolar portions are supplied by the vessels which enter through the Haversian canals in the sides of the alveolus and over the margin.

What disease probably originates in the glands of the membrane?

Phagedenic pericementitis, which first shows a degeneration and finally a suppuration of the glands, resulting in destruction of the membrane.

Describe the changes in the membrane with advancing age.

The thickness of the membrane decreases as age advances by the formation of bone on the inside of the alveolus and the formation of cementum on the surface of the root. The number of cellular elements decreases, the glands become somewhat fewer in number.

In the young membrane the blood vessels are found in the center, half way between the cementum and the bone, and form quite a vascular area there; in the older membrane the blood vessels come to lie close to the bone, often in grooves in the wall of the alveolus.

EMBRYOLOGY.

Define embryology.

Embryology is the study of the development of the individual from the fertilized ovum or egg.

From the standpoint of evolution, what relation is there between the development of the individual and the development of the race or type?

The higher animals pass through in a few months or weeks the development from an animal of one cell to the fully developed type; made up of many tissues with special functions, made up of millions of cells, and with the organs especially adapted to their use. In this development the individual passes through many stages corresponding to types which the race has passed through in its development from the lower forms of life. But these stages are hurried over, as if the race development of many centuries were condensed into a few months in each individual.

What is the ovum?

The ovum is the cell produced by the female, which, when combined with the male element, has the power of reproducing the type

What is the difference between the animals classed as oviparous and those classed as viviparus?

Viviparus animals bring forth their young alive. The oviparus animals lay eggs which hatch outside the

body. Only the early stages of division of the ovum are accomplished in the body of the parent, then the ovum with a small amount of nourishment is discharged to complete its development outside of the parent.

In the viviparous animals there is an ovum just the same, but if fertilized it is retained within the body of the parent and is nourished by the parent till development to the type is completed or is almost completed, when the young is brought forth alive.

What is the sperm ?

The sperm is the male element which unites with the ovum to reproduce the individual.

What is fecundation ?

Fecundation is the union of the sperm with the ovum. More accurately, it is the union of the head of the sperm with the nucleus of the ovum producing the segmentation nucleus.

What is maturation ?

Maturation is a process by which the fecundated ovum divides with karyokinetic figures forming two bodies, the polar bodies, which are cast off before segmentation begins. The exact significance of the process is not known, but has been the subject of much speculation.

What is segmentation ?

Segmentation is the process of division of the fecundated and maturated ovum, first into two, then four, then eight cells and so on till a hollow sphere is formed, the center of which is known as the segmentation cavity.

What is the gastrula ?

The gastrula is formed from the segmentation sphere

by a process of invagination forming a double layered bag. This corresponds to the type of such animals as the hydra and coral.

What are the layers of the blastoderm?

Epiblast.
Mesoblast.
Hypoblast.

Where is the epiblast found?

The epiblast makes up the outer layer of the gastrula or blastoderm.

Where is the hypoblast found?

The hypoblast is the inner layer of the gastrula lining the cavity of the double bag, or the deepest layer of the blastoderm.

Where is the mesoblast found?

The mesoblast is found between the epiblast and the hypoblast. In the gastrula it first appears where the epiblast and hypoblast join around the opening where the invagination took place.

What is the difference between the epiblast, mesoblast and hypoblast, and the epiderm, mesoderm and hypoderm?

The termination "blast" refers to the layers of the blastoderm or gastrula. From these layers the three characteristic embryonal tissues, the epiderm, mesoderm and hypoderm, are formed, and from these all the tissues of the adult organism.

What tissues in the body are developed from the epiderm?

From the epiderm the entire nervous system is developed, the epithelium covering the surface of the

body, the enamel, the nails, the hair, the organs of special sense, and all glands except those opening on the alimentary canal between the œsophagus and the rectum.

What tissues in the body are developed from the hypoderm?

From the hypoderm is developed the epithelium lining the alimentary canal and the glands opening into it.

What tissues in the body are derived from the mesoderm?

From the mesoderm are derived all of the connective tissues, blood, bone, fibrous tissue, tendon, etc, the muscles and the dentine and cementum.

What is the first indication of the formation of teeth in the embryo?

A thickening of the epithelium along the arch which is to form the jaw, marking out the arch of the temporary teeth. This is known as the dental ridge.

How early does it appear?

The thickening of the epithelium begins as early as the fourth week.

Describe the formation of the dental ridge.

The dental ridge appears very early in foetal life, simply as a thickening of the epithelium on the arch which is to form the jaw. As the cells multiply they not only rise above the level of the membrane, but sink down below it into the mesodermic tissue below, forming what is called the dental groove, the elevation being called the dental ridge.

Trace the formation of the enamel organ from the dental ridge.

The dental ridge thickens with a characteristic folding, and grows down into the tissue beneath. At ten points along the ridge the cells grow down into the tissue below in the form of a thread, which becomes bulbous or club shaped on the deep end, then the bulbous end becomes invaginated, forming the enamel organ.

Describe the fully formed enamel organ.

The enamel organ is a double layered bag, made up of an outer layer of epithelial cells called the outer tunic, an inner layer of epithelial cells called the inner tunic, and a stellate reticulum made up of large stellate or round cells which form a rather open tissue, filling the space between the two tunics. The thread connecting the enamel organ with the dental ridge is broken and the fully formed enamel organ is left covering the dental papilla.

Describe the dental papilla.

The dental papilla is a cone-shaped papilla of mesodermic connective tissue which grows up into the invaginated enamel organ so that the inner tunic is immediately in contact with the surface of the papilla which is covered by the layer of odontoblasts. The function of the papilla is to form dentine, and the remnant of it inclosed in the dentine is persistent as the dental pulp.

What are the ameloblasts?

The ameloblasts are the columnar cells of the inner tunic which form enamel. When they first appear they are in contact with the odontoblasts. The odont-

oblasts form the dentine beginning from the outside and forming inward, the ameloblasts form the enamel beginning from the inside and forming outward. The first formed layer of dentine is the outermost layer of dentine, the first formed layer of enamel is the innermost layer.

In which tunic are the ameloblasts found?

In the inner tunic.

What is the function of the stellate reticulum?

Dr. Williams' work seems to show that the stellate reticulum performs the function of a gland providing the ameloblasts with the material for the calcification of the enamel.

Describe the formation of the enamel organ for the permanent teeth.

When the enamel organ for the temporary teeth is formed, a thread of cells grows down from the band which connects the organ with the dental ridge to form the enamel organ for the permanent tooth, in the same way that that for the temporary one was formed; but as there are eight teeth on a side in the permanent set and only five in the temporary, three enamel organs must take their origin from the dental ridge directly; this usually occurs along the posterior part of the ridge forming the organs for the permanent molars.

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