# LABORATORY COURSE IN HISTOLOGY

ELWYN AND STRONG

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IN

# HISTOLOGY

BY

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# PREFACE.

THE directions here printed represent essentially an outline of the laboratory work in histology, including the minute structure of the nervous system, given at the College of Physicians and Surgeons, Columbia University, N. Y. They are based almost entirely on the permanent study collections which are loaned to the student for the academic year. The instructions are in the main directive, though a certain amount of description has been introduced where the complexity of the section makes necessary an orientation of the structures. Such description has been found of greatest value in the difficult sections of the nervous system. As a whole the directions are intended to enumerate to the student the more important structural features, while their detailed study is left to his own initiative.

Questions have been introduced for the purpose of stimulating the student to supplement and interpret the structures studied in the laboratory.

The histology of the nervous system has assumed such large proportions, that in this college, as well as in many others, a separate course is devoted to it. It is for this reason that the nervous part has been placed separately, forming the second part of the syllabus. The directions cover the microscopic work of the course in neuro-anatomy.

In order to facilitate the introduction of special sections or fresh material, blank pages have been provided, so that the student may note down changes or additions to the laboratory work made by the instructor. In this way the

book is made more adaptable to courses in other institutions, whose teaching material may differ from ours.

It is hoped that this book will economize the time of both student and instructor. The latter will thereby be able to devote more time to informal and individual teaching, and to the discussion of topics which he may deem of especial interest or importance.

ADOLPH ELWYN,
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# CHAPTER I.

## THE CELL.

### A. Cell Structure.

1. Epithelium from skin of onion mounted in normal NaCl solution.

Study with low and high power. Note size, shape and arrangement of cells. Identify nucleus, nucleolus, cytoplasm, cell wall. Study carefully character of nucleus and cytoplasm, and draw several cells showing parts seen.

2. Make a similar study of a thin slice of the potato. Note especially the thick cell wall and the starch granules. What is the shape of the latter? Are they part of the living cytoplasm? Sketch several cells.

3. Section of starfish ova.

Select good cell and study with high power. Note size and shape of cell, nucleus, cytoplasm and cell membrane. Is the latter as well defined as in the epithelium of the onion? Make out the following structures:

In nucleus—Nuclear membrane.
Nuclear sap (karyolymph).
Chromatin and linin.
Nucleolus (plasmosome).

In cytoplasm—Hyaloplasm.
Spongioplasm.
Cell inclusions (metaplasm), consisting here almost entirely of yolk.
Ectoplasm and endoplasm. How do they differ?

Make careful high power drawing, labelling all parts.

4. Dissociated liver cells from salamander.

Study with high power. Note the large spherical nuclei imbedded in cytoplasm. Is a definite cell membrane present? Compare with starfish ovum and onion cells. In nucleus identify nuclear membrane, nuclear sap, linin and chromatin. The chromatin granules are often aggregated into larger masses (chromatin knots, karyosomes, false nucleoli) which must be distinguished from the true nucleoli (plasmosomes). Are there any karyosomes in the cells under observation? In cytoplasm note again hyaloplasm and spongioplasm. Cell inclusions such as fat and glycogen may be present. Draw several cells.

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5. Study and draw demonstration preparations showing mitochondrial filaments and mitochondrial granules. Are these part of the living cytoplasm? What is their general significance?

6. Study and draw demonstrations of astral system in the segmenting or maturing egg of some invertebrate. Note the centrosome, centrosphere and astral rays.

7. Cell inclusions. Pigment.

Study pigmented cells from retina. Note shape and arrangement of cells, and the rod-shaped pigment granules which pack the cytoplasm. The clear spots in the center represent the unstained nuclei. Sketch several cells. Study in the same way pigmented cells from choroid, and note the round pigment granules. Sketch.

8. Cell inclusions. Zymogen granules.

Study preparations of salivary glands or pancreas. Note the numerous granules in the distal part of the cell. Are the granules of the same size? Are they part of the living cytoplasm, or products of cell metabolism? Sketch a few cells showing shape of cell, position of nucleus and secretory granules.

9. Cell inclusions. Fat.

Study fat cells in derma of skin or subcutaneous tissue. These are large oval cells consisting of a peripheral rim of cytoplasm, enclosing a large unstained area which in the living state is occupied by fat globules. The nucleus is situated at the periphery surrounded by a small amount of cytoplasm and gives to the cell a signet ring appearance. Sketch a few cells.

10. Section through various organs of salamander.

Review of cell structure. Select various types of cells and study briefly, identifying as far as possible structures studied above. Do the cells vary in size, shape and cytoplasmic make-up? Note especially the shape and structure of the nucleus and its position in the cytoplasmic mass.

**B. Cell Division.**

1. Section through tip of growing onion or hyacinth root to show mitosis (karyokinesis).

Study carefully with high power, find and draw the following stages:

1. Cell with nucleus in resting condition.
2. Nucleus with close spireme.
3. Nucleus with open or loose spireme.
4. Segmented spireme.

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5. Arrangement of chromosomes in equatorial plane (monaster).
6. Metakinesis. Chromosomes show longitudinal splitting. Often hard to find and should be seen in demonstration.
7. Diaster. Several stages in the migration of the daughter chromosomes derived from the longitudinal splitting, to the poles of the cell.
8. Several stages showing reconstitution of the daughter nuclei, the daughter nuclei first forming an open and then a close dispireme.
9. Daughter cells with reconstituted nuclei (in resting condition).

At which of the above stages does cytoplasmic division begin? How does cytoplasmic division take place? Is the nuclear membrane present in all the stages? When does it disappear? When reappear? Answer the same questions with regard to the nucleolus. If possible, make out achromatic spindle. Centrosomes have not been demonstrated in the higher plants.

2. Study demonstration of mitosis in animal cell with especial reference to astral system (centrosome, centrosphere, amphiaster).

3. Study preparation of living yeast cells mounted in Ringer's solution, and sketch several cells in the process of amitotic division. Compare with demonstration showing amitotically dividing animal cells (bladder cells, cells of epididymeal duct). Which is the most common type of cell division? What is the significance of mitosis?

**C. Cytomorphosis.**

1. Section of skin from finger tip.

Select representative cells from each of the several layers of epidermis, study carefully with high power and draw. Note the changes that take place in the shape of the cell and the character of the nucleus and cytoplasm as you go from the innermost layer to the surface. What is meant by cytomorphosis?

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# CHAPTER II.

## EARLY DEVELOPMENT.

### A. The Sex Elements.

1. Section of starfish ova.

Review structure of ova studied at a previous exercise, identifying parts enumerated before. What is the shape of the cell? Its comparative size? How are the deutoplasmic (yolk) granules distributed? What is their significance?

2. Human ovary. Study of ovum (primary oöcyte).

Find ovum in Graafian follicle and study with low power. Note the nucleus cytoplasm, perivitelline cleft and zona pellucida. (The ovum is surrounded by follicular cells, the innermost layer of which forms the corona radiata). As in previous slide, identify the various structures in nucleus and cytoplasm. Is the nucleus rich in chromatin? Are yolk granules present? If so, how distributed? Is there a differentiation into ectoplasm and endoplasm? To what type does the human ovum belong, judging from amount and distribution of yolk present? Make careful drawing.

3. Study ovum of frog. Compare with human ovum regarding size, shape, position of nucleus, amount and distribution of yolk. What is meant by the following terms: meiolecithal, mesolecithal, polylecithal, isolecithal, telolecithal, centrolecithal?

*Note.*—The importance of the yolk granules can hardly be overestimated. Yolk represents stored up food stuff containing the elements necessary for the growth of the embryo.. In addition, it exerts in a purely physical way a profound influence on the growth of the embryo, as will be seen in subsequent studies.

4. Living spermatozoa from guinea pig.

Under low power there will be seen in the fresh preparation numerous flagellated cells in rapid movement. Occasionally a cluster of spermatozoa may be seen moving in a unit. Study with high power. When movement has slowed down or ceased, make out the acrosome (perforatorium), head, body and tail of the spermatozoa, noting carefully the shape and relative size of each. Find spermatozoa showing profile view. The head will appear flattened, the acrosome resembling a spur extending forward. Draw, showing face and profile views.

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5. Human spermatozoa. E5.

These are extremely difficult to find owing to their minute size. A careful low power search will reveal a number of bluish granules. Study these carefully with high power. Each granule has a small filament coming from it. This is the tail, the granule representing the nucleus of the head. Can you see a small amount of cytoplasm surrounding the nucleus? Is a middle piece (body) discernible? How does the human sperm compare in size with that of the guinea pig? Draw.

*Note.*—Compare the two sex elements wth regard to size and shape. With what function is the peculiar shape of the sperm associated? What is the significance of the voluminous cytoplasm of the ovum? As far as you know, is the chromatin content of the two sex elements correspondingly modified?

**B. Maturation and Fertilization.**

1. Maturation of Ascaris ova.

The scattered ova of the thread-worm Ascaris present a number of stages of the maturation process. In this species the maturation divisions take place after the entry ot the sperm. The latter (male pronucleus) will be recognized as a dark granule in the interior of the cytoplasm. Find, study and draw the following stages:

Tetrad stage. How many tetrads present? How different from ordinary chromosomes?
First maturation spindle.
First polar body (dyad stage).
Second maturation spindle.
Second polar body.
Male and female pronuclei. Are chromosomes distinguishable?

What is the numerical relation of tetrads to the somatic chromosomes? What is the significance of the polar bodies? Are polar bodies formed during spermatogenesis?

2. Spermatogenesis (grasshopper, salamander, mouse).

Study demonstration preparation showing spermatogonia, primary spermatocytes, primary spermatocyte division, secondary spermatocytes, secondary spermatocyte division, spermatids, and spermatozoa in several stages of development. Compare the process of maturation in the sperm and ovum. Is the process essentially the same in both? What are the main differences?

*Note.*—What types of maturation are recognized? Characteristics of each type? General significance of maturation?

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3. Study demonstrations showing fertilization of sea urchin ovum, noting entry of sperm, approach of the two pronuclei, formation of astral system, and nuclear changes during first segmentation division. How is the amphiaster formed?

**C. Cleavage, Blastula Formation.**

1. Cleavage of sea-urchin and starfish ova.

Study several slides showing cleavage stages from 2 cell stage to late blastula and draw a representative series. Is cleavage complete? Equal? How many layers of cells in the wall of the blastula?

2. Cleavage of frog ova.

The specimens represent 32 cell stages in vertical section. Study with ocular and low power. Are the blastomeres of the same size? Are the pigment granules equally distributed? Which are micromeres and which macromeres? Which the animal and which the vegetal pole? What type of cleavage is shown? The small cavity in the interior of the egg is the segmentation cavity. Draw, showing all parts. Under high power note large amount of highly refractile yolk granules in macromeres. Is yolk present in micromeres?

*Note.*—How does the yolk affect the process of cleavage? How are eggs classified as to their yolk content? To what class does the starfish egg belong? That of the frog? What are the so-called "laws" of cleavage? How do they explain longitudinal and latitudinal division?

3. Blastula of frog, vertical sections.

Study with ocular and low power. The wall of the blastula shows a thinner roof consisting of pigmented micromeres, and a thicker floor consisting of macromeres containing a large amount of yolk granules. The yolk cells extend mound-like into the eccentrically placed segmentation cavity. Note carefully the marginal zone, transitional between micromeres and macromeres. This is a region of great importance in the subsequent stages. Compare blastula of starfish and frog. Draw, showing parts studied. Under high power study briefly the distribution of pigment and yolk granules. Can you see the cell boundaries of the micromeres? of the macromeres?

**D. Gastrulation. Germ Layers.**

1. Section through gastrula of frog.

Study with ocular. Select gastrula with opening in ectoderm through which the pale staining cells of the yolk plug protrude. The opening is the blastopore. The gastrula con-

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sists of an outer more pigmented layer (ectoderm), and an inner less pigmented layer (entoderm). The entoderm is thin on one side, but much thicker on the other side where it becomes continuous with yolk plug. The cavity enclosed by the entoderm is the archenteron (primitive gut). Low power. The ectoderm is seen to consist of several layers of pigmented cells of the yolk entoderm protrude through the blastopore derm becomes continuous with the thin entoderm (protentoderm) forming the roof of the archenteron. Follow the protentoderm and note its merging with the heavier mass of yolk entoderm which forms the floor of the archenteron. Some cells of the yolk entoderm protrude through the blastopore forming the yolk plug. Does the ectoderm of the ventral lip become continuous with the entoderm, as in the dorsal lip? How do you explain this difference, if any? In many cases two cavities will be seen separated by a thin layer of yolk cells (the completion plate). The rupture of this completion plate will unite the original archenteron with the segmentation cavity still remaining, producing a more spacious archenteron. Note that the blastoporal lips are greatly thickened, consisting of a solid mass of cells. These cells form the anlage of the peristomial mesoderm. Make careful drawing showing all parts.

*Note.*—How does gastrulation in frog differ from that of Amphioxus? How is this difference explained to a large extent? Does the gastrula of the frog already show evidence of bilateral symmetry? If so, locate the anterior, posterior, dorsal and ventral sides of the embryo.

2. Transverse section of frog embryo. Late stage in formation of neural tube.

Study with ocular and low power. The outline of the embryo is symmetrical except on the dorsal side where an elevation appears due to the developing neural tube. The ectoderm consists of several layers of deeply pigmented cells. Note the medullary folds and medullary groove (or canal if the folds have fused). Is the ectoderm continuous with the medullary (neural) plate? From what germ layer is the neural tube derived? The archenteron is surrounded by entoderm, thin dorsally but forming a heavy mass ventrally. Note the character of the entodermal cells immediately lining the enteric cavity. The mesoderm is the layer between ectoderm and endoderm. Is it sharply demarcated from the two primary layers? On the sides of the neural tube the mesoderm is thickened to form the primitive somites (segments) of the embryo. The oval mass of cells directly underneath the neural tube and between the two somites is the notochord (chorda).

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Is there any evidence of a cœlomic cavity? Make careful drawing, labelling all parts.

*Note.*—Distinguish between peristomial and gastral mesoderm. Compare chorda and mesoderm formation with that of amphioxus.

3. Chick embryo of about 27 hours incubation. Section through region of primitive streak.

Low power study. The blastoderm appears as a narrow band in the middle portion of which may be seen the three germ layers. Note the sharp notch on the ectodermal surface where the three layers are fused. This is the primitive groove, and the fused layers underneath constitute the primitive streak. Trace ectoderm along its entire extent and note that toward the end of the section it rests upon the yolk (stained black). Trace entoderm. Does it extend laterally as far as the ectoderm? The zone where it merges with the yolk is the germ wall. Trace mesoderm in similar fashion. Where does it end? Drawing. With high power study primitive streak region noting shape and arrangement of cells in the three layers. Draw. Trace the layers to germ wall. Compare ectoderm of this region with that of primitive streak. Are nuclei present in the yolk mass? Note that near the entoderm the yolk granules are smaller than near the end of the section. Can you explain this fact? Study mesoderm cells of this region. Does mesoderm extend farther laterally than entoderm. Draw portion of germ wall region.

*Note.*—It must be kept in mind that the germ layers are spread out flat on large yolk mass, from which they were removed previous to preparation. The space underneath the entoderm between left and right germ wall is the archenteron. When viewed from above that portion of the blastoderm covering archenteron appears translucent and is called the area pellucida. The surrounding portion of the blastoderm appears opaque and is called the area opaca.

4. Chick embryo of about one day incubation. Section through various regions of embyro.

Study representative sections from anterior, middle and posterior regions of embryo. How can you identify region of primitive streak? What are the main differences in sections anterior to primitive streak? Sketch section through cranial region.

5. Chick embryo (about 36 hours incubation).

Compare with (4). Note ectoderm extending on each side, invaginating medullary plate and medullary groove, notochord, and entoderm extending from germ wall to germ wall. Meso-

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derm forms a definite somite on each side of notochord. Laterally somite is continuous with a narrower portion the intermediate cell mass (nephrotome). Lateral to nephrotome mesoderm splits into parietal and splanchnic layers. What is the cavity enclosed by these layers? Where does cavity end? Trace parietal and visceral layers.? In the latter numerous spaces are seen containing cells. These are blood-vessels with included blood cells. The two thin walled vessels lying ventral to the somites are the dorsal aortæ.

High power. Study and compare cells making up the following structures: Neural plate, non-neural ectoderm, mesodermic somites, nephrotome, parietal and visceral layers of mesoderm, entoderm. How far does ectoderm extend? Mesoderm? Delimit area pellucida, area opaca.

6. Chick embryo (about 42 hours incubation).

Low power. Compare with (5) and identify same structures as before. What main changes have taken place? Note the large number of blood-vessels found in visceral layer of mesoderm. Under high power note carefully the nature of tissues composing the various structures studied. Make careful outline drawing and fill in details. What is meant by somatopleure? splanchnopleure? Is there any evidence of amnion formation?

7. Chick embryo (about 62 hours incubation).

Study under low power and compare with (6). Identify the neural tube, notochord, dorsal aortæ. Ventral to the notochord is seen an inverted groove due to the convergence of the opposite splanchnopleures. This is the intestinal groove and is lined by entoderm. Note that a short distance from the midline the somatopleure (ectoderm and parietal mesoderm) bends sharply ventrad forming a groove. This is the lateral sulcus which delimits the body of the embryo from the extra-embryonic portion of the germ layers. Trace remainder of somatepleure. Identify amnion, chorion. Of what layers does each consist? Identify amniotic cavity, extra-embryonic cœlom. Study the mesodermic somite. Note its differentiation into narrower epithelial bands, the myotome or muscle plate, and a larger mesial portion, the sclerotome, consisting of more loosely arranged tissue. Is there any evidence of a cavity (myocœle) in the somite? To what other cavity studied is this homologous? The nephrotome (intermediate cell mass) has enlarged and bulges into cœlom. In it identify the post-cardinal vein, the kidney duct (mesonephric duct) and mesonephric tubules. Make large low power drawing showing parts studied. Emphasis should be laid on proper proportion

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of parts. Study is facilitated by tracing separately each germ layer. As in previous slide study various structures under high power noting the nature and arrangement of its cellular make-up.

**E. The Vascular System. Early Development.**

*Note.*—Most of the following slides have been studied before. They are now reviewed with especial reference to the vascular system.

1. Chick embryo (about 27 hours incubation).

Identify mesoderm. A short distance from primitive streak there may be seen in mesoderm clumps of cells. These blood-islands are the earliest anlages of blood-vessels and blood tissue. Study cells under high power. Revise earlier drawing.

2. Chick embryo (about 36 hours incubation).

Identify dorsal aortæ. Study blood-vessels in visceral layer of mesoderm. Note endothelial lining and included primitive blood cells. Are all the blood cells detached from the endothelial wall? Explain. All these blood-vessels belong to the vitelline circulation.

3. Yolk sac of chick.

Note again blood-islands in mesoderm (close to entoderm). Are any blood-vessels present? Compare with (2).

4. Chick embryo (about 42 hours incubation).

Study and compare with (2). What changes have taken place?

5. Heart of chick (about 42 hours incubation).

Locate neural tube, notochord, dorsal aortæ. Note shallow foregut cavity ventral to notochord. Below the foregut is the tubular heart. Note the inner endothelial, and outer mesothelial wall. How has the heart been formed? What is the dorsal mesocardium? From what part of this primitive heart does the latter musculature (myocardium) develop? The part of the cœlom surrounding heart is the pericardial cavity. The lateral sulcus and early amniotic folds are shown in this specimen. Drawing of complete embryo.

6. Demonstration of models showing complete circulation of early chick embryo.

**F. The Nervous System.**

*Note.*—The following slides are reviewed with especial reference to the nervous system. Revise drawings previously made.

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1. Chick embryo of one day incubation.

Select section through primitive axis (anterior to primitive streak). Note neural plate, neural groove, neural folds. Of what tissue is neural plate composed?

2. Chick embryo, about 36 hours incubation.

Identify same structures as in previous slide. What changes have taken place?

3. Chick embryo, about 42 hours incubation.

The neural tube has been formed. The walls are thick, the roof and floor plates thinner. What is meant by neural (ganglionic) crest? Is it seen in this specimen? Explain the presence of the skin ectodermal layer dorsal to the neural tube.

4. Chick embryo, about 62 hours incubation.

Note the relative thickness of walls, floor plate and roof plate. A shallow furrow (sulcus limitans) along each side of central canal divides each lateral wall into a dorsal (alar) and ventral (basal) plate. Under high power examine region outside of neural tube on its dorso-lateral surface. Groups of large cells may be seen invading the region of the sclerotome. These are cells migrating from the neural crest, and form the rudiments of the spinal ganglia.

5. Pig embryo (20 mm.).

Note that the neural tube is completely surrounded by mesenchymal tissue. The wall of the neural tube exhibits three well marked areas, an inner (nuclear) layer, a middle (mantle) layer, and an outer (marginal) layer. What is the significance of these layers? Is a sulcus limitans visible? Outside of neural tube identify: spinal ganglion, dorsal root, ventral root, spinal nerve, ramus communicans, sympathetic ganglion. Discussion of specimen at time of study. Draw, showing all parts seen.

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# CHAPTER III.

## EPITHELIUM.

### A. Simple Epithelium.

1. Simple squamous epithelium (mesothelium) from mesentery of rabbit.

Select small area and study with high power. Note shape of cell, irregular serration of cell borders, position and shape of nucleus. Draw small area.

2. Stomach (or intestine).

A layer of simple squamous epithelium (mesothelium) lines the outer surface of the stomach and intestine. Note flatness of the cells, and the oval bulging nuclei. Draw small strip.

3. Simple squamous epithelium (endothelium) from pia mater.

With high power study carefully the lining of the smaller blood-vessels. Compare with preceding slides. Note that the long axis of the endothelial cell is parellel with that of the blood-vessels. Sketch.

4. Endothelium from blood-vessels of skin.

Select small blood-vessel shown in cross-section and study endothelial lining. Sketch.

5. Study simple squamous epithelium in alveoli of lung. How does it differ from endothelium and mesothelium studied above?

6. Synovial membrane.

The epithelium lining synovial membranes is sometimes called a false epithelium. It consists of an epithelioid arrangement of connective tissue cells. The cells may appear as simple squamous or low cuboidal. Which type is present in your specimen? Draw small strip.

7. Organs of salamander. Simple columnar epithelium.

Find columnar epithelium of intestine and study with high power. Note shape and arrangement of cells, position and shape of nuclei and character of cytoplasm. Note delicate basement membrane separating cells from the underlying tissue, and the thickened cuticular border of the free surface (distal border). Draw.

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8. Study epithelial lining in stomach and small intestine, making out structures mentioned on previous slide. Compare the size of the cells with those of salamander. Compare cuticular border in stomach and intestine. Draw several cells.

9. Kidney of guinea pig. Cuboidal epithelium.

Study some of the cuboidal cells in the straight tubules. Note the regular outline of the cells, the shape and position of the nucleus. How may these cells be distinguished from squamous epithelium? from high columnar?

10. Liver.

With high power study carefully the polyhedral (cuboidal) epithelium of the liver. Note the general shape of the cell, the large vesicular nucleus and the cytoplasmic inclusions (glycogen granules and fat droplets). The cells are arranged in columns and the cell outlines are difficult to distinguish. Draw small area.

11. Submaxillary. Pyramidal (glandular) epithelium.

The secreting tubules of most glands are lined by cells of pyramidal form (a modification of columnar or cuboidal epithelium). The clear cells, whose protoplasm is unstained, are mucous cells. Study carefully and draw. The purplish staining granular cells are serous cells. Note the coarse granules toward the free end of cell, and clearer zone of ergastoplasm toward base of cell. Draw several cells. Compare with mucous cell.

12. Small intestine. Goblet cells.

Some of the columnar cells of the epithelium become mucous secreting cells (goblet cells). Study with high power and draw several stages in the development of one of these cells.

13. Study ciliated columnar cells isolated from epithelium of trachea. Note shape of cell, position of nucleus, cilia and basal granules. Draw.

### B. Stratified Epithelium.

1. Œsophagus. Stratified squamous epithelium.

With high power find purplish staining inner border which comprises epithelium of œsophagus. Make careful high power study, noting the basement membrane, the shape of the cells, the shape and position of the nuclei, and the character of the protoplasm, in the various layers of the epithelium. Draw narrow strip through entire layer.

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2. Study stratified squamous epithelium in thick skin. Compare with œsophagus. Study carefully cells from the deeper layers, noting especially the intercellular bridges. What is the probable function of the latter? Draw a few cells.

3. Transitional epithelium from ureter or bladder.

Study under high power and compare with stratified squamous epithelium with regard to thickness of membrane and shape of cells. Why is it called transitional? Draw strip through entire thickness.

4. Study stratified columnar epithelium lining the cavernous portion of the urethra and compare with the other types studied. Draw strip.

5. Pseudo-stratified (stratiform) epithelium from trachea.

Find epithelial lining of trachea and study with high power. Note shape and arrangement of cells, broad basement membrane, cilia and basal granules. (The superficial columnar cells of this type of epithelium are nearly always ciliated.) Is this a true stratified epithelium? Draw narrow strip.

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# CHAPTER IV.

## THE CONNECTIVE TISSUES.

### A. Connective Tissues Proper.

1. Pig embryo (14 mm.). Mesenchyme (embryonal connective tissues).

Select area of loosely arranged tissue and study with high power. Note the loosely packed cells whose processes anastomose to form a network (syncytium). The spaces between the cells are filled with a clear fluid ground substance (matrix). Draw a small area, showing shape, structure and syncytial character of cells. (Mesenchyme is the mother tissue from which all the types of adult connective tissue are formed.)

2. Umbilical cord of fœtal pig.

Study the embryonal (mucous) connective tissue, noting the shape and arrangement of the cells and the nature of the intercellular substances. Are fibrils present in the latter? Draw small area.

3. Umbilical cord of 7 months fœtus. Mucous connective tissue.

Select area near periphery and study with high power. Compare with preceding slide, especially with regard to form of cells, and character and quantity of intercellular substance. Draw small area.

4. Areolar (fibro-elastic) connective tissue from sub-cutis.

Study with low and high power. Note the small number of cells and large amount of intercellular substance consisting of clear matrix, collagenous and elastic fibers. The collagenous fibers are arranged in wavy bundles. Do the bundles anastomose? The elastic fibers are stouter, run singly and may branch, forming a wide-meshed network. The cells are but vaguely indicated by the stain. Find, if possible, the following types: Lamellar cells (ordinary connective tissue cells), plasma cells, mast cells. Draw, showing all parts seen.

5. Areolar (loose fibrous, fibro-elastic) connective tissue from skin.

As before note the large amount of intercellular substance. The cells are scattered and recognized mainly by their nuclei, the cytoplasm having shrunk during preparation. Note the clear matrix and the pink staining wavy bundles of collagenous fibers. Can you see any elastic fibers? How do you explain their seeming absence? Examine various portions of the connective tissue on the slide, and note the varying density of

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fiber arrangement. Note especially condensation of connective tissue around blood-vessels and glands. What is the probable explanation? Draw small area.

6. Study demonstration preparation showing elastic fibers in areolar connective tissue of skin.

7. Inactive mammary gland.

Study the fibrous connective tissue and compare with previous slide. Note the more compact arrangement of the intercellular substance.

8. Ovary of 10 year old child.

The fibrous connective tissue of the ovary is exceptionally cellular. Study with high power. Note the close arrangement of the connective tissue nuclei, and the collagenous fibers in the intercellular substance. Draw small area.

9. Muscle and tendon. Dense white fibrous connective tissue.

The tendon is seen in longitudinal section, and may be distinguished from the muscle by its lighter stain. Study with high power. Note densely packed collagenous fibers arranged in parallel rows to give tensile strength. The ground substance is scanty and the cells few in number. Study shape and arrangement of cells. Draw.

10. Elastic connective tissue from Ligamentum nuchæ of elephant.

Study with high power. Note the coarse elastic fibers surrounded by a small amount of fibrous connective tissue in which may be seen the nuclei of connective tissue cells. Draw transverse and longitudinal section.

11. Adipose (fat) tissue from skin.

Adipose tissue is a modified type of areolar tissue. Under low power fat appears as groups (lobules) of large ring-like cells, fibrous connective tissue separating the lobules, and to a less extent the individual cells. Sketch, showing lobule and connective tissue investment. Study and draw a few cells under high power noting the thin layer of cytoplasm, the nucleus, the intercellular connective tissue and the small blood-vessel. Be sure to distinguish the nuclei of the intercellular connective tissue from those of the fat cells. Explain the ring-like appearance of the cells.

12. Developing fat from fœtal pig.

The fat globules are stained black by osmic acid. Find and draw several cells in different stages of fat formation.

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13. Reticular connective tissue from lymph node.

In the lighter portion of the specimen will be found a delicate pale staining reticulum, showing flat stellate cells at the intersections of the anastomosing fibers. Study carefully and draw small area. What is the relation of the cells to the fibers? Note the great number of dark staining cells (lymphocytes) found in the meshes of the reticulum. These must be carefully distinguished from the cells of the reticular tissue. The reticular tissue plus the enmeshed lymphocytes is known as lymphoid tissue. Draw small area of lymphoid tissue.

14. Pigmented connective tissue from choroid of ox.

Study and draw several cells showing shape and arrangement of cells and character of pigment.

15. Cornea of rabbit, to show relation of cells in connective tissue.

Two specimens will be found on slide. The silver nitrate preparation shows the cell spaces clear and intercellular substance dark. The lighter gold chloride preparation shows the converse of the first picture. No details of structure are seen. Study shape of cells with high power. Do the cells anastomose? Sketch several cells.

**B. Cartilage.**

1. Hyalin cartilage from trachea.

Low power study of complete plate of cartilage. Note homogeneous matrix, shape and grouping of cells, cell capsules and perichondrium. High power study of central and peripheral portions of plate and of perichondrium. Note the transition from the cartilage to the fibrous connective tissue of perichondrium, the cell groupings, lacunæ, capsules and hyalin matrix. Can you find any blood-vessels in the cartilage? Draw strip from central portion through perichondrium.

2. Elastic cartilage from dog's ear.

Find cartilage plate and study with high power. Note the dense network of interlacing elastic fibers permeating the matrix. Compare with hyalin cartilage regarding shape and grouping of cells, lacunæ, perichondrium, and presence of blood-vessels. Sketch strip including portion of perichondrium.

3. Fibro-cartilage from intervertebral disk.

Study with high power. Note the small number and arrangement of the cells, and the dense fibrous tissue (collagenous fibers) filling the matrix. Is a perichondrium present? How does it differ from hyalin or elastic cartilage? From tendon? Draw small area.

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4. In 14 mm. pig embryo study condensed mesenchymal tissue in region of future rib or vertebra. This tissue represents a stage in the development of cartilage and is known as precartilage. Compare cell groupings with those of adult hyalin cartilage. Are capsules present?

**C. Bone.**

1. Ground bone sections, transverse and longitudinal.

Study transverse section under low power. Note the haversian systems (haversian canal and concentric lamellæ), interstitial lamellæ, circumferential lamellæ, lacunæ. Examine haversian system under high power, identifying central canal, lacunæ, canaliculi and arrangement of lamellæ. What are the contents of the canal? of the lacunæ? Why are the contents missing? What is the significance of the canaliculi? Study interstitial and circumferential lamellæ. How do they differ from haversian systems? Find Volkman's canals of interstitial lamella, if present. What is their function? Examine longitudinal section and note, if possible, branching of haversian canals. Draw area (cross-section) including haversian system and interstitial lamellæ.

2. Femur of cat, decalcified, cross and longitudinal sections.

Study with low and high power identifying structures seen in previous slide. In addition, note periosteum, endosteum, bone cells in lacunæ and perforating fibers of Sharpey. What is the significance of these fibers? Draw narrow strip extending from periosteum to endosteum.

3. Spongy bone from transected rib.

Low power study. Note the irregular bone trabeculæ, which anastomose enclosing spaces in which the bone marrow is contained. Have the lamellæ a definite arrangement, as in compact bone?

4. Intramembranous bone development. Skull of human fœtus.

With low power identify periosteal and endosteal regions, bone trabeculæ, osteogenic tissue, osteoblasts. How are the latter arranged? Significance? Draw strip through bone. Under high power study carefully shape and arrangement of osteoblasts. What is their relation to the bone trabeculæ? In the trabeculæ are found numerous lacunæ enclosing bone cells. How have these been formed? The loose tissue surrounding the trabeculæ is osteogenetic tissue. How are the osteoblasts related to this tissue? Study the blood-vessels, especially with regard to size of lumen and thickness of wall. Compare vas-

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cularity of developing bone with that of adult bone. From some of the trabeculæ may be seen extending fine pink staining spicules. These are calcified fibers. What part do they play in bone formation? Search your slide carefully and note the occasional presence of large multinuclear cells. These are the osteoclasts, and are usually found closely applied to the bone, often in a small indentation in the bone (Howship's lacuna). What is the significance of the osteoclasts? On what surface of the bone trabeculæ are they usually found? Explain. Study carefully tissue of periosteum. Of what tissue does adult periosteum consist? Draw strip through whole of thickness of bone showing parts studied.

5. Intracartilaginous bone development. Leg bones of pig embryo.

Study with ocular and low power. Make out,—

Shape of bone.

Periosteum (or perichondrium).

Center of ossification. In this region will be found osteogenetic tissue, osteoblasts, bone trabeculæ, blood vessels and primary marrow spaces. In the trabeculæ note the presence of degenerating cartilage cells and cartilage matrix. Explain their presence. Underneath the periosteum are elongated plates of bone, the sub-periosteal bone trabeculæ. How are they formed? Compare with intramembranous bone.

Center of calcification. Found on either side of the ossification area. Note especially shape and arrangement of cartilage cells.

Normal cartilage. What type of cartilage is present?

Make topography drawing of complete bone. Under high power study carefully the structure of the following parts: Osteogenetic tissue, structure and arrangement of osteoblasts, bone trabeculæ with included lacunæ and bone cells, blood-vessels. Are osteoclasts present? Study cartilage in area of calcification, and trace to normal cartilage. What changes have taken place in structure and arrangement of cells? Is the change from normal to calcified cartilage abrupt? Draw strip extending from normal cartilage to center of ossification and include periosteum.

*Note.*—How does intramembranous differ from intracartilaginous ossification? To what class does sub-periosteal ossification belong? How do long bones grow in length? in diameter? How is the marrow cavity formed? What is meant by spongy bone?

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# CHAPTER V.

## MUSCLE TISSUE.

### A. Smooth Muscle (Non-striated, Involuntary).

1. Isolated smooth muscle cells from gizzard of chicken.

High power study. Note shape of cell, position and shape of nucleus, myofibrils, sarcoplasm and delicate cell membrane (sarcolemma). Many cells should be examined until all elements are identified. Draw several cells.

2. Smooth muscle from stomach and intestine.

With low power find area showing smooth muscle in cross and longitudinal section.

High power study of fibers in longitudinal section. Note the elongated, rod-shaped nuclei, and arrangement of the fibers into muscular membrane. Sketch small area.

High power study of cross-section fibers. Note arrangement of fibers and position of nuclei. Explain the varying diameter of the fibers, and the absence of nuclei in many of them. Draw small area.

3. Umbilical cord of 7 months fœtus.

Study smooth muscle in the walls of the blood-vessels. Can you find any intercellular cement? Intercellular bridges? Sketch a few cells.

### B. Striated Muscle (Voluntary).

1. Teased striated muscle fibers.

Select suitable muscle fibers and make careful high power study. Note the longitudinal fibrils (myofibrils), sarcoplasm and cell membrane (sarcolemma). Where the fibers have been crushed the sarcolemma may be easily seen spanning the break. Note the alternating dark (anisotropic) and light (isotropic) bands forming the cross striations of the fibers, Hensen's line (mesophragma), Krause's line (telophragma). Find some fibers which show a terminal cleavage into the constituent myofibrils. Draw portion of fiber showing parts seen.

2. Stained striated muscle fibers.

Two specimens will be found on slide. Study pink stained muscle fibers and note position, shape and number of nuclei. Compare with smooth muscle. Draw, showing myofibrils, sarcolemma, nuclei, dark and white bands. Can you see Hensen's

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or Krause's lines? Study purple stained fibers and compare with above.

3. Transected muscle of dog.

Low power. Note arrangement of muscle fibers into bundles separated by connective tissue (perimysium), the connective tissue surrounding group of bundles (epimysium). Sketch.

High power. Note the delicate connective tissue (endomysium) surrounding individual fibers. Make out sarcolemma, myofibrils, sarcoplasm, structure and position of nuclei. What is meant by Cohnheim's areas? Draw several fibers in cross-section.

4. Œsophagus. Upper end.

Find and study striated muscle fibers in cross and longitudinal section. Compare with previous slides.

5. Juncture of muscle and tendon.

Study carefully termination of muscle fibers in tendon. What is the relation of the tendon fibers to myofibrils? to sarcolemma? Note the increased number of nuclei at level of junction. What is their significance? Draw.

6. Demonstration of Purkinje fibers and atrio-ventricular bundle (bundle of His).

**C. Cardiac Muscle (Striated Involuntary).**

1. Teased isolated trabeculæ (fibers) from macerated heart.

Select lighter staining "fibers" and study with high power. Note irregular shape of fibers, position of nucleus, myofibrils, sarcoplasm, sarcolemma, cross striations. Sketch a few fibers.

2. Ventricle of heart, transverse and longitudinal section.

High power study. In longitudinal section note the branching muscle trabeculæ (fibers) forming syncytium. Note shape and position of nuclei, myofibrils, sarcoplasm, sarcolemma, cross striations, intercalated discs. Study transverse section and identify sarcolemma, myofibrils, sarcoplasm and nucleus. How may the cardiac muscle be distinguished from striated voluntary muscle? From smooth muscle? Significance of intercalated discs? Draw small area of fibers in transverse and longitudinal section.

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# CHAPTER VI.

## BLOOD AND LYMPH.

1. Fresh blood.

With sterile needle, prick tip of finger or lobe of ear previously sterilized with alcohol and allowed to dry. Mount small drop under cover slip and study immediately with high power. Note the fluid plasma (matrix) and the great number of red blood corpuscles (erythroplastids, erythrocytes). What is their color when seen under high power? Study corpuscles in face and profile view, and note formation of rouleaux. Are the corpuscles nucleated? Sketch. After a while the plasma will become hypertonic due to evaporation, and corpuscles of shrunken irregular outline will appear (crenated corpuscles). Study and draw. Among the corpuscles may be seen occasional leucocytes, which are colorless and glistening in appearance.

2. As before mount drop of blood on slide under cover glass, and add drop of distilled water. Study under high power and note what changes have taken place. Explain. How do erythroplastids react to hypertonic and hypotonic solutions?

3. Mount drop of blood on slide and let dry. Add drop of distilled water and wait until it dries again. Study under high power the numerous hemoglobin crystals with regard to color, size and shape. Draw a few crystals. Why was the distilled water added?

4. Stained blood smear. Study of leucocytes and blood platelets. Study with high power or oil immersion lens. Various types of leucocytes will be found scattered among the numerous red blood corpuscles. Find, study and draw the following types: small lymphocyte, large lymphocyte, transitional (large mononuclear) leucocyte, polymorphonuclear neutrophilic leucocyte, eosinophilic leucocyte, basophilic leucocyte (mast cell) and blood platelets. (The eosinophiles and basophiles are relatively rare and slide should be carefully searched.) Compare the various types with regard to structure of nucleus, size of cell, relative amount of cytoplasm and granular make-up of cytoplasm. What is the relative abundance of each type in normal blood? Are the blood platelets nucleated? What is their probable origin and function?

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5. Find blood-vessels in wall of stomach and intestine and study contents, identifying the various blood cells present. Sketch.

6. Study contents of the chorionic blood-vessels of a pig embryo and note the nucleated red blood corpuscles. Are they all of the same size and shape? Sketch.

7. Bone marrow. Smear preparation.

Under low power note general cell mass, which seems to be riddled by numerous round or oval spaces. These spaces in the living marrow are filled with fat which has been extracted during preparation of slide. Study with high power or oil immersion lens and identify, if possible, the following cells: (*a*) Nucleated red blood cells (erythroblasts), (*b*) erythrocytes, (c) myeloblasts or marrow cells (primitive blood cells), (*d*) various types of leucocytes, (*e*) giant cells (megakaryocytes and polykaryocytes). Is there any evidence of mitosis? Do you find any blood pigment? Significance? Note also the framework of reticular tissue. Draw cells of each type observed.

What are the main foci of hematopoiesis in the embryo? In the adult? What is the probable origin of blood platelets?

8. Study and draw the various types of blood cells in a smear preparation of lymph. Are red blood corpuscles present? Blood platelets? Does lymph coagulate?

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## CHAPTER VII.

### THE CIRCULATORY SYSTEM.

1. Blood-vessels from pia mater of brain.

Under low power a number of small vessels may be seen. The thicker walled small arteries give off branches which become progressively smaller until the capillaries are reached, forming a network. The wall of a capillary consists of only a layer of endothelium. The capillaries converge to form small veins, which have a larger lumen and thinner wall than the corresponding small arteries. Draw, showing general arrangement and relative diameter of blood-vessels. Make also high power drawing of capillary, small artery and small vein. Identify the contents of the blood-vessels.

2. Skin.

In the derma (lighter stained portion) of the skin numerous blood-vessels are seen in transverse and longitudinal section. Find the following vessels, study with high power and draw: capillary, arteriole, venule, small artery, small vein. How does an arteriole differ from a capillary? from small artery? How may small arteries be distinguished from small veins?

3. Blood-vessels from pia mater. Silver nitrate preparation.

Study some of the capillaries with high power and note outline and arrangement of endothelial cells. What is the relation of the long axis of the cells to the long axis of the blood-vessel? Sketch.

4. Medium-sized artery and vein.

Low power study. The artery may be recognized by its relatively smaller lumen and thicker wall. Note the corrugated inner surface and the three coats (intima, media, adventitia) forming the wall of the artery. Sketch. Study with high power and draw narrow strip through entire wall. Note endothelial lining, internal and external elastic (fenestrated) membranes and relative thickness of the three coats. Make similar study and drawings of vein. Compare artery and vein and note main differences. (The elastic fibers are unstained and hence difficult to recognize. Their distribution will be seen on next slide.)

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5. Medium-sized artery and vein. Section showing elastic fibers.

The elastic fibers are stained deep purple. Study artery and vein, noting the distribution of elastic fibers in each. In which coat are the fibers most abundant? Compare relative abundance in artery and vein. Draw small strip through wall of each vessel.

6. Aorta.

Two sections will be found on slide, the darker one showing elastic fibers in stained condition. Study carefully with low and high power. Note the relatively large intima, the very large media and the narrow adventitia. Compare with wall of medium-sized artery. Can you distinguish a definite internal and external membrane? Study carefully distribution of elastic fibers in the three coats, noting especially the great amount of elastic fibers among the muscle cells of the media. Draw strip through entire wall.

7. Inferior vena cava.

Study wall and note the large amount of longitudinally disposed smooth muscle cells in the adventitia. Compare with medium-sized vein.

8. Study wall of umbilical arteries in umbilical cord. The wall consists of an inner longitudinal and an outer circular layer of muscle. Is elastic tissue present? Collagenous? Compare with umbilical vein on same preparation.

9. Study demonstration preparation of a large cerebral vein, noting the almost complete absence of muscle tissue. Possible significance.

10. Study small lymphatics (from skin, alimentary tract or lymph node). Compare with vein regarding thickness of wall and abundance of muscular and elastic tissue. Draw.

11. In a similar manner study section of the thoracic duct. Identify the three layers and tissue composing each. Compare with vein. Draw.

12. Heart, section through ventricle.

Study carefully with low and high power. Identify endocardium, myocardium, epicardium. Of what tissue is each composed? Make low power sketch through whole thickness, and detailed drawing of portion of epicardium and endocardium. Compare structure of heart with that of artery or vein. What are chief differences? Similarities?

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13. Heart, section through mitral valve.

Study carefully with low and high power. Note the nature of the endocardium lining both sides of the valve, and the fibro-elastic tissue between the two folds of the endocardium. Where is the elastic tissue most abundant? Is muscle tissue present? What type of muscle? How distributed? Significance? Drawing of whole valve.

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# CHAPTER VIII.

## THE LYMPHOID ORGANS.

1. Lymph node.

Study with ocular and low power. Note the capsule and trabeculæ of connective tissue extending into interior of node. Do they contain blood-vessels? Near the periphery (cortex) the dense lymphatic tissue is arranged in the form of lymph nodules with germinal centers, while the central portion is composed of irregular anastomosing lymph cords. Note the cortical and peripheral sinuses. What is their content? Sketch entire node. Make high power drawing of strip including capsule, lymph nodule and portion of medulla. Are erythrocytes present? What is the most characteristic type of cell found in node?

2. Hæmolymph node.

The main structure is similar to lymph node. Identify capsule, trabeculæ, lymph nodules and lymph cords, sinuses. What is the content of the latter? How different from lymph node? Note also the numerous leucocytes and scattered masses of hemoglobin pigment. Significance? Is there any direct evidence of phagocytosis? Draw small area including part of sinus.

3. Study preparation of hemolymph node showing endothelial lining of blood sinuses.

4. Tonsils.

Ocular and low power study, noting arrangement of lymph nodules, capsule, stratified squamous epithelium covering outer surface of tonsils and mucous glands. Do the nodules show germinal centers? Under high power note and sketch small area showing infiltration of stratified squamous epithelium with lymphocytes.

5. Thymus of child.

Study with ocular and low power. Note capsule and interlobular connective tissue dividing gland into more or less complete lobules. Sketch several adjacent lobules noting cortex and medulla in each lobule, and presence of Hassall's (thymic) corpuscles in medulla. Make high power sketch, including portion of cortex and medulla and Hassall's corpuscle. Distinguish latter from small blood-vessel. Compare structure of thymus with that of lymph node.

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6. Spleen.

With ocular and lower power note capsule, trabeculæ containing blood-vessels, splenic corpuscles and splenic pulp. Sketch. Study with high power and draw strip including capsule, splenic corpuscle and splenic pulp. Of what tissues is the capsule composed? How does the splenic corpuscle differ from an ordinary lymph nodule? The splenic pulp consists of diffuse lymphoid cords and intercordal venous sinuses, containing various types of blood cells. Identify the following cells: lymphocytes, erythrocytes, splenic cells (large mononuclear leucocytes). How may the spleen be distinguished from lymph nodes? from hæmolymph nodes?

7. Study preparation of spleen demonstrating the framework of reticular tissue.

**Serous Membranes. Synovial Membranes.**

1. Study pieces of mesentery mounted flat on slide and treated with silver nitrate. The serrated borders of the pavement epithelium (mesothelium) are clearly brought out. Are stomata present? Significance? Draw.

2. Study section of diaphragm or of parietal peritoneum. Note the mesothelial lining and underlying connective tissue. Are lymphatics present? Sketch.

3. Study section of synovial membrane. What kind of cells line the inner surface. What kind of tissue beneath the epithelioid cells? Draw.

*Note.*—The serous membranes are moistened by a lymph-like fluid and are often in direct connection with the lymphatic vessels by means of stomata. The synovial membranes are moistened by a fluid unlike lymph in character and they are included here only for convenience.

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# CHAPTER IX.

## THE ALIMENTARY SYSTEM.

### A. Headgut and Appendages.

1. Section through entire thickness of lip.

The lip is lined on both sides by stratified squamous epithelium forming the epidermis on the external surface. Compare epithelium on both sides regarding thickness and keratinization. Study connective tissue (dermis) below epidermis. Are hair follicles present? Sebaceous glands? Sweat glands? Blood-vessels? Study similarly connective tissue below epithelium of mucous membrane and note the numerous glands. What kind are they? Can you see their ducts? In center of lip note bundles of smooth muscle forming orbicularis oris muscle. Low power drawing through entire lip.

2. Vertical section through tooth, undecalcified.

With low power identify crown, neck, root, enamel, cement, dentine, pulp cavity and root canal. Sketch whole tooth.

3. Study demonstration preparation of ground sections of tooth. Note the hexagonal prisms constituting enamel. In dentine find dentinal tubules? Significance? Study cement. Are lacunæ present? Canaliculi? Compare structure of dentine and cement with that of bone.

4. Transverse section through root of decalcified tooth.

Study pulp under high power, noting delicate connective tissue, blood capillaries and nerves. Near periphery of pulp find odontoblasts (close to dentine). What is their relation to the dentinal tubules? Are lacunæ present in the dentine? Sketch showing pulp and dentine.

5. Section through head of pig embryo. Anlage of tooth.

Find oral epithelium, dental groove, dental lamina. Of what does the latter consist? Draw.

6. Section through head of pig showing late stage of tooth development.

Study with low power and identify (*a*) enamel organ consisting of outer enamel cells, enamel pulp and inner enamel cells, (*b*) enamel, (*c*) dentine, (*d*) odontoblasts, (*e*) dental papilla (future pulp). From what layer is the dentine derived? the papilla? the enamel? With high power make out detailed structure of various parts and draw narrow strip. Are blood-vessels found in papilla?

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7. Tongue, section vertical to dorsal surface.

The tongue is essentially a muscular organ. Study with ocular and low power. Note the thick stratified squamous surface epithelium covering irregular projections of the underlying fibrous connective tissue. These projections together with the covering epithelium form the papillæ of the tongue. Below the mucosa (epithelium and underlying connective tissue) note large amount of striated voluntary muscle. Compare the relative amount of muscle and connective tissue. In mucosa identify filiform and fungiform papillæ. How do they differ? Explain the absence of circumvallate papillæ. Study distribution of striped muscle, noting the longitudinal transverse and vertical arrangement. Make topographical (low power) drawing showing features seen. Are there any glands in the tongue?

8. Circumvallate papillæ from tongue.

Study with low power and draw, noting secondary papillæ, trench surrounding papilla, and the serous glands of Ebner with their ducts. What type of glands are these? Can you find any taste-buds?

## B. Foregot, Œsophagus and Stomach.

*Note.*—The wall of the alimentary tract and many other tubular structures consists of four coats. From within outward these are (1) mucosa (mucous membrane), (2) submucosa, (3) muscularis, (4) fibrosa or serosa.

The mucosa consists of a layer of *epithelium* (often forming glands which may or may not extend into submucosa), a layer of delicate connective tissue (*stroma, tunica propria*) containing the finer blood-vessels and nerves, and a thin layer of smooth muscle called the *muscularis mucosæ* (not always present).

The *submucosa* comprises coarser connective tissue, containing the larger blood-vessels and nerves. The submucous plexus of Meissner is found in this layer.

The *muscularis* consists usually of two layers of smooth muscle, an inner circular and outer longitudinal. In the connective tissue septum between the two layers, is found the myenteric plexus of Auerbach.

The *fibrosa* consists of fibrous connective tissue containing blood-vessels and attaching tube to surrounding structures. The *serosa* (serous membrane) consisting of fine fibrous tissue and a layer of mesothelium, takes the place of fibrosa where the tube or organ extends into the cœlomic cavity.

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The above represents a fundamental but general plan of the structure of the alimentary wall. The individual modifications of the various parts will be noted as they are successively studied.

1. Œsophagus, upper end.

With ocular and low power identify the four coats—mucosa, submucosa, muscularis, fibrosa. Note the stratified squamous epithelium resting on the stroma. Is a muscularis mucosæ present? Note the presence of solitary lymph nodules in stroma. What kind of glands, if any, are found in submucosa? In muscularis find inner and outer layer of muscle. How is each disposed? What type of muscle is represented? Note character of fibrosa. Make topography drawing of narrow strip through entire thickness. Is this a transverse or longitudinal section.

2. Œsophagus, lower end.

Study and compare with previous slide, noting especially changes in muscular coat. What is the distribution of the two varieties of muscle (smooth and striped) in the œsophagus?

3. Juncture of œsophagus and stomach from dog.

Study œsophageal portion identifying parts studied before. Note especially the abundance of mucous glands in submucosa, and type and arrangement of muscle in muscularis. Compare with man. Study zone of juncture with stomach. Is the change from stratified squamous to simple columnar epithelium abrupt or gradual?

4. Stomach, region of fundus.

Ocular and low power. Identify the four coats, noting presence of serosa with its mesothelial lining. Note the temporary ridges (rugæ). What coats are involved in their formation? Note the minute depressions (gastric pits) on surface of mucosa. The submucosa is especially rich in blood vessels. Are there any glands in submucosa? Compare with œsophagus. In muscularis note inner oblique, middle circular and outer longitudinal layer. Is the muscle of smooth or striped variety? Topography drawing.

High power study of mucosa. Study epithelium of the surface of the mucosa, the gastric pits and gastric glands. Select glands in longitudinal section. Make out neck, body and fundus of gland, chief and parietal cells. What is the shape and distribution of latter? Find gland in transverse section, noting again the chief and parietal cells. Note the presence of diffuse lymphoid tissue and solitary lymph nod-

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ules in greatly reduced stroma. Is a muscularis mucosæ present? Draw narrow strip through mucosa, showing detail of structures studied.

5. Stomach. Transition from fundus to pylorus.

Study with ocular and low power. How does the mucosa of the pylorus differ from that of fundus, and is the transition abrupt or gradual? Make high power study of pyloric gland and compare with fundus gland. Note the deep gastric crypt and nature of cells in body and fundus. Are parietal cells present? Enumerate main differences between fundic and pyloric glands. Sketch gland.

**C. Midgut.**

1. Juncture of stomach and duodenum. Longitudinal section.

Study duodenum with low power, identifying four coats and comparing with pylorus part for part. In duodenum note the following:

(*a*) Villi, how do they differ from gastric pits?

(*b*) Intestinal glands (crypts of Lieberkuehn).

(*c*) Duodenal glands (Brunner's glands) mainly in submucosa.

(*d*) Valvulæ conniventes (Plicæ circulares). What coats are involved in their formation? How do they differ from rugæ in stomach? (The valvulæ are poorly shown in this specimen.)

(*e*) Submucosal plexus of Meissner, and myenteric plexus of Auerbach. These will be found in same relative location throughout gastro-intestinal tract.

How does the duodenum differ from pylorus? Is transition abrupt? Topography drawing of duodenum. With high power study cross-sected tubules of Brunner's gland, noting the character of epithelium. What type of gland is it? How distributed? Draw.

2. Jejunum.

Low power study of general topography. Note the mucosa, submucosa, muscularis and serosa. Note the tall valvulæ conniventes and compare with duodenum. In mucosa note slender leaf-shaped villi, crypts of Lieberkuehn, muscularis mucosæ, isolated lymph nodules. In submucosa note blood-vessels, adipose tissue, and find plexus of Meissner. Do you find any Brunner's glands in jejunum? The muscularis is typical, consisting of inner circular and outer longitudinal muscle. Between the two layers find plexus of Auerbach. Examine the structure of serosa, the mesothelial lining of

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which is often torn away. Is this a transverse or longitudinal section? Make topography drawing showing strip through entire wall.

High power study of mucosa. Study villus in longitudinal and transverse section. What layers are involved in its formation? Study epithelium noting the numerous goblet cells, and the striated cuticular border of the cells. The stroma contains connective tissue and lymph cells. Find, if possible, central lymph vessel (chyle vessel) and capillaries. Draw. Study crypt of Lieberkuehn, noting character of epithelium. In the fundus are found cells with coarse eosinophilic granules (cells of Paneth). What is their probable function? Draw. Is muscularis mucosæ present?

3. Small intestine of dog. Osmic acid preparation.

Study epithelium with high power. Note the presence of minute fat globules (stained black) in the epithelial cells of the villi. In the stroma of the villus leucocytes will be found whose cytoplasm contains similar fat droplets. What significance is attached to the presence of fat in these cells? Note also the thick cuticular border, characteristic of the epithelium of the small intestine. Draw portion of villus showing features seen.

4. Ileum.

Study with ocular and low power. Note the aggregation of lymph nodules (agminated follicles) which form Peyer's patch. These nodules are structures of the mucosa but extend secondarily into submucosa. What is their distribution in ileum? In the mucosa they extend to the surface covered only by a layer of epithelium. Are villi present at those places? Note the breaking up of the muscularis mucosæ where the nodules are encountered. The muscularis and serosa are typical. Make topography drawing including portion of Peyer's patch.

*Note.*—Compare the three parts of the small intestine with regard to (*a*) nature and distribution of glands, (*b*) shape of villi and of valvulæ conniventes (plicæ circulares), (*c*) abundance and distribution of lymphoid tissue.

**D. Hindgut**

1. Colon.

Ocular and low power study. Is the section transverse or longitudinal? Are villi present? Valvulæ conniventes? Note the simple tubular glands extending to the muscularis mucosa, and the great number of goblet (mucous) cells. Are cells of

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Paneth present? Note the solitary lymph nodules. Are these confined to mucosa? Is muscularis muscosæ well defined? The submucosa, muscularis and serosa are typical. Find again the nerve plexuses of Meissner and Auerbach. Topography drawing of strip through wall. High power drawing of gland. How does colon differ from small intestine? What are the lineæ coli? Are they shown in the specimen? Explain.

2. Vermiform appendix.

Study with ocular and low power. Note the scattered simple tubular glands in mucosa. Compare epithelium with that of colon. The muscularis mucosa is broken up by the great abundance of lymph follicles which extend into submucosa. The muscularis is well developed. Serosa typical. Topography drawing.

3. Juncture of rectum and anus. Longitudinal section.

Study with low and high power. Compare rectum and anus with regard to (*a*) type of epithelium, (*b*) arrangement of muscle tissue, (*c*) nature of glands.

Low power drawing.

4. Study demonstration preparations of stomach, small and large intestine showing distribution of blood-vessels in the various coats.

**E. The Large Glands of the Alimentary System.**

1. Submaxillary gland.

Ocular and low power study. Note capsule and connective tissue trabeculæ dividing gland into lobes and lobules. These trabeculæ contain blood-vessels and the large ducts (interlobar and interlobular) which may be easily recognized by their regular columnar epithelium. Each lobule consists mainly of terminal secreting tubules, but contains also the intralobular ducts, small blood-vessels and connective tissue. Both serous and mucous secreting tubules are present, the former taking a purplish stain, the latter showing a practically clear cytoplasm. Which are more numerous? Make topography drawing of several lobules.

High power. Study and draw interlobar and interlobular duct, noting type of epithelium, position of nuclei and character of cytoplasm. Study intralobular (secretory) ducts, noting basal striations in cytoplasm. Significance? Draw. Study serous and mucous secreting tubules (acini) and compare with regard to shape of cell, position of nucleus, character and staining quality of cytoplasm. In serous tubule, note central granular zone and clearer basal zone. Around mucous

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tubule find demilunes of Heidenhain (crescents of Gianuzzi). What is their significance? Draw tubule of each type. What type of gland is the submaxillary? What is its duct system?

2. Submaxillary of dog. Resting and stimulated.

With low power note the relative abundance of mucous and serous tubules. Compare with man. Under high power study secreting tubule of resting and stimulated gland. How do they differ? Draw tubule in each stage.

3. Study submaxillary of cat and note the large number of mucous tubules. How do demilunes compare with those of man?

4. Parotid gland.

Study gland with ocular and low power noting as before general sub-division into lobes and lobules, interlobar and interlobular ducts, intralobular ducts and secreting tubules. Are mucous tubules present? With high power study and draw terminal tubule (acinus) and intermediate (intercalary) duct. Note coarse granules of the secreting cells. How are they distributed? Is the gland in resting or secreting condition? What is meant by parenchyma? Stroma? Compare duct system of parotid and submaxillary.

5. Pancreas.

Ocular and low power study. Note capsule and trabeculæ of connective tissue, containing the larger (interlobar and interlobular) ducts and general mass of secreting tubules. Are they serous or mucous tubules? Among the tubules may be seen small oval or circular areas taking a lighter stain. These are the islands of Langerhans. Topography drawing.

High power study terminal tubule (acinus). Note the shape of the cells and position of nuclei. In each cell two areas can be made out, a homogeneous (or finely granular) area containing nucleus, and a central area containing coarser zymogen granules. What is the significance of these granules? Find, if possible, tubules containing centro-acinar (centro-tubular) cells. How is their presence explained? Can you find any intercalary (intermediate) duct? Draw tubule showing parts seen. Study islands of Langerhans, and make out the cords of anastomosing cells surrounded by capillaries. Do the cells contain zymogen granules? Are they connected with the duct system of the pancreas? What is the significance of the numerous capillaries? Draw islands of Langerhans. Study and draw portion of wall of interlobar or interlobular duct. What type of epithelium is present? What type of gland is the pancreas and what is its duct system? How may the pancreas be distinguished from the parotid gland?

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6. Pancreas. Osmic acid preparation.

The tubules are shown in outline, the cells containing zymogen granules. Draw tubule showing distribution of granules.

7. Study and draw preparation of pancreas (guinea pig, rabbit) showing mitochondrial filaments. Possible significance of mitochondria?

8. Liver.

Under low power the specimen exhibits a great number of pink staining anastomosing bands or cords (liver cords) separated by lighter spaces, the liver capillaries (capilliform sinusoids). Closer inspection shows that the cords generally radiate from common centers and that the light spaces correspond in arrangement. Any one of these radial centers represents the cross-section of a lobule of the liver. Note that adjacent lobules are not separated by connective tissue, but that the cords of one lobule anastomose freely with those of another. This great reduction of interlobular connective tissue is characteristic of the human liver. (Compare with liver of pig, noting the connective tissue septa which divide the liver into distinct lobules.) Note that frequently in the center of the lobule there is a small opening (central vein, intralobular vein) from which the cords radiate. Frequently there will be seen between adjacent lobules, a vein, a small artery and small duct bound together by some connective tissue. These are respectively branches of the portal vein, hepatic artery and bile duct, and together with surrounding connective tissue constitute a "portal canal." On one side of the specimen may be seen a portion of the connective tissue capsule which invests the liver. Make topography drawing showing above features.

Make high power study and drawing of liver "cords" and capillaries. Note type of epithelium, position and structure of nuclei and character of cytoplasm. How many rows of cells in a liver cord? Is there a definite cell membrane? What are the secreting tubules of the liver? Note the relatively large size of the capillaries and the endothelial lining wherever possible. Find the stellate cells of Kupfer. How do you explain their presence? What is the relation of the capillaries to the liver cords? Make also high power study and drawing of "portal canal."

9. Liver, blood-vessels injected.

Study blood supply of lobule with ocular and low power. Note the branches of the portal vein and hepatic artery, the intralobular capillaries converging to form central vein (intra-

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lobular vein) and sublobular vein. Make diagrammatic drawing of blood supply of lobule. Under high power note relation of capillaries to liver cells and the presence of intracellular (vascular) canaliculi.

10. Liver. Silver nitrate preparation to show bile capillaries.

Select suitable lobule and study with low and high power. The fine dark brown or black lines are the lumina of the bile capillaries. Where are they situated? Note that fine branches can be traced to the interior of the liver cells. Find, if possible, juncture of bile capillaries with small bile duct. Draw.

11. Liver of dog.

Study with high power, noting the glycogen granules in the liver cells. Draw.

12. Study section of liver treated with Scharlach R. and note presence of fat globules in liver cells.

*Note.*—How does the liver differ in structure from the pancreas? Why is it called a tubulo-reticular gland? Compare the secreting tubules of the liver and pancreas with regard to type and arrangement of cells and blood supply.

13. Gall bladder.

With low power identify the various coats of the wall and note the irregular folds of the mucosa. High power study. What type of epithelium is present? Do you find lymphoid tissue? Glands? What type? How distributed? How is the muscle tissue disposed in the muscularis? Is the outer coat a serosa or a fibrosa? Topography drawing.

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## CHAPTER X.

### THE RESPIRATORY SYSTEM.

1. Larynx. Longitudinal section.

Study with low power. Identify the true vocal cords, the false vocal cords, the laryngeal ventricle, the thyroid and cricoid cartilages. Study with high power. What type of epithelium lines the true vocal cords? The remainder of the laryngeal surface? Of what tissue are the vocal cords composed? Is muscle tissue present? What kind? How disposed? In the submucosa note the presence of mucous glands especially in the region of the false vocal cords. Is lymphoid tissue found? Where most abundant? What is meant by laryngeal tonsil? Make low power drawing showing general topography of larynx.

2. Trachea.

Study with low power and verify details with high power. Identify the three coats (mucosa, submucosa, fibrosa). In mucosa note the stratiform ciliated columnar epithelium, the broad basement membrane, the stroma and elastic layer. Are goblet cells found in the epithelium? Is a muscularis mucosæ present? What kind of glands are found in the submucosa? Where do they open? Note presence of cartilage plates in fibrosa. What type of cartilage? How disposed in trachea? Is this a transverse or longitudinal section? Draw strip through wall.

3. Trachea. Transverse section.

Identify same structures as before, and note the incomplete ring of cartilage. In the interval between the two ends of the cartilage find the smooth muscle tissue constituting the trachealis muscle. What type of muscle? How disposed? Sketch.

4. Lung from dog.

Study with ocular and low power. The specimen appears as a loose-meshed spongy mass in which are seen round or oval openings of definite outline and varying size (blood-vessels, larger and smaller bronchi, and bronchioles). The blood-vessels may be easily distinguished from the bronchi by their thin walls, endothelial lining and content (red and white blood cells). A thin pink staining band along one edge of the specimen is the visceral layer of the pleura. Note the large

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irregular spaces (infundibula, atria), each of which is surrounded by a number of small thin-walled compartments (alveoli). All of these alveoli communicate with the infundibula, though some alveoli appear as closed compartments, the section being above or below their level of communication. If possible find several infundibula in continuity with alveolar duct and terminal (respiratory) bronchioles.

*Note.*—The continuity from small bronchus to terminal alveoli is as follows: Small bronchus, terminal (respiratory) bronchiole, alveolar duct, infundibulum with surrounding alveoli. These connections are hard to find on a thin section, but may often be traced after careful search.

Make topography drawing showing pleura, general arrangement of blood-vessels, bronchi of various sizes, infundibula and alveoli.

5. Lung.

With ocular and low power briefly review structures seen in preceding slide. Make high power study and drawings of wall of large bronchus, small bronchus, and, if possible, of respiratory bronchiole. Compare with regard to character of epithelium, presence of muscularis mucosæ, glands, and cartilage plates. How does larger bronchus differ from small one? from trachea?

Study alveoli in tangential section and note the flat non-nucleated (respiratory) epithelium, among which are found low nucleated cells (fœtal cells). What is the significance of the latter? Study the cross-sected walls of adjacent alveoli noting again respiratory and fœtal cells. What intervenes between the walls of adjacent alveoli? Draw several alveoli.

During breathing many dirt particles pass through trachea and bronchi, ultimately reaching alveoli. Find dust particles in alveoli or in connective tissue surrounding alveoli. What is the ultimate fate of this foreign matter? Give reasons for your conclusion. What type of a gland does the lung resemble morphologically?

6. Lung. Blood-vessels injected. With low power note larger blood-vessels (interlobular vessels) and dense capillary network around pink staining alveoli. Make high power drawing showing arrangement of capillaries around alveolus. What tissues intervene between blood in capillaries and air in alveoli?

7. Study and draw demonstration preparations showing distribution of elastic tissue around pulmonary alveoli.

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# CHAPTER XI.

## THE URINARY SYSTEM.

1. Kidney of guinea pig.

With naked eye note general outline, hilus, renal papilla pointing toward hilus and fitting into cup-shaped space (pelvis). Outside of the kidney, near the pelvis, is seen a transverse section of the ureter. Under ocular and low power note the following parts: Capsule, cortex, medulla, papilla of medulla extending into pelvis. In cortex identify cortical labyrinths (cortical pyramids) and medullary (cortical) rays. Note that the kidney is packed with tubules in transverse and longitudinal section. In the cortical pyramids the tubules are convoluted and among them are found circular objects (the renal corpuscles). What is the direction of the tubules in medullary rays? In medulla the tubules run in a parallel radial fashion, forming the ducts of Bellini which open into the renal pelvis. Make topography drawing of whole kidney.

*Important Note.*—The kidney is a compound tubular gland having a definite arrangement of tubules, which must be clearly understood. Following are the parts of a uriniferous tubule and their location in the kidney, given in the order of their succession: (1) Renal corpuscle, in cortical pyramid, (2) first (proximal) convoluted tubule, also in cortical pyramid, (3) descending arm of Henle's loop, passing straight down into medulla, (4) ascending arm of Henle's loop, extending from medulla into medullary ray and thence back into cortical pyramid, (5) second (distal) convoluted tubule, again in cortical pyramid, (6) a small arched tubule emptying into (7) straight collecting tubule located in medullary ray. The straight collecting tubules converge to form (8) papillary ducts (ducts of Bellini) which run through medulla and open into the renal pelvis which is the dilated portion of the main excretory duct (ureter). What is meant by simple kidney? To what type does human kidney belong?

2. Kidney. Section vertical to surface.

With ocular and low power locate capsule, cortex, medulla, cortical pyramids and medullary rays, noting direction of tubules in each. Make high power study of renal corpuscle, noting the double layer of the capsule (Bowman's capsule) and the glomerulus. Type of epithelium in Bowman's capsule? Find, if possible, renal corpuscle showing neck (leading to first convoluted tubule), and corpuscle showing afferent and

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efferent glomerular vessels. Draw. Make high power study and drawings of first and second convoluted tubules, ascending and descending arms of Henle's loop, arched tubule, straight collecting tubule and duct of Bellini.

Where does the secreting portion of the tubule end, and excretory begin? How is this shown by the staining reactions of the two portions? In each part studied make out type of epithelium, cell outline, position of nucleus, character of cytoplasm, and relative width of tubule.

3. Kidney, tangential section.

Study with low power. Explain why no portion of medulla is seen. How can you distinguish cortical pyramids from medullary rays? Under high power identify and briefly review structures studied on previous slide.

4. Kidney, injected preparation.

With ocular and low power note the arched arteries and veins shown in cross-section between medulla and cortex, cortical arteries and veins, medullary arteries and veins (straight vessels). Find renal corpuscle showing afferent and efferent glomerular arteries and glomerular capillaries. Under high power study and draw glomerulus with afferent and efferent vessels, and portion of capillary net among convoluted tubules.

5. Study demonstration preparations showing shape and distribution of mitochondria in epithelium of convoluted tubule.

6. Ureter.

Study with ocular and low power. Note the three coats (mucosa, muscularis, fibrosa). What kind of epithelium in mucosa? How are the muscle cells disposed in muscularis? How would the muscularis differ in a more distal portion of ureter? Make topography drawing.

7. Renal pelvis.

Study wall and note its similarity to ureter. If possible, observe transition from simple columnar epithelium of papillary ducts to transitional epithelium of pelvis.

8. Bladder.

Study and compare with ureter with regard to (*a*) epithelium of mucous membrane, (*b*) presence of smooth muscle in muscularis, (*c*) presence of glands and lymph nodules. How does the epithelium of the collapsed bladder differ from that of the distended organ? Explain. Topography drawing.

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# CHAPTER XII.

## THE REPRODUCTIVE SYSTEM.

### A. The Male Reproductive Organs.

1. Testis and epididymis.

Study with naked eye and ocular. Identify testis proper, capsule of testis (tunica albuginea) and epididymis. The tunica albuginea is thickened on the flat side of the testis to form the mediastinum testis in which are located a number of irregular, anastomosing dark staining tubules, the rete testis. From the mediastinum connective tissue septa radiate into testis dividing latter into lobules. The epididymis consists of fibrous connective tissue containing blood-vessels and tubules. The tubules with the irregular lumina are the vasa efferentia, those with regular lumina represent sections of the vas epididymis. Review these structures with low power and note that the tunica albuginea has an inner vascular and an outer dense layer. Note also that the testis is packed with tubules (seminiferous tubules) cut in various planes and separated by interstitial tissue. Make topography drawing showing features studied. What type of gland is the testis morphologically? functionally? What represents its secreting portion? Enumerate in order of their succession the various parts of the duct system of the testis. Make careful high power study of convoluted seminiferous tubule in transverse section. Note the fibro-elastic connective tissue forming a more or less definite capsule, and the many-layered epithelium. Identify the various spermatogenic cells—the basal layer of spermatogonia; a few layers of primary and secondary spermatocytes; the small spermatids nearest the lumen; and the spermatozoa, either free in the lumen or with their heads embedded among other cells. How may the spermatocytes be distinguished from the spermatogonia? from spermatids? Note that many of the cells are in active mitosis. Among the spermatogenic cells may be seen some large pale nuclei belonging to the supporting cells of Sertoli. Note general character of stroma, find and study interstitial cells of Leydig. Significance of cells of Leydig? Draw strip through wall of tubule including some of the stroma and interstitial cells.

Study carefully tubules of rete testis, vas efferens, vas epididymis, noting especially the nature of the epithelium. Draw, including in each case some of the surrounding tissue

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2. Vas deferens.

Study with low power and note the various coats—mucosa, submucosa, muscularis and fibrosa. How many layers of muscle in muscularis? How disposed? Is the arrangement of muscle tissue the same along whole extent of vas deferens? Compare with ureter. Examine mucosa with low power and note type of epithelium. Topography drawing.

3. Male urethra (corpus spongiosum).

Study with naked eye, ocular and low power. Note mucosa surrounding irregular lumen, and broad submucosa containing reddish irregular patches (cavernous veins). Is there a definite muscularis? Draw segment through entire wall.

High power study. What kind of epithelium lining lumen? Is the same epithelium found throughout urethra? What kind of tissue is found between cavernous veins? What is meant by erectile tissue? In mucosa find glands of Littré. What type of glands are they? Is a muscularis mucosa present? Draw small strip of mucosa and gland of Littré.

4. Penis. Transverse section.

Study with ocular and low power. Identify the corpora cavernosa with their thick tunica albuginea, the corpus spongiosum containing the urethra, and the integumentary envelope. What forms the septum penis? Are blood-vessels present? Where situated? Under high power study tunica albuginea of corpora cavernosa. Is elastic tissue present? Smooth muscle tissue? In corpus spongiosum make out the various coats of the urethra. Are glands of Littré seen? Topography drawing.

5. Prostate.

Note size and shape of alveoli and the abundance of muscle fibers in the connective tissue stroma. What epithelium lines the alveoli? The ducts? Do you find prostatic concretions (corpora amylacea) in the alveoli? What type of gland is the prostate? Draw alveolus and some of the surrounding fibro-muscular tissue.

6. Study section of Cowper's gland (bulbo-urethral gland) noting especially (*a*) the epithelial lining of the alveoli, (*b*) the character and amount of muscle fibers in the stroma.

## B. The Female Reproductive Organs.

1. Ovary of young girl.

With naked eye and ocular note shape of organ, cortex and medulla. Note that the substance of the medulla is con-

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tinuous at the hilus with an irregular band of connective tissue extending some distance beyond ovary and containing numerous blood-vessels. This is the mesovarium by which the ovary is attached to the broad ligament. Under low power identify enveloping peritoneal layer (germinal epithelium), superficial capsule (tunica albuginea), cortex and medulla. The stroma of both cortex and medulla consists of richly cellular connective tissue, and contains blood-vessels. In cortex note (1) numerous primitive Graafian follicles, each consisting of a large pale staining cell (primary oöcyte) and a layer of small (follicular) cells; (2) Graafian follicles in intermediate stages of growth; (3) older Graafian follicles, identifying follicular cavity, stratum granulosum, germ hill (discus proligerus, cumulus oöphorus) containing ovum, and the follicular capsule (theca folliculi). Make topography drawing. Study and draw under high power (*a*) Germinal epithelium. How does it differ from ordinary mesothelium? (*b*) Primitive follicle showing oöcyte surrounded by a single layer of smaller follicular cells. (*c*) Follicle in intermediate stage of growth. Is a follicular cavity present? (*d*) Portion of older Graafian follicle including germ hill and theca folliculi. In germ hill note shape and structure of ovum, zona pellucida, corona radiata. What is the content of the follicular cavity? How is it formed? How is the ovum extruded? Of what tissue is the theca composed? Find and draw interstitial cells of ovarian stroma. What is their probable function? Compare with interstitial cells of testis.

2. Ovary of adult.

Review structures seen in previous slide and note the presence of corpora lutea and corpora albicantes.

3. Corpus luteum.

With ocular note irregular deep staining core, surrounded by pale convoluted band outside of which is a connective tissue capsule. Under low power note that capsule sends trabeculæ to convoluted bands consisting of lutein cells. The central core is the remnant of blood clot (corpus hemorrhagicum) containing blood cells, fibrin and some connective tissue. Topography drawing. Study and draw lutein cells under high power. What is the function of the corpus luteum? How does it develop?

4. Oviduct, section through ampulla.

Study with ocular and low power. Note mucosa with its primary and secondary convolutions, muscularis and serosa. How many muscle layers? How distributed? What type of

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epithelium in mucosa? Are any glands present? Topography drawing. How do ova reach oviduct?

5. Oviduct, section through isthmus.

Study and compare with previous section regarding size of lumen and distribution of muscle tissue. How may the oviduct be distinguished from the ureter and the vas deferens?

6. Uterus, section through body in resting condition.

Under low power identify endometrium (mucosa), myometrium (muscularis) and perimetrium (serosa). What is the relative thickness of each? In myometrium identify, if possible, stratum submucosum, stratum vasculare and stratum supravasculare. How is the muscle tissue disposed in each of the layers? Between the muscle fibers note the rich connective tissue stroma containing bood-vessels. Topography drawing. Study with high power and draw carefully strip through mucosa including a gland. Note the columnar ciliated epithelium of the surface (often the cells are cuboidal and non-ciliated), the basement membrane containing flattened cells and the cellular stroma. Study epithelium of gland and compare with surface epithelium. What type of gland? What type of secretion? Significance of glands of the uterine body?

7. Uterus, longitudinal section through cervix.

Identify endometrium, myometrium, perimetrium, cervical canal, vaginal portion and fornix. Study with high power. What kind of epithelium lines the surface? the vaginal portion and fornix? Study gland of cervix and compare with gland from body with regard to epithelium, length of gland and nature of secretion. What are Nabothian follicles? Are any seen in your specimen? What is their content? Draw cervical gland.

8. Uterus, early menstrual period.

Under low power identify the three coats and compare relative thickness of each with that of resting uterus. Note that the surface epithelium, the superficial portion of the glands and outer portion of the stroma are destroyed. The deeper portion of endometrium likewise shows disintegration, the glands breaking down, the stroma ragged and containing a large number of red blood cells which have escaped from ruptured blood-vessels. Note that the glands are enlarged (hypertrophied), somewhat tortuous and broken; the vessels engorged with blood. Study carefully with high power and draw strip through mucosa. In myometrium note enlarged muscle fibers. What is meant by decidua menstrualis?

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9. Vagina.

Under low power identify mucosa, submucosa, muscularis and fibrosa. What kind of epithelium in mucosa? Any glands present? In submucosa note sinus-like blood-vessels and mixture of connective tissue with muscle fibers, giving general character of "erectile tissue." What is arrangement of muscle fibers in muscularis? Topography drawing of strip through wall. How may the wall of the vagina be distinguished from that of the œsophagus?

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# CHAPTER XIII.

## THE PLACENTA.

1. Uterus and chorion of pig (simple type of placenta).

Low power study. Identify chorion and uterine wall. Note that the chorion is thrown into folds or papillæ which fit into corresponding depressions of the uterine mucosa, thereby achieving an intimate contact of the two surfaces. In fœtal portion identify chorionic epithelium, amniotic epithelium and intervening stroma containing blood-vessels. In uterus identify the various coats noting especially the more regular distribution of muscle tissue in muscularis (compare with man).

Under high power study carefully and draw strip through chorion and uterine mucosa. Type of epithelium lining chorion? Amnion? Uterine mucosa? Kind of tissue in chorionic stroma? Contents of chorionic blood-vessels. Compare with corresponding parts in uterine mucosa and explain differences. How does nutritive material from the mother reach the embryo?

2. Fœtal placenta, two months.

Under low power identify chorionic epithelium (trophoderm), chorionic stroma and numerous villi in transverse and longitudinal section. In most specimens the trunk of a primary villus is seen as an evagination from the chorion. In the intervillar spaces may be seen dense groups of cells (trophoderm masses) and blood tissue. Explain the presence and source of each. Topography drawing. Under high power study and draw chorionic villus. The epithelium consists of an inner layer of regularly arranged cells (cyto-trophoderm) and an outer syncytial layer (plasmodi-trophoderm). Study nature and vascularity of stroma, and note type of blood cells in blood-vessels. Find cells of Hofbauer. What is their significance? Study and draw portion of trophoderm masses in intervillar spaces, noting size and shape of cells and presence of canalized fibrin. Significance of trophoderm masses and canalized fibrin?

3. Fœtal placenta, six months.

Under low power identify again—amnion and chorion with intervening mesoderm core, villi, trophoderm masses and maternal blood tissue in intervillar spaces. Can you distinguish between floating and fastening villi? Are decidual cells pres-

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ent? Where found? Topography drawing. Study with high power and enumerate changes which have taken place in (*a*) chorionic epithelium. How many cell layers present? (*b*) Character of stroma. (*c*) Vascularity and contents of blood-vessels. Explain. (*d*) Amount of trophoderm masses and presence of canalized fibrin. Draw villus showing parts seen. Study and draw several decidual cells. How do you explain their presence?

4. Maternal placenta, seven months.

Study gravid uterus under low power and identify mucosa (endometrium) and muscularis (myometrium). A number of villi may be seen in close contact with mucosa. Note that the uterine epithelium has entirely disappeared. The stroma shows a superficial compact layer consisting mainly of decidual cells, and a deeper vascular layer containing blood-vessels and the atrophied uterine glands. Under high power study and draw strip through mucosa showing structure of decidual cells and character of uterine glands. Study myometrium and note the enormously enlarged muscle cells. Compare structure of resting, menstruating and gravid uterus.

5. Study demonstration preparations showing section of complete placenta (maternal and fœtal) and identify structures seen before.

*Note.*—What is meant by chorion frondosum, chorion læve, decidua basalis, decidua parietalis, decidua capsularis? Which of these structures enter into formation of the placenta? How does exchange of material take place between the maternal and fœtal blood? What are the types of placenta found in mammals?

6. Umbilical cord.

Identify amnion, stroma, umbilical vein and umbilical arteries. Study with high power. Nature of epithelium? of stroma? Is there any vestige of allantois or yolk sac? How do you explain the unpaired umbilical vein? Compare wall of umbilical blood-vessels with that of normal arteries and veins. Enumerate main differential features. Low power drawing.

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# CHAPTER XIV.

## THE SKIN AND APPENDAGES.

1. Skin from finger tip or palm of hand. Thick skin.

With ocular and low power note the deeper staining epidermis, the dermis (corium) and the subcutis (tela subcutanea). In epidermis identify the various layers (stratum germinativum, stratum granulosum, stratum lucidum, stratum corneum), and note the spiral epidermal portions of the ducts of the sweat glands. In dermis identify (1) pars papillaris sending numerous papillæ into germinative layer of epidermis; (2) pars reticularis containing coarser connective tissue, the larger blood-vessels and nerves. The subcutis consists of fat and loose connective tissue and in it are found the secretory portions of the sweat glands, nerve fibers in transverse or oblique section, and the concentric corpuscles of Pacini. Low power drawing through entire thickness.

Under high power study and draw several cells from each layer of epidermis noting (1) shape of cell, (2) presence and position of nucleus, (3) granularity of cytoplasm, (4) visibility of cell outline. What process is illustrated? Are intercellular bridges seen? Where? Pigment granules? Where found? What is the lining of the epidermal portion of the sweat glands?

Study dermis and tela subcutanea. Find nervous and vascular papillæ and draw tactile corpuscle of Meissner. Study and draw sweat gland. What type of gland? Nature of epithelium of secretory tubules and ducts? How does gland open to exterior? Study and draw Pacinian corpuscles, noting the protoplasmic core and the concentric layers of flattened epithelioid cells separated by seemingly structureless lamellæ.

2. Skin from negro.

Study and draw strip of epidermis under high power, noting the distribution of melanic pigment granules. Compare distribution of such granules in white man and negro.

3. Thin skin.

Low power. Compare with thick skin. What layers are missing in epidermis? Is the dermis as papillated as in thick skin? In the derma may be seen occasional hair follicles in cross-section. Compare abundance of sweat glands in thick and thin skin. Where are they most numerous? Note occasional bundles of smooth muscle in dermis. What do they represent? Draw strip showing features seen.

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4. Scalp.

Study with ocular and low power. As before, note epidermis and dermis with glands and blood-vessels. The striking feature of this section is the presence of hair and the structures connected with it, the sebaceous glands and the arrector pili muscles. In hair, note shaft (projecting above the skin) and root which expands at its lower end into a knob-like enlargement, the hair bulb, enclosing the cup-like hair papilla derived from the corium. The root of the hair is enclosed by the follicle. Do the hairs come out perpendicular to the surface? What is the structure of the arrector pili? What is its function? Find and study sebaceous gland. What type of gland? Where does it open? Topography drawing showing proper proportion of the parts.

Under high power study suitable hair follicles (including hair) in transverse and longitudinal section. Note cortex, medulla and thin cuticle of hair. Make out the inner and outer root sheath of follicle. What is the derivation of the sheaths? In inner sheath make out cuticle, Henle's layer, Huxley's layer and note structure of each. Of what type of cells is the outer root sheath composed? Note the outer connective tissue sheath identifying, if possible, the vitreous (glassy), vascular and fibrous layers. Draw follicle enclosing hair. Study area of transition from root and follicle to hair bulb. Are the various layers of the root sheaths distinct? Explain. Study carefully and draw sebaceous gland. What is its relation to the hair follicle? What type of gland? Epithelium of duct? of secretory alveolus? How is secretion formed?

5. Nail. Longitudinal vertical section.

Study with ocular, verify with low power. Identify nail body, nail root, nail fold, nail furrow. The horny epithelium of the nail fold is reflected over the nail body forming an adherent membrane, the eponychium. The under surface of the free portion of the nail is similarly invested by a horny membrane (the hyponychium) continuous with the epidermis of the finger tip. Note that the nail consists of two layers (1) a stratum lucidum continuous posteriorly with stratum lucidum of epidermis, but ending distally in a free margin; (2) a stratum germinativum continuous with similar layer of epidermis. Is there indication of a granular layer in any portion of the nail? Below the nail note the nail bed (corium, dermis) continuous with the corium of the skin. Is the nail bed vascular? Is it elevated into papillæ? Low power drawing showing parts seen. Under high power study and draw strip through nail body and nail bed.

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6. Mammary gland, active.

Under ocular and low power note the connective tissue trabeculæ dividing gland into lobes and lobules, the interlobar and interlobular ducts, and the groups of terminal alveoli. Are blood-vessels present in connective tissue? Make low power drawing of several lobules including larger duct.

High power study of alveolus. Note the simple cuboidal epithelium, and the great number of fat globules (unstained) found in the lumen. Are similar globules found in the cytoplasm of the epithelial cells? Explain this fact. Note the greatly reduced inter-alveolar stroma containing spindle-shaped cells. Are blood-vessels present in the stroma? Examine section of active mammary gland in which the fat globules are stained black by osmic acid. Note again the presence of fat globules in cell cytoplasm as well as in the lumen. Draw two adjacent alveoli. What type of gland is the mammary gland morphologically? How does secretion take place? What are colostrum corpuscles? At what period are they found in milk?

7. Mammary gland, inactive.

Study with ocular and low power. How does it differ from active gland? Topography drawing.

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# CHAPTER XV.

## THE ENDOCRIN GLANDS.

1. Thyroid gland.

Under ocular and low power note capsule and connective tissue trabeculæ dividing gland into incomplete lobules. Each lobule contains numerous alveoli, oval or irregular in shape, whose lumen is filled with a pink staining homogeneous substance (colloid). How does the colloid get there? Note the fibro-elastic stroma between the alveoli. Low power drawing. Under high power study and draw alveolus. What is the nature of the epithelium? Can you distinguish chief and colloid cells. Are any blood-vessels present in interalveolar stroma? How can you distinguish thyroid from prostate gland? What, in a general way, is the function of the thyroid? What morbid conditions are associated with atrophy and hypertrophy of thyroid?

2. Parathyroid and thyroid of dog.

At one end of the thyroid may be seen a small dark staining area. This is a section of the parathyroid. Study with low and high power. Note the dense cords of cells, separated by stroma containing capillaries and small blood-vessels. Identify "principal" and "acidophilic" cells. Which are in the majority? Draw small portion under high power. Probable function of parathyroid?

3. Human parathyroid.

Study under high power and compare with preceding preparation. Often the gland appears as numerous epithelial masses separated widely by adipose and loose connective tissue.

4. Thymus.

This gland has been previously studied as a lymphoid organ and its structure should be briefly reviewed. What special features indicate its function as gland of internal secretion?

5. Adrenal gland (suprarenal gland).

Under ocular and low power make out capsule, cortex, medulla and fine connective tissue trabeculæ extending from capsule and forming framework of gland. In cortex note the glomerular, fascicular and reticular zones. The medulla is stained light in this specimen. Does it contain blood-vessels? Make topography drawing.

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High power. Study carefully structure and arrangement of cells in the three zones of the cortex. The cytoplasm of these cells is filled with many fat droplets which give to the cytoplasm a reticulated appearance. This is especially marked in the cells of the fascicular zone. Note the presence of brownish pigment granules in reticular zone. In medulla note irregular cords of oval or polyhedral cells which stain deeply with chromic acid salts. These are the "chromaffin" cells of the adrenal gland. What is their specific secretion? Study wall of central vein. How does it differ from other veins studied? Draw strip including capsule, cortex and medulla, indicating structures studied in each.

6. Adrenal of dog.

Compare with man and note that medulla is separated from cortex by thin connective tissue capsule. Significance?

*Note.*—What is the probable function of the cortex? of the medulla? What evidence do we have that the human adrenal represents a fusion of two originally separate glands? What other "chromaffin" masses are found in the human body? What is their origin? What is peculiar about the blood supply of the adrenal gland?

7. Pineal gland (epiphysis). Longitudinal section.

Under low power note body and stalk of gland, capsule and trabeculæ giving the gland an incomplete lobation. Study gland with high power and note (*a*) epithelial ("secretory") cells, (*b*) neuroglia cells and fibers, (*c*) sinusoid capillaries. Reticular connective tissue may be present and mingle with the neuroglia fibers. How can you distinguish "secretory" from neuroglia cells? Do you find any melanic pigment granules? Where? What is meant by brain sand? Is any found in your specimen? High power drawing of portion of gland. What function is ascribed to the epiphysis? From what structure is it derived? What histological features distinguish the old from the young epiphysis?

8. Pituitary gland (hypophysis). Sagittal section.

With ocular and low power identify the posterior lobe (pars neuralis), the intermediate part (pars juxta-neuralis), anterior lobe (pars distalis). The cleft between the intermediate part and the anterior lobe is the lumen residuale. What is the derivation of each of the above parts? Study under high power and draw small area of (*a*) posterior lobe, noting the large amount of neuroglia cells and fibers, (*b*) intermediate part. Note cuboidal cells arranged in form of alveoli, and sinusoidal capillaries. Is colloid present in alveoli?

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(*c*) Anterior lobe. Note capsule and delicate trabeculæ traversing lobe. Note central cords of cells (acidophilic and neutrophilic) surrounded by capillaries, and narrow peripheral zone of basophilic cells. What is meant by "chromophil" and "chromophobe" cells? Significance? What is the probable function of the pituitary gland?

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# CHAPTER XVI.

## NERVE TISSUE.

### A. The Neurone; The Neurone Body.

1. Transverse section of the lumbar enlargement of the spinal cord. Cajal's silver stain. (Neurone bodies and processes stained brown to black, neurofibrils stained black.)

Low power. Note the pia surrounding the cord, the ventral longitudinal sulcus, dorsal septum and central canal (if present). Note blood-vessels in pia mater and cord. Within the cord note the dorsal and ventral gray columns or horns, surrounded by the white matter (here showing transversely cut axis-cylinders of nerve fibers), composing the white columns of the cord. In the ventral horn note the large motor cells, the present object of study. Select a motor cell which displays well its dendrites, nucleus and neuro-fibrils (not stained too darkly nor too pale).

High power. Study and draw the body (perikaryon), dendrites and neuro-fibrils (forking at acute angles), nucleus and nucleolus (dark stained). Do the neuro-fibrils extend into the dendrites? What is their general arrangement? Do you think they anastomose? Find, if possible, and draw a cell showing the axone (axis-cylinder process), distinguishable by its tapering rather abruptly, on leaving the cell body, to a slender thread and then enlarging again to a uniform diameter. Can you distinguish neurofibrils within it? If you find an axone given off from a dendrite, notify one of the instructors. Note everywhere in the gray the cut-off pieces of axones and dendrites of various nerve cells. Do you think the neurofibrils may conduct the nerve impulses? Reasons?

2. Transverse section of the lumbar enlargement of the spinal cord. Nissl's stain (nuclear chromatin and cytoplasmic chromophilic substance of Nissl stained blue).

Low power. Note the same features in general as in the preceding section. Under low power note especially the blood-vessels and the nuclei of neuroglia cells scattered throughout the section. Select a motor cell of the ventral horn which shows its nucleus.

High power. Study and draw the body, dendrites, nucleus, nucleolus and chromophilic bodies, carefully in-

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dicating the distribution, size, shape and arrangement of the latter. Is their arrangement around the nucleus different from that near the periphery? Are there any chromophilic bodies in the dendrites? If so, what is their shape in the dendrites? Find one at the bifurcation of a dendrite. Are there any within the nucleus? Is there any pigment present? If so, draw it. Find, if possible, and draw a cell showing the axone hill, distinguishable by the complete absence of chromophilic bodies. Do you think the chromophilic bodies conduct nerve impulses? Reason? Study the smaller nerve cells found in the gray. Do their nuclei differ from those of the ventral horn cells? How does their shape differ from the latter, also the size, shape and location and arrangement of their chromophilic bodies? Draw several of these cells, selecting cells that differ from each other.

Study and draw some of the cells in the gelatinous substance of Rolando (at the tip of the dorsal horn). These cells show very little cytoplasm in the Nissl stain (cytochrome cells, as distinguished from the preceding somatochrome cells) and their nuclei are not so easily distinguishable from those of the neuroglia cells.

3. Transverse section of the thoracic spinal cord. Nissl's stain.

Study and draw (high power) one or two of the cells of Clarke's column. How do they differ in shape and arrangement of their chromophilic bodies from the cells of the ventral horn? Study and draw one or two cells in the lateral horn. How do they differ from the ventral horn cells?

4. Demonstration. Transverse section of the spinal cord. Golgi's chrome-silver impregnation (isolated cells with their dendrites and axones, often to their finest terminations, stained black. Granules and irregular masses of silver precipitate are usually present).

Note the branching dendrites and the axone if present.

5. Section of the cortex of the cerebellum. Cajal's silver stain.

Note the cells of Purkinje with richly branching dendrites. The axone is often distinguishable.

6. Demonstration. Section of the cortex of the cerebellum. Golgi's chrome-silver impregnation.

Note the fine dendritic branches beset with "gemmules."

7. Section of the cortex of the cerebellum. Nissl's stain.

Study and draw (high power) a cell of Purkinje, showing nucleus and chromophilic bodies. Draw several of the

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cells of the nuclear layer (caryochrome cells). Can you distinguish any cytoplasm in the latter?

8. Section of the cortex of the pallium (cerebral hemisphere). Nissl's stain.

Study and draw (high power) several pyramidal cells. How do they differ in shape and in the size, shape and arrangement of their chromophilic bodies from the cells of the ventral horn?

9. Demonstration. Section of the cortex of the pallium. Golgi's chrome-silver impregnation.

Note the shapes of the pyramidal cells, their long apical and shorter basal dendrites and their axones arising from the bases of the cells. Sometimes collateral branches from the axones can be seen.

10. Transverse section of the cord. Marchi's osmic stain.

Study and draw (high power), in the ventral horn cells, the pigment (lipochrom) stained black. Is it scattered throughout the cell or aggregated in one place? Is it a solid mass or composed of granules?

11. Transverse section of the thoracic cord. Cajal's silver stain.

Draw (high power) one or two cells of Clarke's column and also of the lateral horn. How does their shape differ from the ventral horn cells?

12. Longitudinal section through a spinal ganglion. Cajal's silver stain.

Low power. Note the general shape of the ganglion, its connective tissue capsule, the numerous bodies of spinal ganglion cells and the bundles of axones passing through it, mostly longitudinally but a number more transversely.

High power. Draw one or two ganglion cells, selecting those showing the greatest length of process. Draw the nucleus and nucleolus and the neurofibrils when shown. If not shown draw them in a thinner slice cut off from a ganglion cell body. Note around the ganglion cell a wreath of brown nuclei, the nuclei of the capsule cells. What is the difference in connections of the longitudinal and transverse fibers? Try to find a bifurcating fiber. What is the significance of the bifurcation?

13. Longitudinal section through a spinal ganglion. Nissl's stain. Also Weigert's iron hæmatoxylin and eosin.

Low power. Note the connective tissue capsule (stained more pinkish in the hæmatoxylin-eosin stain), the numerous

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bodies of ganglion cells, nerve fibers and nuclei (of capsule, neurolemma, connective tissue and ganglion cells). Note blood-vessels.

High power. Study and draw several of the ganglion cells, showing their nuclei, nucleoli and chromophilic bodies. How many types of cells can be distinguished according to the number, size and arrangement of their chromophilic bodies and the depth of the general staining of their bodies? Draw one of each type. Observe and draw the nuclei of the capsule cells enveloping each ganglion cell.

14. Longitudinal section through a vertebral sympathetic ganglion and the sympathetic cord. Ranson's pyridin modification of Cajal's silver stain.

Low power. Note the ganglion containing many closely aggregated ganglion cell bodies and the longitudinally cut axones. The coarser lighter staining processes are the dendrites of the ganglion cells. Fine, more deeply stained fibers between the ganglion cells are fibers from the spinal cord.

High power. Find, if possible, a ganglion cell showing its dendrites and draw it.

15. Demonstration. Section of nerve cells showing the canaliculi of Golgi-Holmgren.

16. Demonstration. Section of nerve cells showing mitochondria.

**B. The Neurone; The Nerve Fiber.**

1. Transverse section through the sciatic nerve. Osmic stain.

Low power. Note that the nerve fibers are arranged in definite bundles (fasciculi), each of which has a definite connective tissue covering, the perineurium. Connective tissue is also present within the fasciculi (endoneurium). Around the whole nerve is an investment of looser connective tissue which also passes within between the perineural coverings of the fasciculi (epineurium). Note the presence of blood-vessels in epineurium, perineurium and within the fasciculi. Study the nerve fibers composing the fasciculi: their myelin sheath, stained black, containing the unstained axis—cylinder or axone. Are the nerve fibers all the same size? Make a rough estimate as to how many are present in the whole nerve. Draw the whole nerve in outline, outlining

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also each fasciculus and adding details in a small portion of one fasciculus.

High power. Study and draw several nerve fibers.

2. Longitudinal section through a nerve. Osmic stain.

Low power. Note the nerve fibers only. Many of them may appear to be swollen and contracted along their course. How do you interpret this? Find a fiber showing a node of Ranvier.

High power. Draw a medullated nerve fiber showing a node of Ranvier. Why are medullated fibers sometimes called double contoured fibers? Upon what optical effect does the phenomenon depend? At the node of Ranvier note, if possible, the axis-cylinder and neurolemma sheath passing across the node. Find and draw a fiber showing the clefts of Schmidt-Lantermann. These divide the myelin sheath into funnel-shaped segments. Do they all extend in the same direction in the same fiber? Are they always the same distance apart? What is possibly their real nature? The nuclei of the neurolemma cells may sometimes be seen but are more evident in sections stained with nuclear stains.

3. Teased, unstained piece of fresh nerve.

A piece of fresh nerve, kept in normal salt solution, should be carefully teased apart with two needles until a few fibers at least are well isolated and then a cover slip placed over it.

Low power. With the diaphragm of the microscope carefully adjusted, look for single nerve fibers which have not been injured and observe the same points as in No. 2. What is the principal difference in appearance between the fresh and osmic stained fiber, and to what is it due? The clefts of Schmidt-Lantermann are very well seen in the fresh nerve.

4. Transverse section of a nerve. Mallory's phosphotungstic hæmatoxylin stain.

Low power. Note the same general structures noted in 1.

High power. Carefully study and draw several individual nerve fibers. Here the axis-cylinder is stained red and the myelin yellowish. The connective tissue is stained blue. Note the radiating lines passing through the myelin sheath. They belong to the "neurokeratin" network. Occasionally the myelin sheath appears to be divided into two concentric rings. To what is this appearance probably due?

5. Longitudinal section of a nerve. Mallory's phosphotungstic hæmatoxylin stain.

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Repeat the observations made on previous longitudinal sections of nerve.

6. Longitudinal section of a nerve fixed in alcohol and stained with hæmatoxylin and eosin.

Low power. Note that the nerve-fibers have a granular appearance. The axis-cylinder is usually indistinct. All nuclei are clearly shown.

High power. Study and draw one or two nerve fibers, showing the neurokeratin network and neurolemma nuclei. While some of the nuclei present are connective tissue nuclei (endoneurium, etc.), those closely applied to the outer side of the myelin sheath may be regarded as neurolemma nuclei. Some of these nuclei appear to be thin, deeply staining nuclei, while others appear to be oval and not so deeply stained. To what is this difference in appearance due?

7. Transverse section of a nerve. Mallory's orange-anilin blue fuchsin stain (axis-cylinder red, myelin orange, connective tissue blue).

High power. Repeat the observations made upon the previous transverse sections of nerve.

8. Longitudinal section of a nerve. Mallory's orange-anilin blue fuchsin stain. This stain demonstrates the neurokeratin network, axis-cylinder and nodes of Ranvier very well.

High power. Repeat the observations and drawings made upon previous longitudinal sections of nerve.

9. Transverse section of a spinal cord. Weigert's myelin stain (stains medullary or myelin sheath blue).

Low power. Note the transversely cut, longitudinal nerve fibers in the white matter and the longitudinally cut nerve fibers in the gray matter. Note also the nerve fibers in the roots just outside the cord.

High power. Draw several nerve fibers in the white matter. What previous preparation do they resemble?

10. Transverse section of a spinal cord. Cajal's silver stain.

Repeat the observations made on section 9. What are the differences in appearance between the nerve fibers here and in 9? To what are they due? In the gray the fragments of axis-cylinders cannot always be distinguished from the fragments of dendrites.

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11. Transverse section of a spinal cord. Hæmatoxylin-eosin or Mallory's phosphotungstic hæmatoxylin.

Repeat the observations made on sections 9 and 10.

12. Longitudinal section of a spinal cord. Cajal's silver stain.

Low power. Note the longitudinally cut fibers of the white matter of the cord.

High power. Draw several of the above.

**C. Secondary Degeneration of Nerve Fibers.**

1. Longitudinal section of the distal stump of a nerve 3 to 5 days after cutting. Osmic stain (staining both normal and degenerating myelin black).

Low power. Note the fragmentation of the myelin sheaths into a series of elongated segments with rounded ends and often completely disconnected. Compare with normal nerve.

High power. Draw portions of several fibers showing the above. Are the segments of degenerating myelin larger than the normal nerve fibers, *i.e.*, are they swollen?

2. Longitudinal section of the distal stump of a nerve 3 to 5 days after cutting. Marchi's stain (staining black only the degenerating myelin and the fatty products of the neurolemma cells).

Low power. Note that the nerve (lightly stained) shows the same changes as in the preceding section but that there are also a number of rather coarse black granules, not present in the normal nerve stained with Marchi's stain.

3. Longitudinal section of the distal stump of a nerve 12 to 15 days after cutting. Osmic stain.

Low power. Note that the larger part of the nerve is now stained pale, owing to the disappearance of much of the myelin sheaths. What is left of the degenerating myelin is groups of black granules of various sizes with here and there an elongated fragment of the former myelin sheath. If the nerve was only partly cut many normal myelin sheaths belonging to the uncut fibers may be seen. The much larger fat cells, stained black, may be seen in the sheaths of the nerve.

High power. Carefully study the above groups of granules. They will appear to be contained in vesicles which are within fibers (band fibers, pale in the osmic stain) which are much thinner between the groups of granules. Note that the granules may be stained with various degrees of

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intensity. How do you interpret this and also the fact that the granules are of various sizes? Draw portions of one or more band fibers, showing several groups of granules.

4. Longitudinal section of the distal stump of a nerve 12 to 15 days after cutting. Marchi's stain, hæmatoxylin and eosin.

Low power. Note that the granules appear much the same, but, in addition, nuclei, connective tissue and band fibers are better stained. Fat cells (black) may be present.

High power. Study and draw several band fibers and their included groups of granules as above. Observe also the thin or oval nuclei, most of which belong to the band fibers. What is the origin of these band fibers and their nuclei? What physiological relation might you infer the band fiber bears to the granules? What may be its function?

5. Longitudinal section of the distal stump of a nerve 12 to 15 days after cutting. Osmic and Weigert's iron hæmatoxylin stain.

Low power. Note the same features as in section 3. If the nerve has been only partly cut many normal medullated fibers may also be seen. The hæmatoxylin stain will usually bring out the band fibers and their nuclei more distinctly (in blue or brown).

High power. Draw portions of several band fibers and their enclosed groups of granules if the preparation shows points not clearly demonstrated by the preceding sections.

**D. Changes in the Neurone Body Produced by Injury to its Axone ("axonal" degeneration) or secondary degenerative changes in Neurone Body.**

1. Transverse section of the medulla of a rabbit in which one of the hypoglossal nerves had been pulled out 3 to 5 days previously. Nissl's stain.

Low power. Locate the cavity lying near the dorsal aspect of the medulla and known as the fourth ventricle. Dorso-laterally to this on each side is a compact group of nerve cells, the dorsal motor "nucleus" (*i.e.*, group of neurone bodies) of the vagus. Ventrally to this and ventro-laterally to the fourth ventricle is another larger group of larger and more scattered nerve cells. This is the hypoglossal nucleus, the axones of which form the hypoglossal nerve. Note that while the cells of one hypoglossal nucleus present Nissl chromophilic bodies of normal appearance,

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those of the other nucleus appear pale and the cell bodies more rounded. Select one of these cells showing also an eccentric nucleus.

High power. Study the above cell, noting that it is swollen, that its nucleus is eccentric and that the chromophilic bodies have disappeared from the interior of the cell leaving only a peripheral rim of these bodies (central chromatolysis). The nucleus does not show so much change but may appear paler than normal. Draw this and other cells showing variations. Some of the cells of the nucleus showing degenerative changes contain nuclei apparently centrally placed. How do you account for this?

How can secondary degeneration be used in the study of the architecture of the nervous system? What does it tend to show as to the relations between neurones? What does it show as to the relation between neurone body and axone?

2. Transverse section of the medulla of a rabbit in which one of the hypoglossal nerves had been evulsed 12 to 15 days previously. Nissl's stain.

Low power. Make the same observations as on the previous section. Note that the cells and their nuclei, in the abnormal nucleus, are still paler and appearances indicate that some of them may have disappeared, the injury having been too severe to allow recuperation (regeneration) of the neurone. Why should the neurone be more severely affected in this case than in other cases of cutting or injury to its axone?

How can "axonal" degeneration be used in the study of the architecture of the nervous system? What does it show as to the relation between neurone body and axone?

3. Transverse section of the lumbar enlargement of a human spinal cord, the cauda equina of which had been previously crushed (thereby crushing the nerve roots below the end of the cord). Nissl's stain.

Low power. Note the presence in the ventral horn of swollen, pale motor cells.

High power. In one or more of these cells study the changes mentioned in section 1. Are there present any normal motor cells? If so, how do you account for their presence?

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**E. Changes in the Neurone Body Produced by Influences Acting Directly upon it ("primary" degenerative change).**

1. Transverse section of the spinal cord of a case of rabies. Nissl's stain.

Low power and high power. Study the motor cells of the ventral horn. Note that the swelling and eccentricity of nucleus are not as marked as in the "axonal" degeneration and especially note that there is a diffuse chromatolysis, *i.e.* not confined to any one part of the cytoplasm. Note also that there is a tendency to a general diffuse staining in addition to the disappearance of the chromophilic bodies.

**F. Regeneration of Nerve Fibers.**

1. Demonstration. Longitudinal section or sections of the distal stump of a nerve cut 15 days previously. Cajal's silver stain. In this section the fatty products of degenerating myelin have been dissolved out in fixation, but in the spaces formerly containing them can be seen the black-stained granular remnants of the axis-cylinder. Note also the band fibers and their nuclei (brown).

In some parts of the nerve there can also be seen thin black nerve fibers principally within the band fibers. These are the new nerve fibers which have grown into the distal from the central stump.

2. Demonstration. Longitudinal section or sections through the central stump and scar of a nerve cut 15 days previously. Cajal's silver stain.

Centrally along the central stump, normal axis-cylinders can be seen. As the scar is approached these are blacker and more slender (new outgrowths), in the scar these fibers take various directions according to the arrangement of the elements of the scar tissue and can also be seen wandering off in the adjacent connective tissue. Some of the growing nerve fibers terminate in large bulbs, others terminate in elongated structures containing spirally wound fibers, the spirals of Perroncito.

**G. Effect of Injury of Motor Neurones upon the Striated Voluntary Muscle Innervated by them.**

1. Longitudinal section of voluntary striated muscle in which the motor fibers have been destroyed (anterior poliomyelitis.) Marchi's stain, hæmatoxylin and eosin.

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Note the numerous muscle fibers, reduced in size but still showing cross-striations (atrophy). Note also other much swollen fibers in which the myofibrils are very distinct but the cross-striations are not visible. Some of these contain fine black granules (osmic blackened fat). These latter fibers show degenerative changes. Note also the large amount of fat present in the muscle sheaths.

**H. Peripheral Terminations of Nerve Fibers.**

1. Vertical section through the tip of the finger. Hæmatoxylin and eosin stain.

Low power. Look over the subepidermal papillæ until one is found containing an elongated compact body with transverse nuclei—the tactile corpuscle of Meissner.

High power. Study and draw one of the tactile corpuscles. Note the transverse striations and nuclei indicating the presence of rather flattened epithelial-like cells, between which are the nerve terminations (not visible in this preparation). Note the connective tissue capsule surrounding the corpuscle.

Low power. In the deeper layers of the derma look for large bodies consisting of concentric lamellæ and presenting an onion-like appearance—the corpuscles of Pacini.

High power. Note in one of the corpuscles (preferably one cut transversely) the regular connective tissue lamellæ surrounding a homogeneous core which contains the termination of a nerve fiber (not visible in this preparation). About how many lamellæ are there? In some corpuscles an outer and inner portion of the whole lamellar coat may be distinguishable. What is the probable function of this thick covering to the enclosed nerve ending? Of what part of the nerve is it a continuation?

2. Vertical section of a finger tip. Cajal's silver stain.

Low power. Look over each papilla until one is found which contains fine brown or black fibers (barely visible with low power). If the fibers cannot be distinguished with low power, examine each one with high power until a papilla containing nerve terminations is found. In this preparation the only portion of the tactile corpuscles clearly visible are the nerve endings within it. Note the nerve fiber or fibers proceeding upward and entering the tactile corpuscle after which it divides into several branches which pass around forming a spiral or whorl within the corpuscle. Draw one or more of the corpuscles showing their nerve terminations.

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If there are any corpuscles of Pacini present, note the points observed in section 1, and also the brown-stained nerve fibers in their cores.

3. Demonstration. Section showing intraepithelial nerve terminations. Golgi's chrome-silver impregnation.

Note the black stained nerve fibers passing between the epithelial cells (outlines not visible) and terminating near the surface.

4. Demonstration. Section showing termination of a motor nerve in a motor end plate in striated voluntary muscle.

5. Demonstration. Section through the heart of an amphibian. Golgi's chome-silver impregnation.

Note the delicate black nerve fibers, with varicosities, passing among the muscles. Owing to their simple unbranched character, the exact mode of termination is not easily determined.

6. Demonstration. Section through the gut of an amphibian. Golgi's chrome-silver impregnation.

Note the black nerve fibers passing among the smooth muscle of the wall of the gut and apparently terminating in small bulbs.

**I. The Neuroglia and General Structure of the White and Gray Matter, including the Mesodermal Elements. The Meninges.**

1. Demonstration. Transverse or longitudinal section of the spinal cord. Golgi's chrome-silver impregnation.

Note the two types of neuroglia (or glia) cells; those with irregular, shorter, rough processes, in which probably the cytoplasm of large glia cells is stained, and smaller cells with long thin, often straight, unbranched processes. The latter are especially seen in the white matter and in them the glia cell body and glia fibers in connection with the cell body are stained. In this or other preparations glia cells attached by their processes to walls of blood-vessels may be seen.

2. Demonstration. Section of the spinal cord (either normal or multiple sclerosis). Weigert's neuroglia stain (staining glia fibers blue).

Note the glia cell nucleus surrounded by pinkish or yellowish, vaguely outlined glia cytoplasm. The glia fibers (blue) tend to form the boundary of the cell and pass off in its processes.

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3. Transverse section of the spinal cord. Mallory's phosphotungstic hæmatoxylin stain (Zenker fixation).

Study the structure of the ependyma, surrounding the central canal. The ependymal cells resemble, in such stains, columnar epithelial cells.

Low power and high power. In the outermost part of the cord a thin zone can be seen, immediately beneath the pia and destitute of nerve fibers. This is the marginal glia Note a thin blue line forming its outer boundary, the external limiting glia membrane Immediately beneath can be seen a number of small branched cells, marginal glia cells. Throughout the white matter and gray can be seen the nuclei of glia cells.

Note also the blood-vessels (red blood corpuscles deep blue). Their structure is the same as elsewhere. Can any connective tissue be distinguished around the endothelium of the capillaries in the cord? Note the pia mater and its structure (better in following sections).

Make high power drawings of ependyma, marginal glia and adjacent pia and white matter and drawings of blood-vessels within the cord.

4. Transverse section of spinal cord Mallory's phosphotungstic hæmatoxylin (fixation in Orth's fluid).

Repeat the observations made in section 3. The central canal may be obliterated. Note the clump of glia cells representing its former location. There may be also smaller nests of glia cells in the central gelatinous substance in the vicinity.

Note especially the marginal glia and the glia septa passing inward among the transversely cut nerve fibers. Now and then individual (blue) glia fibers can be distinguished. How do the nerve fibers of the white matter appear?

Note the structure of the pia and its blood-vessels. Note the entrance of blood-vessels into the cord from the pia.

Make high power drawing of the pia, marginal glia and white matter, also of a blood-vessel. Enumerate the mesodermal histological elements found within the spinal cord (and central nervous system in general).

5. Transverse section of the spinal cord. Marchi's stain and safranin.

Study (high power) the ependyma cells and note the numerous glia fibers in the central gelatinous substance.

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6. Transverse section of the spinal cord (infant). Nissl's stain.

Note the deeply stained nuclei of the ependyma cells. Throughout the gray and white matter note the numerous glia nuclei. In certain portions of the gray, especially the gelatinous substance of Rolando, it may be difficult to distinguish between the neuroglia nuclei and the nuclei of certain small (cytochrome) nerve cells; in the white matter, however, there are no nerve cells to cause this confusion. Small portions of gray and white should be drawn (high power) showing the glia nuclei.

Study and draw (high power) also, portions of some of the larger blood-vessels and capillaries of the cord. Enumerate the various histological elements in the cord to which the various nuclei belong. Draw a small portion of the pia.

7. Transverse section of the spinal cord. Cajal's silver stain.

Note the marginal glia. Study and make high power drawing of a small portion of the gray matter showing cells, nuclei, fragments of dendrites and axones. High power drawing of a small part of the white matter. The glia nuclei are not deeply stained but can usually be distinguished.

8. Transverse section of the spinal cord. Weigert's myelin stain.

Repeat the observations and drawings made on section 7.

9. Vertical section of the cerebral cortex with pia-arachnoid attached.

Low power and high power. Study and draw a small portion, showing its loose connective tissue and blood-vessels.

10. Transverse section of the dura mater. Hæmatoxylin and eosin stain.

Draw the dense white connective tissue of which it is composed. Is it as vascular as the pia? Why?

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# CHAPTER XVII.

## THE NERVOUS SYSTEM.

### A. The General Arrangement of the Peripheral Nervous System.

1. Transverse section of the body of a 14 mm. pig embryo. Hæmatoxylin and eosin stain.

Low power. Note the gut and its appendages, cœlom, body wall, spinal cord, vertebral column (notochord), mesentery and aorta.

Note the spinal ganglia connected with the cord and with the ventral root by dorsal root fibers and the ventral root fibers emerging, often in several bundles, from the ventral part of the cord. Note the junction of dorsal and ventral roots to form the spinal nerve. Beyond this is given off the dorsal branch or division to the medial dorsal part of the trunk. Still further peripherally is given off a branch which passes, latero-ventral to the vertebral canal, towards the mesentery. This is the white (and gray) ramus communicans. Ventro-lateral to the vertebral column scattered cells stained somewhat more darkly can often be seen. They are the vertebral sympathetic ganglia. The nerve cannot usually be traced further, but in the mesentery it passes into the prevertebral ganglia. Draw an outline of the dorsal part of the body down to the gut, and carefully indicate and label the various structures enumerated above. Most of the connections will be present on either one side or the other.

2. Transverse section or sections of a chick embryo of the 6th or 7th day of incubation. Golgi's chrome-silver impregnation.

Low power. Repeat the observations made in the preceding section. The young nerve fibers are stained black. There are present also many granules and masses of silver precipitate of no significance.

In the chick the vertebral sympathetic ganglion is closely adjacent to the ventral root at about the point of its junction with the dorsal root. Some fibers may be seen entering it. In one of the sections a few of the embryonic bipolar spinal ganglion cells are stained. Trace the central process into the cord and the peripheral process as far into the spinal nerve as possible. Occasionally the embryonic nerve fibers can be seen in the sympathetic plexuses in the wall of the gut. What are the ultimate destinations of the

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peripheral processes of the spinal ganglion cells? Of the fibers of the white rami communicantes? Of the rest of the ventral root fibers? Of the axones of the vertebral sympathetic ganglion cells? Of the axones of the prevertebral (not seen in the preparation) sympathetic ganglion cells? What are the gray rami communicantes? Why "gray"?

3. Longitudinal section of a vertebral sympathetic ganglion and the sympathetic cord (previously studied). Ranson's modification of Cajal's silver stain.

Low power. Note especially the longitudinally cut axones (mostly medullated but the myelin not present or stained) of the sympathetic cord, entering or passing by the vertebral ganglion. What are the destinations of these fibers?

**B. Spinal Cord: Histogenesis and General or Fundamental Arrangement of its Nervous Elements.**

1. Transverse section of the body of a 14 mm. pig embryo (previously studied). Hæmatoxylin and eosin stain.

Low power. Locate the spinal cord and note its shape, central canal, the black stained nuclei (chromosomes) of certain cells next to the central canal, the radially arranged nuclei of the nuclear layer, the mantle layer (in the ventro-lateral portion of the cord external to the nuclear layer) with more rounded and loosely arranged nuclei and, next to the periphery, the thin marginal layer, destitute of nuclei. Note the dorsal roots entering the marginal layer of the dorso-lateral part of the cord. What is their origin? Note the ventral root fibers passing, usually in several fasciculi, from the ventro-lateral mantle layer, through the marginal layer and then leaving the cord. What is their ultimate destination? Note the transversely cut fibers in the marginal layer just ventral to the entering dorsal root fibers and in the ventro-lateral marginal layer. Note also the fibers passing transversely around the cord between the nuclear and mantle layers (internal arcuate fibers) and crossing to the other side ventral to the central canal (ventral commissure of the cord). (For their origin and destination see following sections). Is the cell proliferation confined to one locality? What is the natural consequence as to the further location and differentiation of the daughter cells? Is differentiation further advanced in the dorsal or ventral part of the cord? Evidence? How do you account for the different appearance of the mantle layer? What is

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the ultimate fate of the nuclear layer? Of the mantle layer? Of the marginal layer?

Make (low power) a rather large outline of the whole cord and its central canal, faintly indicate the boundaries of the above layers and fill in (using low power and high power) the details (arrangement of nuclei and fibers) in a portion at least of one side.

2. Demonstration. Longitudinal horizontal section of the body of a chick embryo of 6 or 7 days incubation, passing through the dorsal part of the spinal cord. Golgi's chrome-silver impregnation.

Low power. Locate the cord and note the dorsal root fibers entering from the sides and undergoing in the cord Y-shaped divisions into longitudinal ascending and descending arms. Usually either from the main dorsal root fiber or from its arms right angled branches (collateral branches) are seen. (See also section 4). Draw the outline of the cord and carefully draw the bifurcations of several of the dorsal root fibers. Disregard silver precipitates (see next section).

3. Transverse section of the body of a chick embryo of 6 or 7 days incubation. Golgi's chrome-silver impregnation.

Low power. Note that in all parts of the preparation there are black granules and irregular black masses. These are silver precipitates and should be ignored. In the cord there is also often a coarse, anastomosing, brown meshwork. These are capillaries and are not to be confused with the much finer, black, non-anastomosing nerve fibers. Locate the cord and note its shape and central canal. Distinguish also between the nuclear and mantle layers (future gray matter of the cord) and the marginal layers (future white matter). The latter is usually somewhat lighter in color and often contains a number of black stained axones cut transversely or obliquely. In the former layers try to find (low power and high power) one or more embryonic neurones whose axones can be traced to the marginal layer. The dendrites can usually be distinguished from the axones by their coarser, rougher, tapering appearance and irregular branching, whereas the axones are uniformly thin and usually smooth in outline. If the axone passes to the marginal layer on the same side it is a tautomeric column cell, if to the marginal layer of the opposite side it is a heteromeric column cell. Occasionally one may be seen in which the axone splits, one division going to the same and the other to the opposite side (hecateromeric column cell). The turn-

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ing and splitting of the above axones into the longitudinal fibers in the marginal layer cannot usually be seen in transverse sections. What are the possible ultimate destinations of the axones of the column cells? In the section there are also often to be seen cells extending transversely from central canal to periphery, of rough appearance and branching especially in the marginal layer. These are spongioblasts (embryonic glia cells).

Draw a fairly large outline of the cord and its central canal and indicate faintly the boundary of the marginal layer. In this outline draw accurately (low power and high power) the column cells whose axones have been traced to or near the marginal layer and some of the spongioblasts.

4. Transverse section of the body of a chick embryo of 6 or 7 days incubation. Golgi's chrome-silver impregnation.

Low power. Locate the cord and note its layers and central canal as in section 3. Note that from various parts of the marginal layer delicate transverse nerve fibers enter the nuclear and mantle layers and terminate there in arborizations. Sometimes it can be seen that these fibers are collateral branches ("collaterals") of the coarser longitudinal (transversely cut) fibers lying in the marginal layer. Note that some of them come from the fibers in the dorsal part of the marginal layer (future dorsal white column of the cord) where the dorsal root fibers enter, *i.e.*, from the ascending and descending arms of the dorsal root fibers. (See also section 2). Others come from the lateral and ventral parts of the marginal layer (from the future lateral and ventral white columns of the cord). Origin of these fibers? In some preparations collaterals from the dorsal root fibers may be seen passing all the way to the ventral (future) gray matter. Some of the fibers passing in from the marginal layer are terminations of the main fibers ("terminals"), not collateral branches.

5. Longitudinal, horizontal section of the body of a chick embryo of 6 or 7 days incubation, passing through the spinal cord. Golgi's chrome-silver impregnation.

Low power. Locate the cord and note the bands of longitudinally cut axones (black). These are the longitudinal fibers in the marginal layer or future white columns of the cord. The number of bands depends upon the plane and direction of the section (compare with previous transverse sections).

From among the longitudinal fibers finer transverse fibers can be seen entering the (future) gray matter. These

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are the collaterals studied in the previous section. Find (low power and high power) some longitudinal fibers which show the T-shaped branching of one of its collateral branches, thereby demonstrating the exact origin of many of the transverse fibers. Other transverse fibers are obviously the axones of the column cells passing to the white matter and then by bending or splitting forming a longitudinal column fiber, or a longitudinal column fiber turning into the gray to terminate ("terminals") there. It may not always be possible to observe these latter points. The student should now be able to construct from the neurones studied the following reflex spinal arcs or circuits: (*a*) An uncrossed arc, involving two neurones, from a receptor to striated voluntary muscle. (*b*) An uncrossed or crossed arc, involving three neurones, from a receptor to voluntary striated muscle. (*c*) An uncrossed or crossed arc, involving four neurones, from a receptor to a smooth muscle or gland.

**C. Spinal Cord: General Topography and Arrangement of Fibers.**

1. Transverse section of the lumbo-sacral spinal cord of a 7 months human fœtus. Weigert's myelin stain.

Note the dorsal and ventral gray horns and the few transverse medullated fibers passing between the white columns and the gray. What are the probable origins and destinations of these fibers? (Compare with B, 4).

2. Transverse section of the lumbo-sacral (infant's) spinal cord. Weigert's myelin stain.

Naked eye, ocular and low power. Note the general shape of the cord, its central canal (open in the young cord), the ventral longitudinal sulcus, the dorsal medial septum and the enveloping pia mater. Note the dorsal and ventral gray columns or horns (stained lighter than the white matter. Why?). In the dorsal gray horn note a somewhat narrower basal part (cervix or neck) expanding dorsally into the caput or head. Capping the latter is a very light area (few medullated fibers) of a homogeneous appearance, the gelatinous substance of Rolando, properly a part of the dorsal horn. In the infant, the light area indicating the presence of the gray horn apparently extends to the periphery. When examined more closely it is seen to be composed of a lighter portion next to the gelatinous substance and containing a plexus of fibers. This belongs to the gray and is the zona spongiosa. External to this, between it and the periphery of the cord is an area oc-

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cupied by fine transversely cut nerve fibers. This is the terminal (dorso-lateral) zone of Lissauer and is properly the lateral, fine-fibered portion of the dorsal white column of the cord. Note the large ventral gray horn with protrusions due to the presence within it of groups of large motor cells. The portion of the gray connecting the dorsal and ventral horns is the intermediate gray. Note the commissures connecting the two halves of the cord. Note, ventrally to the central canal, a conspicuous bundle of fibers crossing from one side to the other, the ventral or anterior white commissure of the cord. Between it and the central canal is some gray matter, the ventral gray commissure. Dorsal to the canal is more gray matter (dorsal gray commissure) and, further dorsal, a comparatively few, crossing fibers (dorsal white commissure). The light, homogeneous area around the central canal is the central gelatinous substance. It is in reality different from the gelatinous substance of Rolando, consisting largely of neuroglia while the gelatinous substance of Rolando is largely composed of small nerve cells (see section D. 1).

Note outside the gray matter of the cord, the darkly stained white matter. One light area in the lateral portion of the white matter in the infant, is the as yet non-myelinated or incompletely myelinated lateral pyramidal tract. Distinguish the dorsal, or posterior, white column (or funiculus) comprising that portion of the white matter from dorsal septum to and including the zone of Lissauer, the lateral white column extending from the zone of Lissauer and merging, at about the exit of the ventral root fibers, into the ventral white column comprising the rest of the white matter.

Draw, using naked eye and ocular, a full page outline of the whole (or at least more than one-half) of the cord and central canal, and indicate by faint lines the outlines of the gray matter and the gelatinous substance of Rolando. Study and draw, in one field (low power) at a time, the details of the arrangement of the nerve fibers. Study the entrance and distribution of the dorsal root fibers. Note that on entering, fine fibers pass laterally from the root and enter the zone of Lissauer (fine-fibered portion of dorsal root). Note that the remaining, coarse fibers (coarse-fibered medial portion of dorsal root) usually pass through the zone of Lissauer, dividing it into larger lateral and smaller medial portions. They then can be seen to pass medially along the dorsal and mesial side of the gelatinous substance of Rolando. This is the zone of entry and

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radiation of the dorsal roots (obviously applicable only to the coarse fibers) and is the area in which their fibers split into ascending and descending arms. Some of the coarse root fibers, in some levels, appear to pass through the medial part of the gelatinous substance of Rolando and into the caput of the dorsal horn before dividing.

From the zone of entry and also from the dorsal white column medial to this, bundles of fibers can be seen passing into the gray. Some of these bundles pass through the gelatinosa and some sweep around medial to it (some of the latter fibers probably end in the gelatinosa). Note that the fibers composing these bundles are finer than the root fibers and the longitudinal fibers of the dorsal column, thereby indicating that they are collaterals. Note that many of these bundles can be traced into the intermediate gray and occasionally even further ventrally. What would be the probable significance of those traceable into the ventral horn? Other fibers from the zone of entry which either pass medially to or through the gelatinosa form a plexus in the caput of the dorsal horn, and still others pass laterally and curve dorsally into the gelatinosa. (Other collaterals from the zone of Lissauer also contribute to this plexus and others terminate in the zone of Lissauer, but many of these are not visible in Weigert preparations, being non-medullated.) Study the fine fibers of the dorsal white commissure. Some of these are collaterals from the dorsal white column, others are lost in the gray (ultimately collaterals from the lateral columns and some axones of cells in the gray). Study the transverse fibers passing between the dorsal part of the lateral columns and the gray, in part collaterals, in part terminals, in part fibers to the white matter. Note that in the ventral horn two sizes of fibers are very apparent. A comparatively few are very coarse and are obviously the myelinated axones of the large motor cells of the ventral horn (ventral root fibers). Besides these note the great number of finer fibers entering the gray from the white columns on all sides. Larger numbers separate the groups of motor cells, a smaller number pass between the individual motor cells. Many of these also are collaterals. Study the fibers of the ventral white commissure. The bulk of these are coarse fibers, many of them connecting the gray of one side with the opposite ventral white column. What is the origin of most of these fibers? Note that there are also fine fibers, in part probably collaterals. Carefully label all parts shown in the drawing.

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3. Transverse section of the lumbo-sacral adult spinal cord. Weigert's myelin stain.

Naked eye, ocular and low power. Observe the points named in section 1. Note that the number of medullated fibers in white and gray has much increased and that the plexuses in the latter cannot be analyzed so readily. Note the great increase in fine medullated fibers in the zone of Lissauer.

4. Transverse section of the lumbo-sacral (infant's) spinal cord. Cajal's silver stain.

Low power. Study the arrangement of the fibers noting the same points as in section 1.

5. Transverse section of the lower thoracic (infant's) spinal cord. Weigert's myelin stain.

Low power. Note the points covered in section 1. Study in this especially the fibers related to Clarke's column. Note that from the middle of the dorsal white column bundles of fine fibers, evidently collaterals, enter and form a plexus within Clarke's column. Note also that from the ventral side of Clarke's column coarse, heavily myelinated fibers issue and pass laterally across the gray and into the lateral white column to a point near the periphery where coarse fibers can be seen cut transversely. Interpret these appearances. What are the relations of the fine and coarse fibers respectively to Clarke's column?

6. Transverse section of the lower thoracic adult spinal cord. Weigert's myelin stain.

Low power. Note the same points as in section 5 and the increase in medullated fibers as noted in section 3.

7. Transverse sections of the lower thoracic adult and infant's spinal cords. Cajal's silver stain.

Low power. Note the points mentioned in section 5 concerning Clarke's column and fibers in relation with it. Note especially the fibers from the dorsal white column to Clarke's column, their size, exact origin, course and termination in Clarke's column. Distinguish carefully here the well marked, fine-fibered zone of Lissauer.

**D. Spinal Cord: Cell Groups.**

1. Transverse section of the lumbo-sacral infant's spinal cord. Nissl's stain.

Low power. Make a fairly large outline of the cord and outline faintly its gray matter. In the latter indicate

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the following cell groups: (*a*) The large motor cells of the ventral horn. Distinguish in them the dorso-medial and ventro-medial groups, the ventro-lateral, dorso-lateral and central groups. What are the destinations of their axones? (*b*) The large-celled (magnocellular) groups. Two of these are present here: the pericornual (marginal) group around the dorsal horn and the central cells of the dorsal horn. These two groups are only represented by scattered cells. (*c*) The cells of the substantia gelatinosa of Rolando (nucleus sensibilis). These are very numerous small cells. (*d*) The diffuse cells, quite small, scattered more or less diffusely throughout the gray.

2. Transverse section of the lumbo-sacral (infant's) spinal cord. Cajal's silver stain.

Note especially the motor groups of the ventral horn and the cells of the gelatinosa of Rolando. Examine the latter high power. The other cells are not very distinct.

3. Transverse section of the lower thoracic spinal cord. Nissl's stain.

Repeat the observations made on section 1, noting the reduction in number of the motor cells of the ventral horn. Why are these fewer here? Note, in addition, the presence of the large celled basal group (nucleus magnocellularis basalis), or column of Clarke, and the intermedio-lateral group of preganglionic sympathetic cells in the lateral horn. What is the destination of the axones of these latter cells? Make a drawing similar to that of section 1.

4. Transverse section of the lower thoracic spinal cord. Cajal's silver stain.

Note the same points as in section 3.

5. Transverse section of the cervical enlargement of the spinal cord. Nissl's stain.

Note the same points as in section 3. Note the absence of the cells of Clarke's column and of the sympathetic group, also the increase of motor cells of the ventral horn as compared with the thoracic cord. Why? What are the destinations of these cells here?

6. Transverse section of the cervical enlargement of the spinal cord. Cajal's silver stain.

Note the cell groups observed in section 5, as far as visible.

7. Transverse section of the cervical enlargement of the spinal cord. Weigert's myelin stain.

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Note the general shape of the cord and of its gray, and as far as possible locate the cell groups.

8. Transverse section of the upper cervical spinal cord. Weigert's myelin stain.

Note that the ventral horn is much smaller than in the cervical enlargement. Why? In the very high cervical segments, the dorsal horn becomes larger.

Note also the presence of lateral roots, *i.e.* fibers passing dorsally from the ventral horn in the gray where some of the fibers turn longitudinally and others pass laterally or dorso-laterally, to emerge on the lateral surface of the cord at a variable distance ventrally to the zone of Lissauer. These are the roots of the spinal accessory or cranial nerve XI.

In general what are the variations in size and shape of the gray matter in the various levels of the cord and to what do you attribute them? What are the variations in amount of white matter and to what do you attribute them?

**E. Spinal Cord: Fiber Tracts.**

1. A series of transverse sections of the thoracic, cervical enlargement, and upper cervical segments of a spinal cord in which the lumbo-sacral region had been crushed some time previously. Weigert's myelin stain. (To be compared with section 3 below).

Naked eye, ocular and low power. Note that there are light, comparatively unstained areas in the white columns, especially in the dorsal white column. In general to what are these due? What appearances in the sections prove that the lesion affected the cord itself and not simply its roots in the cauda equina? In each dorsal white column note that in the lowest section (the one nearest the injury) practically the whole dorsal column is light, possibly including a portion of the zone of Lissauer. In the following sections the light area of degeneration becomes progressively smaller and also becomes separated from the dorsal horn by an increasingly larger stained, undegenerated, area. How do you account for these changes in the degenerated and undegenerated areas in the dorsal column? What do they prove as to the positions and lengths of the ascending arms of the dorsal root fibers entering at various levels of the cord?

In the ventro-lateral white columns are less well marked light (degenerated) areas. These are more evident and extensive in the lower levels. In these levels the largest

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dark (undegenerated) area is in the lateral column alongside the dorsal horn. This area is occupied principally by the lateral pyramidal and rubro-spinal tracts. Why should they show no degeneration? Outside the lateral pyramidal tract and next to the periphery there can be seen slight evidences of degeneration (compare with a similarly stained normal cord). This area is occupied by the dorsal spino-cerebellar tract. Why does it not show more degeneration? Further ventrally the area of partial degeneration is wider and more marked. The peripheral portion of this area is occupied by the ventral spino-cerebellar tract and the medial part, protruding into the rest of the white column, is occupied by the lateral spino-thalamic tract. Extending medially into the ventral white column is an ill-defined area of diffuse degeneration which is occupied by the "medial spino-thalamic" tract. Note that in the higher levels of the cord these areas tend to become less pronounced and less wide spread. How do you account for this? Draw an outline of each section and outline its gray. Indicate by shading the degenerated areas and label the tracts they represent.

2. Transverse section of a high cervical segment of a spinal cord in which the low cervical region had been crushed some time previously. Weigert's myelin stain.

Naked eye, ocular and low power. Note the area of degeneration in each dorsal white column, separated from the dorsal horn by an undegenerated area. What fibers normally occupy the degenerated area? What are the fibers in the undegenerated area? How do the degenerated and undegenerated areas compare in size with the similar areas in a section of the same level in 1? How do you account for this difference? Are there any undegenerated fibers in the degenerated area? What does this prove? Does the degenerated area correspond to the column of Goll in either section? What does this prove as to the origin of the fibers composing the columns of Goll in the high cervical cord?

In the ventro-lateral white columns note the same areas of degeneration noted in series of sections 1; also note that they are all much more marked, except the area of the medial spino-thalamic, especially the area of the dorsal spino-cerebellar tract which is very light (*i.e.*, free from normal fibers) and well defined. How do you account for this difference between this section and the same level in 1? Does the medial spino-thalamic area differ much from the corresponding level in 1? What two alternative conclusions

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could you draw from this as to either the level of origin or length of fibers in this area? Note in many of these sections the presence of undegenerated fibers in the ventral part of the dorsal spino-cerebellar tract. These are aberrant fibers of the lateral pyramidal tract. Why have they escaped degeneration? Note the general presence of the dorsal and ventral root fibers and look for any lateral rootlets of the spinal accessory nerve which may be present. Draw an outline of the cord and of its gray and indicate by shading the degenerated areas. Label the tracts they represent. Indicate also the dorsal and ventral root fibers and any spinal accessory root fibers, if present.

3. Transverse sections of various thoracic segments of a spinal cord in which the lumbo-sacral region was crushed a short time previously. Marchi's osmic stain of degenerating myelin. Compare carefully with the corresponding level in 1.

Ocular and low power. Note in general the areas occupied by degenerating medullated fibers, indicated by the presence of black granules.

Select the section of the lowest level (*i.e.* the one nearest to the injury) by inspection of the dorsal white columns in each section. In this section, besides the degeneration throughout the dorsal columns, all of the ventro-lateral columns contain scattered black granules excepting an area in the dorsal part of the lateral column corresponding to the darkest area in the lowest levels in series 1. This is obviously the area of the lateral pyramidal tract. Compare this section with one of the sections of a higher level. In the latter what differences are there in the dorsal white column? Compare with series 1 and explain. In the ventro-lateral white columns the black granules are now confined to the areas previously described (series 1—compare sections of corresponding levels) as occupied by the dorsal and ventral spino-cerebellar and the lateral and medial spino-thalamic tracts. The same difference between the low and higher thoracic levels was seen, less distinctly, in series 1. How do you account for it? What degenerating fibers are present in the low level which are not present in the higher level? In addition to the tracts mentioned above, black granules may be seen in the ventral white columns adjacent to the ventral longitudinal sulcus, the sulco-marginal tract of Marie.

In general, what kind of degeneration is present in 1, 2 and 3? Upon what law does it depend? Are these degenerations of ascending or descending tracts or both? Do

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they throw any light upon the direction of conduction? Why?

4. Transverse section of thoracic and lumbo-sacral segments of a spinal cord in which the lower cervical segments had been crushed some time previously. Weigert's myelin stain.

Naked eye, ocular and low power. In the section of the highest level (*i.e.* just below the injury) note any area of softening in the dorsal white columns due directly to the injury. Note besides this in the dorsal columns areas of degeneration. These may in part be due to the close proximity of the lesion but in part are probably true descending secondary degenerations of such systems as the comma and septo-marginal tracts. In the ventro-lateral white columns note the extensive areas of degeneration involving nearly all of the dorsal portion of the lateral column and extending around the margin of the rest of the ventro-lateral columns. It is evident at once that the degeneration includes the ascending spino-cerebellar and part at least of the spino-thalamic tracts and that there must therefore be more than a pure secondary (descending) degeneration. Why? The degeneration of these tracts is of a traumatic, primary character, but in some cases also involve whole neurones owing to the severity of the injury and its proximity to the neurone body. If the degeneration of the ascending tracts (compare 1, 2 and 3) be subtracted from the degeneration present there will be found to be an extensive degeneration (secondary and descending) in the dorsal part of the lateral column between the dorsal spino-cerebellar area and the dorsal horn. This is the area which was darkest in 1 and 2 and contained no granules in 3. It is the area of the lateral or crossed pyramidal and rubro-spinal tracts. In the ventral portion of the lateral column and in the ventral column, if the area of the ventral spino-cerebellar, and spino-cerebellar and spino-thalamic tracts be subtracted (compare carefully 1, 2 and 3) there will be found to be a considerable remainder of true descending degeneration, especially at the margin of the cord. In the lateral column this is the area occupied by uncrossed Deitero-spinal and other vestibulo-spinal fibers, in the ventral column it is the area occupied by uncrossed and crossed Deitero-spinal or vestibulo-spinal fibers, possibly by colliculo-spinal fibers, by fibers from the interstitial nucleus in the midbrain and by the medial or uncrossed pyramidal tract. Note that the area of degeneration in the ventral column adjacent to the ventral longitud-

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inal sulcus is separated from the latter by a thin rim of undegenerated fibers. These are probably the ascending fibers of the sulco-marginal tract noted in 3. Note that there are some intact fibers in the dorsal part of the dorsal spino-cerebellar tract. How do you explain this? Can you draw any conclusions as to the possible arrangement of the fibers in the dorsal spino-cerebellar tracts? What conclusions?

The preceding degenerations thus principally involve the long tracts. Note that the white matter of the ventro-lateral columns adjacent to the gray is much less affected. By comparing with the ascending degenerations in 1, 2 and 3, in which these areas are also unaffected, it is evident that they are the areas of the short, intersegmental or spino-spinal fibers often called, together with some longer fibers, the ground bundles of the cord. They are naturally not entirely free from degeneration (fibers from cell bodies in lesion and retrograde degeneration of the fibers entering the lesion). The dorsal portion, constituting the thin un-degenerated layer between the lateral pyramidal tract and the dorsal horn is often called the lateral limiting layer. Make an outline of the cord and its gray and indicate by shading the degenerated areas. Label the tracts occupying the degenerated areas. Note and indicate in the drawing the presence of the lateral horn. In the lower thoracic section note that the degenerated areas have diminished and that in those sections not too low the dorsal spino-cerebellar tract contains more intact fibers. Why?

In the lumbo-sacral section note the diminished lateral pyramidal tract now lying next to the periphery of the cord. Why is it smaller? Why is it no longer separated from the periphery of the cord by the dorsal spino-cerebellar tract?

5. Transverse section of the cervical enlargement of the spinal cord of a hemiplegic. Weigert's myelin stain.

Naked eye, ocular and low power. Note the lighter areas in one lateral and one ventral white column, formerly occupied by the crossed and uncrossed pyramidal tracts. Note that they are on opposite sides of the cord. Do you think this degeneration could have been caused by a lesion in the cord? Why? Any suggestions as to the explanation?

In general, the student should not only learn the positions of the tracts but should understand exactly how the degenerations studied in these sections have been produced.

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6. Transverse section of the cervical spinal cord of a fœtus of about 8 months. Weigert's myelin stain. Illustrating the myelogenetic method of distinguishing fiber tracts.

Naked eye, ocular and low power. Note the unstained areas occupied by the as yet non-medullated axones of the lateral and medial pyramidal tracts. Note also the asymmetry of the latter. Note also in general the comparatively large area occupied, for this level (compare other cervical sections of adult cord), by the gray matter.

Draw an outline of the cord and its gray and indicate by shading the positions of the non-medullated pyramidal tracts. Also indicate the boundary between the columns of Goll and Burdach (fasciculus gracilis and fasciculus cuneatus) which are well marked in this section.

7. Note the light areas occupied by the non-medullated or only partly medullated fibers of the lateral pyramidal tracts in the previous sections of the infant's cord stained by Weigert's myelin stain.

8. Transverse section of the cervical enlargement of the spinal cord of an infant (5 weeks). Weigert's myelin stain. Many of the tracts can be distinguished by their relative degrees of myelinization. Compare carefully with the preceding sections 1 to 6.

Naked eye, ocular and low power. Note the dark narrow band occupying the periphery of the lateral white column and gradually getting thinner ventrally. What tracts occupy this area? (Compare 2.) Note the thin dark area next to the gray laterally to the dorsal horn, rather abruptly widening at the upper border of the ventral horn and thence passing around the ventral horn as a wide dark area. What tracts occupy this area? (Compare 4.) Note the large light area occupying the dorsal part of the lateral white column. What tract occupies this area? (Compare 2, 4, 5 and 6.) The other tracts can be located with reference to these by comparison with the preceding sections.

Note also in this section the various parts of the gray, the dorsal and ventral roots and the commissures, and distinguish the columns of Goll and Burdach. Note also the processus reticularis, a mixture of gray and white situated laterally to the dorsal horn. Draw a large outline of the cord and its central canal and gray, indicating also the processus reticularis, the boundaries between the columns of Goll and Burdach and the dorsal and ventral root fibers. In this outline indicate by shading the relative depths of

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staining of the white matter and locate all the previous tracts of the cord. Label.

Before taking up the structure of the various parts of the brain the student should be thoroughly familiar with the tracts of the cord, their origins, courses and locations in the cord and their terminations. In addition to this, he should know the path of which each tract is a part, in detail that portion of each path lying in the body and cord, and in a more general way, the higher continuation and destination or origin of each path in the brain.

In general, in the study of the sections of the brain as well as of the cord, the student should, in addition to noting the location of nuclei, tracts, courses of fibers, etc., endeavor to comprehend the connections of which they are a part and the functional significances of these connections. For each nucleus or mass of gray, *i.e.* for each group of neurone bodies, he should endeavor to learn: (1) What fibers originate in it and what is their termination? (2) What fibers terminate in it and what is their origin? It is obvious that each nucleus must have this double connection. (3) What is the path of which it is a part (beginning of the path, neurone groups composing it and its destination)? (4) What is the functional significance of the nucleus and of the path of which it is a part and what is the effect of injury to either? For every tract or bundle of fibers he should endeavor to learn: (1) What is its origin, *i.e.* from what neurone bodies do its fibers arise? (2) What is its termination, *i.e.* among what neurone bodies do its fibers end? (3) What is the path of which it is a part (beginning of the path, neurone groups composing it and its destination)? (4) What is the functional significance of the tract and of the path of which it is a part and what is the effect of injury to either? These questions must be regarded as applying to the nuclei and tracts in each one of the following sections of the brain, even though they are not, for the sake of brevity, repeated in each section.

The student should also compare the external markings or configuration of each section with the corresponding region in a brain or brain model or, if not available, with illustrations of the same.

**F. Rhombencephalon (Medulla Oblongata or Bulb, Pons, Cerebellum and Isthmus).**

1. Transverse section of the medulla of an infant through the decussation of the pyramids.

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Naked eye, ocular and low power. Note the shape of the section. Next to the median line dorsally is the eminence produced by the fasciculus gracilis or column of Goll, separated laterally by the paramedian fissure from the fasciculus cuneatus or column of Burdach. Laterally to the fasciculus cuneatus is a slight eminence known as the tuberculum cinereum (gray tubercle) or tuberculum trigemini or tubercle of Rolando. Why are each of these names descriptive? The ventral fissure is shallower owing to the decussating pyramidal fibers. Fibers of the most anterior dorsal and ventral cervical spinal roots may still be present. Look for spinal accessory roots (see also section E. 2). Note that the dorsal gray horn has increased in size. Why? (See below.) Note that the ventral horn is cut off from the rest of the gray by the masses of pyramidal fibers passing through the intermediate gray. In addition to this change, the longitudinal fibers of the lateral white column adjacent to the gray (short tracts) are becoming mingled not only with the gray of the dorsal horn, as in the processus reticularis of the cord, but also with the adjacent intermediate and ventral gray. This intermingling of short intersegmental tracts and gray is known as the gray reticular formation (formatio reticularis grisea). Note that the central gray extends further dorsally and, in the higher sections through the pyramidal decussation, a protrusion from it extends into the fasciculus cuneatus. There may also be seen a mass of gray appearing within the fasciculus gracilis (see next section).

The fasciculus gracilis and cuneatus are well marked off from each other by a septum. Note that the zone of Lissauer (light-staining fibers) appears to have increased in size. This is due to the presence of descending trigeminal root fibers (tractus spinalis radicis trigemini or spinal V). What is the origin of their fibers? Study (high power) their relation to the dorsal horn, comparing with the cord. Outside the zone of Lissauer are usually to be seen dark staining coarse fibers. They are obviously bundles from what tract? The continuation of the lateral white column has now lost its lateral pyramidal tract, the fibers of which are either imbedded in the region of the intermediate gray or are crossing the median line to the opposite ventral white column where they join the uncrossed pyramidal tract. The ventral white column is obviously increased in size by the accession of the light staining pyramidal fibers. What important physiological fact is explained anatomically by this crossing? Besides the three changes mentioned in the

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lateral column (what are they?), the remainder has the same arrangement of its constituent ascending dorsal and ventral spino-cerebellar and lateral spino-thalamic tracts and descending rubro-spinal and vestibulo-spinal tracts (origins, terminations, paths?). A peripheral light area at about the junction of the lateral and ventral columns is occupied by the tract of Helweg (possible origin and termination?).

Encircling the ventral horn note the dark stained U-shaped mass of fibers, the medial portion of which is obviously the continuation of the ventral columns of the cord and containing the same tracts (vestibulo-spinal, colliculo-spinal, tract from interstitial nucleus, medial spino-thalamic and short intersegmental tracts, in addition to the uncrossed pyramidal which has been increased by fibers from the lateral pyramidal tract as already mentioned. Origins, terminations, paths? See general paragraph preceding this section). Laterally the U-shaped mass of fibers is seen to spread out into the lighter staining mass of the lateral column already described.

Draw an outline of the section, or use the outline given out, and indicate by shading (using lead pencil and not crayon) the gray and the variously stained longitudinal fibers. Draw carefully all transverse fibers. On one side of the outline colors may be used to indicate more schematically the various tracts, but one side should be drawn as it appears.

Label all external markings, tracts, masses of gray, etc. It would be advisable for the student to make a synopsis covering the points mentioned in the general paragraph preceding this section.

2. Similar section of an adult medulla. Weigert's myelin stain.

Note the same points, many of which are not so distinct owing to the increased myelinization, especially of the pyramidal tract and the plexuses in the gray.

3. Similar section of the medulla. Nissl's stain.

Study the cell groups in the above masses of gray. At this level they do not differ much from those in the cord. Some of the nuclei mentioned in 5 may be present. A separate drawing may be made or the cell groups indicated in the drawing of 1.

4. Similar section of the medulla. Cajal's silver stain.

Repeat, as far as possible, the observations made in 1, 2 and 3.

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5. Transverse section of the medulla of an infant through the decussation of the medial fillet or medial lemniscus. Weigert's myelin stain.

Naked eye, ocular and low power. Note the external markings: The eminences produced by the fasciculi gracilis and cuneatus are more prominent (why?), and are now called the clava and cuneus respectively. The tubercle of Rolando is also more prominent. Why? Ventrally there are now two conspicuous prominences, one on each side, the pyramids. Explain their size. Are there any decussating pyramidal fibers? Compare with a brain, brain model or illustrations of the same.

The dorsal horn, or its continuation, is still larger. Why? In addition two new masses of gray have appeared, one in the fasculus gracilis (nucleus fasciculi gracilis or nucleus of the column of Goll) and the other in the nucleus cuneatus (nucleus fasciculi cuneati or nucleus of the column of Burbach). What are their relations to the columns? Study (high power) indications of this relation and indicate it in the drawing. What is the relation of the dorsal horn to the spinal V? Study (high power) indications of this relation and indicate it in the drawing. The intermediate gray and ventral horn are now about completely intermingled with longitudinal (transversely cut) bundles of nerve fibers besides being traversed by the usual transversely running fibers. This mixture, the gray reticular formation, has thus increased. In the gray reticular formation, in addition to the diminished remnant of the ventral horn cells, are the ventral motor nucleus of nerve X (nucleus ambiguus) and possibly other vagus nuclei, various nuclei known as the nuclei reticularis and, at the lateral border, the nucleus funiculi lateralis. None of these nuclei are easily distinguishable at this level in Weigert preparations. Note the external arcuate or arciform nuclei, forming indentations in the outer borders of the pyramids. What are their probable connections? In some of the higher sections of this level, the inferior olivary nucleus, especially its accessory portion, may be seen in the vicinity of Helweg's tract (see next level). The central gray is large and may now contain the following nuclei (not easily made out, at this level, with the Weigert stain): the nucleus commissuralis (IX and X), the dorsal motor nucleus of nerve X, possibly the dorsal sensory nucleus of nerve X and the nucleus of nerve XII. They are better distinguished in the next section.

The dorsal white columns show some diminution, especially the column of Goll? Why? From the nuclei of

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the columns of Goll and Burdach fibers can be seen emerging which pass ventrally, curving around the central gray (as internal arcuate or curved fibers) and decussating ventrally to it. Note carefully their apparent destination. It will be seen that they tend to insert themselves between the pyramids and the darkly stained continuation of the ventral white columns of the cord. Here, as subsequent sections will show, they turn cephalad and build up a large longitudinal tract, the medial fillet or medial lemniscus. The decussating fibers should be sharply distinguished from the continuations of the ventral columns which are laterally to them. What is the relation of these fibers to the nuclei of the columns of Goll and Burdach, and what is the general significance of the latter? Of what path are these structures a part? What important physiological fact is anatomically explained by this decussation? Note, in this and higher sections, the lightly stained lateral portion of the nucleus cuneatus. This is the external cuneate or von Monakow's nucleus, probably having different connections from the rest of the cuneate nucleus. The spinal V is larger. Why? The continuation of the lateral column is practically unchanged. Indicate its constituent tracts in the labels of the drawing. The tract of Helweg is more conspicuous. The pyramidal tracts have been mentioned. Laterally to the pyramidal tracts may be seen the dark mass of fibers constituting the continuation here of the ventral columns of the cord (excepting the pyramidal tract). What are its constituent tracts? Indicate them in the labels of the drawing. The L-shaped lateral extension of this mass contains the more lateral Deitero- or vestibulo-spinal fibers and the medial spino-thalamic tract. Further laterally it merges into the continuation of the lateral column of the cord. In many sections at this level there can be seen transverse fibers passing around in the outer border of the section. Such curved fibers are called superficial or external arcuate fibers in distinction from deep or internal arcuate fibers. The superficial arcuate fibers at this level are probably fibers to the cerebellum (via restiform body, see later sections) and in part probably originate from the nuclei funiculi lateralis and the arcuate nuclei. Study carefully (high power) the indications of the former shown by fibers passing dorsally, near the surface, from the region of the lateral column and thereby gaining a position, together with fibers from the dorsal spino-cerebellar tract, external to the spinal V. This constitutes the first indication of the formation of the restiform body (see next level).

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Draw and label according to directions given for section 1.

6. Transverse section through the same level of an adult medulla in a case of crush of the lower cervical cord. Weigert's myelin stain.

Naked eye, ocular and low power. Note especially the disappearance or degeneration of the fibers of the column of Goll and the partial disappearance of those of the column of Burdach. Why this degeneration? What fibers of the column of Burdach have disappeared and what are intact? Note that the internal arcuate fillet fibers and the fillet itself are intact. Why? Note the presence of fibers in the nuclei of the columns. What are they? Note the degeneration in the continuation of the lateral columns of the cord. What tracts here are degenerated and why? Is the spinal V degenerated? Why? A drawing may be made showing especially the above points.

7. Similar section of normal adult medulla. Weigert's myelin stain.

Follow the directions given for section 5. Note changes in myelinization of fibers.

8. Similar section of medulla. Nissl's stain.

Locate and study the nuclei mentioned in section 5. Draw as directed in 3.

9. Similar section of medulla. Cajal's silver stain.

Repeat, as far as possible, the observations made on sections 5, 7 and 8.

10. Transverse section of the medulla of an infant through the lower middle portion of the inferior olivary nucleus. Weigert's myelin stain.

Naked eye, ocular and low power. Note that the central canal has widened out into the fourth ventricle, the roof of which is formed by the thin tela and plexus chorioideus (often torn away in the preparation). If present, note in the latter the outer vascular connective tissue portion formed by the pia and the layer of low epithelium lining its inner surface. What is the physiological significance of these thin-walled portions of the brain? What apertures are there in the chorioidea of the fourth ventricle and between what cavities do these apertures form communications? What is the general effect of the opening of the cord into the fourth ventricle upon the topographical relations of the various structures of the medulla? In the floor

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of the ventricle note the following markings: (1) The medial eminence (here containing the nucleus hypoglossi and therefore called the trigonum hypoglossi). (2) The inferior fovea, ala cinerea or trigonum vagi (the last name on account of structures connected with the vagus lying in this area). Why the terms inferior fovea and ala cinerea? (3) The sulcus limitans. (4) The area acustica, small here but large in higher levels. Laterally to this is the tænia forming the lateral boundary of the ventricle and the attachment of the chorioidea. Note on the external surface: (1) That the clava and cuneus have practically disappeared; (2) the restiform body; (3) the olive (due to the presence within of what structure?); (4) the postolivary furrow; (5) the preolivary furrow; (6) the pyramid. The vagus roots may usually be seen emerging in the postolivary furrow and the hypoglossus roots emerging in or near the preolivary furrow. What kind of fibers are found in these nerves? What do they innervate? Compare with a brain, brain model or illustrations of the brain.

Note the nucleus hypoglossi in the medial eminence. What do its fibers innervate? Study this nucleus carefully (high power). Note the coarse root fibers emerging from it and passing ventrally. Trace them to their emergence from the bulb. In addition note the numerous fine fibers in the nucleus. Note that they appear to enter the nucleus from its dorsal, lateral and ventro-medial sides. What is their general relation to the nucleus and from what sources do they probably ultimately come? What functional connections do they probably represent? Dorsal to the nucleus is the nucleus teretis or nucleus eminentiæ medialis and dorso-laterally the nucleus intercalatus (cephalad of the nucleus hypoglossi, the nucleus prepositus). These nuclei are small, small celled and difficult to distinguish. They are probably intra- or intersegmental. Just dorso-lateral to the nucleus intercalatus is a small fine-fibered bundle, the tractus dorsalis tegmenti or dorsal longitudinal bundle of Schütz. What is its character? In the region of the trigonum vagi note the dorsal motor (preganglionic sympathetic) nucleus of the vagus (large and small celled divisions) or nucleus alæ cinereæ. What do its fibers probably innervate? Note the fasciculus solitarius (descending arms of afferent root fibers of nerves VII, IX and X). Where are the cell bodies originating them and what do they innervate peripherally? Dorso-medial to this bundle, in the central gray, is the "sensory" nucleus of nerve X. Another (compact appearing) nucleus in this

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region is the nucleus rotundus vagi. Ventro-laterally to the solitary fasciculus is the small ventral nucleus of the solitary fasciculus and dorsally to it the small dorsal nucleus of the solitary fasciculus. These nuclei cannot be distinguished in all levels. What is the general character of these last three nuclei? Can you suggest any special function for each? Note the poverty of medullated fibers in the vagus nuclei in the central gray. What conclusions do you draw? Locate the nucleus ambiguus or ventral motor nucleus of the vagus, lying in the gray reticular formation. What do its fibers innervate? The vagus probably has another nucleus lying medially to the latter in the gray reticular formation whose preganglionic fibers pass to sympathetic ganglia which send fibers to glands (glandular or secretory nucleus). Trace, as far as possible, the vagus root fibers to and from these nuclei and to the solitary fasciculus. Through what structures do they pass? Beneath the area acustica note the medial vestibular nucleus and further laterally the descending vestibular root fibers and their nucleus. What is the origin of these fibers and what is their relation to the vestibular nuclei? The vestibular area is also called juxtarestiform. Why? What similarity or parallelism is there between the course of the roots of the trigeminus, vestibular and facialis-glossopharyngeo-vagus nerves? Why three separate systems? Study carefully (also high power) the internal arcuate fibers emerging from the vestibular and central gray (vagus) areas and passing ventro-medially. What is their general character? Can you suggest any reflex or other connections mediated by them? Note that laterally to the vestibular fibers and nuclei is still a remnant of the nucleus of the column of Burdach and possibly of the nucleus of the column of Goll. Are there any arcuate fibers from these nuclei? Note the diminished nucleus of the spinal V (continuation of the dorsal horn) and distinguish between the fibers of the spinal V and those of the large restiform body. What are the origins of the latter fibers? Of what general path do they form a part?

Note the continuation of the lateral column of the cord. What tracts are present in it here? Note the great extent of the gray reticular formation. Next to the median line and dorsal to the pyramids is a mass of longitudinal fibers. Which of these constitute the medial lemniscus and which the continuation of the ventral column of the cord? The latter is now called the medial or posterior longitudinal fasciculus. What fibers compose it? Does it occupy the

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same position relatively to the central cavity which it occupied in the cord? Note that the medial longitudinal fasciculus and medial lemniscus are crossed by numerous transverse decussating fibers producing a reticulated appearance. This is sometimes called the white reticular formation (formatio reticularis alba) in distinction from the gray reticular formation. Why is one called gray and the other white? The median line is called the raphé. Why? As far as you can tell what kinds of fibers are decussating here? Dorsal to the inferior olivary nucleus lie part of the vestibulospinal and the medial spino-thalamic tracts. The olivary nuclei, pyramids and medial fillet are thus virtually new structures added ventrally to the cord. Significance? Distinguish in the inferior olivary nucleus the three parts, the medio-ventral and dorsal accessory and the main portions. Which portion or portions are the newer? Why? Trace the fibers from the olivary nuclei to the restiform bodies. Are they mainly crossed or uncrossed? What appearances in the section indicate this? Note and trace any superficial arcuate fibers present. Note the nuclei funiculi lateralis and the nuclei reticularis. What is the general significance of the latter? Of the former? Draw as directed in 1.

11. Section of adult medulla similar to 10. Weigert's myelin stain.

Note the same points as in 10, also compare the degree of myelinization of the pryamidal tracts and the myelinated fibers in various other areas deficient in myelinated fibers in 10.

12. Section of medulla similar to 10. Nissl's stain.

Study the cell groups mentioned in 10. Draw as directed in 3.

13. Section of medulla similar to 10. Cajal's silver stain.

Study the various points covered in sections 10, 11 and 12.

14. Transverse section of an infant's medulla through the middle of the inferior olivary nucleus. Weigert's myelin stain.

The structures present here are the same as those described in 10, excepting the disappearance of the nucleus cuneatus and changes in the sizes of other structures, especially an increase of the inferior olivary nucleus, restiform body, descending vestibular root and nuclei and solitary fasciculus.

If a drawing is made follow the directions given in 1.

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15. Similar section of the adult medulla. Weigert's myelin stain.

Note the differences between this and 14.

16. Similar section of the medulla. Nissl's stain.

If a drawing is made follow the directions given in 3.

17. Similar section of the medulla. Cajal's silver stain.

Study the various points covered in 14, 15 and 16.

18. Transverse section of an infant's medulla through the entrance of the cochlear root of nerve VIII. Weigert's myelin stain.

Naked eye, ocular and low power. Note that the fourth ventricle is much wider and in some sections its long lateral recesses may be seen extending ventrally in two prolongations at the sides of the medulla. In some sections of somewhat higher levels, one or both sides of the medulla are continuous with the cerebellum, the section passing in front or cephalad of the lateral recesses. Note the chorioid plexus protruding into the fourth ventricle and its lateral recesses. Note that the floor of the ventricle is now practically at right angles to the median line of the medulla. Note that the trigonum vagi has disappeared. Why? Laterally to the medial eminence, the floor of the ventricle is occupied by the area acustica of which there are two portions, a medial vestibular (juxtarestiform) and a lateral protuberance, the acoustic tubercle (tuberculum acusticum) which may be called cochlear. Why? Note the olive, post- and preolivary furrows, pyramids and ventral longitudinal sulcus. Compare with a brain, brain model or illustrations of the brain.

Identify the dorsal cochlear nucleus (in the acoustic tubercle) the ventral or "accessory" cochlear nucleus and the cochlear root fibers entering the latter ventrally. What is the origin of the cochlear root fibers, what do they innervate and what is their relation to the cochlear nuclei? What is their function? In some sections (not constant) bundles of fibers pass from the acoustic tubercle across the floor of the ventricle, the striæ acusticæ. What do they represent?

Usually the root fibers of the glossopharyngeus can be seen emerging. What are their origins and what do they innervate? Trace them inwards. Many go to the region of the fasciculus solitarius, now reduced in size. If the fasciculus is very small note, in its former place, the prevagal nucleus gustatorius. What are its probable relation to the

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glossopharyngeus, function and further connections? There may be some remnants of the dorsal motor and "sensory" nuclei of the vagus (and glossopharyngeus) mentioned in 10. Identify the nucleus ambiguus. Medial to it in the gray reticular formation, but not distinguishable, is the preganglionic sympathetic nucleus salivarius inferior. What does it innervate? Function? Note that the nucleus hypoglossi has disappeared. Its place in the medial eminence is occupied by the nucleus prepositus. Beneath the area acustica (vestibular portion) distinguish the descending vestibular root fibers (much increased), their nucleus and the medial (triangular or "principal" or Schwalbe's) vestibular nucleus. Trace carefully (also high power) any internal arcuate fibers proceeding from the above vestibular and glossopharyngeal areas. What is their general significance and what are their various probable connections?

Note the spinal V and its nucleus. Distinguish between the fibers of the spinal V and those of the massive restiform body. Note the large convoluted principal portion of the inferior olivary nucleus and also the dorsal accessory portion. Trace carefully the fibers passing from the inferior olivary nucleus to the restiform body. Are they crossed or uncrossed? Why? Note the large gray reticular formation and the nuclei reticularis, also the nuclei funiculi lateralis. Note the continuation of the remnant of the lateral column of the cord beneath the postolivary furrow. What tracts compose it? Their function? Effect of an injury here? Note the large medial fillets, lying between the inferior olivary nuclei, and dorsal to them the predorsal bundle (colliculo-spinal fibers) and the continuation of the rest of the ventral white column now called the medial longitudinal fasciculus. What fibers compose the latter? The remainder of the vestibulo-spinal fibers and the medial spino-thalamic tract lie dorsal to the inferior olivary nucleus. It will be noted that they still form the portion connecting the ventral and lateral columns as they do in the cord. Note the large pyramids and any superficial arcuate fibers which may be present.

19. Similar section of the adult medulla. Weigert's myelin stain.

Note the same points as in 18.

20. Similar section of the medulla. Nissl's stain.

Study the cell groups mentioned in 18. If a drawing is made, draw as directed in 3.

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21. Similar section of the medulla. Cajal's silver stain. Note, as far as possible, the points observed in sections 18, 19 and 20.

22. Transverse section of an infant's rhombencephalon at the level of the caudal border of the pons and the emergence of the vestibular, facial and abducens nerves. Weigert's myelin stain.

Naked eye, ocular and low power. Distinguish in the whole neural tube the cerebellum, the pons (lighter stain) and the tegmentum. Which of the two latter is the older? Which contains the more fundamental neural mechanisms? What kind of a connection does the pons represent?

Note the shape of the fourth ventricle. In its floor distinguish medial eminence, sulcus limitans and area acustica. Projecting downward is the inferior vermis (nodulus) of the cerebellum. Note the presence of a portion of the plexus chorioideus. Externally the outer portions of the cerebellum have been removed. Note the flocculus cerebelli at the sides. Note, if present, the emerging roots of the vestibular portion of nerve VIII, nerves VII and VI. Between the two former are sometimes seen the slender root of the portio intermedia VII (nerve of Wrisberg, glosso-palatine nerve). What kind of fibers are found in the vestibular, abducens and the two portions of the facial nerves? What do they each innervate and what are their respective functions? Compare with a brain, brain model or illustrations of the brain.

Trace the vestibular root fibers inwards into the vestibular area. What becomes of them there? Where do they pass in relation to the restiform body and spinal V? Distinguish the nucleus of Deiters, the medial vestibular nucleus (smaller here) and (usually at a somewhat higher level) the superior vestibular nucleus (of von Bechterew). Carefully study (also high power) and trace as far as possible any internal arcuate fibers from this region. What in general do they represent? What are their probable connections? Carefully study (also high power) the motor facial nucleus. Note the coarse root fibers emerging from it. In what direction? Note the finer fibers within the nucleus and as far as possible note their sources. What are their probable ultimate sources and what functional connections do they represent? Identify any other portions of the facial roots which may be present. Note the root fibers of the abducens. They may be emerging or traversing the pons or pyramids or they may be imbedded in the

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medial lemniscus according to the exact level of the section. (For the nucleus and deeper origin see next level.)

Note the fibers of the restiform body now beginning to pass into the white matter of the cerebellum. What relation do they have to the conspicuous nucleus dentatus cerebelli? Note the juxtarestiform fibers passing dorso-ventrally in the cerebellum medial to the nucleus dentatus (see next level). Distinguish the spinal V and its nucleus. In some sections ventral to the restiform body may be seen the cephalic extremity of the ventral cochlear nucleus and possibly fibers passing medially from it. In other higher sections only the latter can be seen, passing medially ventral to the spinal V. These are the trapezius fibers. What is their origin, termination and of what path are they a part? Note the superior olivary nucleus (and in some sections the nucleus of the trapezoid body and parolivary nuclei). Can you make out any relation to the trapezius fibers? What is the relation of the superior olive to them? What change in shape has the medial lemniscus undergone? Why? Distinguish the posterior longitudinal fasciculus. Has it changed its position? At about this level it begins to receive ascending vestibulo-spinal fibers. To what? What other fibers does it contain? Have you seen any evidence of its receiving fibers from the vestibular nuclei? Locate the continuation of the lateral column. Does it occupy the same position as formerly? What tracts compose it? Note the complete disappearance (or diminution) of the inferior olivary nucleus. Note in the area previously occupied by it, between superior olivary nucleus and medial lemniscus, a diffuse bundle of fibers, the central tegmental tract. What is its relation to the inferior olivary nucleus? Note the large gray reticular formation and its nuclei (nuclei reticularis).

In the pons distinguish the gray masses (the pontile nuclei; what fibers do they receive and originate?), the longitudinal fibers (what are they?), the transverse fibers (what are they, what is their origin and destination and of what connection or path are they a part?) and the perpendicular fibers. Distinguish the continuation of the transverse pontile fibers into the white matter of the cerebellum. Are they located externally or internally to the other connections? Why?

Draw as directed in 1.

23. Similar section of the adult medulla. Weigert's myelin stain.

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Observe the points mentioned in 22, noting any difference in myelinization or otherwise.

24. Similar section of the medulla. Nissl's stain.

Study the cell groups mentioned in 22. If a drawing is made, draw as directed in 3.

25. Similar section of the medulla. Cajal's silver stain.

Study the various points covered in 22, 23 and 24.

26. Transverse section of the infant's rhombencephalon at the level of the nucleus of nerve VI, deeper portions of the roots of VI and VII and the emergence of the afferent portion of nerve V. Weigert's myelin stain.

Naked eye, ocular and low power. Note the fourth ventricle, the medial eminences on its floor, its general shape and diminished size. Note the three great divisions of the neural tube: cerebellum, pons and tegmentum. Note the emergence of nerve V. What do its fibers innervate? Compare with a brain, a brain model or illustrations of the brain.

Note the root fibers of nerve VII. In what places do you see them? Connect with their position in the previous sections. In the lateral portion of the medial eminence, note the nucleus abducentis, forming part of the eminentia abducentis (and facialis, why the latter?). Trace its fibers, the root fibers of the VI, ventrally through the tegmentum to the medial lemniscus. Connect them here with their position in previous sections and reconstruct the whole central course of the roots. Is there any "kink" in their course? Where and why? What fibers does the nucleus VI receive? Do you see any evidences of them (also use high power)? Note that the nucleus of the spinal V has become somewhat broken up and that the spinal V is passing out to the ventro-lateral surface of the pons. What is the proper anatomical interpretation of this appearance? What is the origin of these fibers and their central course as far as you have studied them?

Note the superior olivary nucleus and distinguish the lateral fillet or lateral lemniscus (not very distinct as yet) dorso-laterally to the superior olivary nucleus. What is its origin and termination and of what path is it a part? Are there any decussating trapezius fibers present? Note the fibers connecting the vestibular (juxtarestiform) region and cerebellum. In the cerebellum they pass upward between the now diminished nucleus dentatus and ventricle. Further forward some pass around outside the superior ped-

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uncle (uncinate bundle). Note that near the medial upper part of the nucleus dentatus is another nucleus, the nucleus emboliformis. Dorso-medial and also ventral to this, in some sections, can be seen the small round nuclei globosi and, probably better in the next level, there is in the roof near the median line on each side the larger nucleus tecti or nucleus fastigii (the nucleus of the roof or of the peak. Why these names?). Distinguish the fibers of the restiform body. How are they situated with reference to the nucleus dentatus? Distinguish in the cerebellum the pontile or middle peduncular fibers. Note that as the nucleus dentatus diminishes it is replaced by a mass of fibers lying next to the ventricle and passing forward. This is the superior cerebellar peduncle (brachium conjunctivum). What are the three cerebellar peduncles, what are the origins and terminations of the fibers composing them and of what cerebellar paths are they a part? What is the general meaning of the terms peduncle, brachium (brachia) and crus (crura)?

Note in the now larger pons the nuclei pontis and the longitudinal, transverse and perpendicular pons fibers. Origins and terminations? The transverse fibers are sometimes distinguished as dorsal or deep, middle, and ventral or superficial, the middle interlacing ones forming the stratum complexum.

Note the medial lemniscus, the medial longitudinal fasciculus and locate the continuation of the lateral column of the cord. What tracts are present in the latter here? Note the gray reticular formation, its nuclei and the central tegmental tract, now assuming a position near its center.

Draw as directed in 1.

27. Similar section of the adult rhombencephalon. Weigert's myelin stain.

Observe the points mentioned in 26, noting any differences.

28. Similar section of the rhombencephalon. Nissl's stain.

Study the cell groups mentioned in 26. If a drawing is made, draw as directed in 3.

29. Similar section of the rhombencephalon. Cajal's silver stain.

Study the various points covered in 26, 27 and 28.

30. Transverse section of the infant's rhombencephalon at the level of the nucleus and exit of the efferent (motor) root (portio minor) of nerve V. Weigert's myelin stain.

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Naked eye, ocular and low power. Note the cerebellum, pons and tegmentum, also that the only connection between the cerebellum and the rest of the neural tube is by means of the now fully formed superior cerebellar peduncle, now beginning to pass ventrally into the tegmentum and forming here the lateral wall of the fourth ventricle. Note the emergence of the portio minor of nerve V. What does it innervate? Compare with a brain, brain model or illustrations of the brain.

Note the motor nucleus (nucleus masticatorius, why so named?) of the trigeminus and the motor root fibers passing from it to the periphery. Note also that some of the fibers come from a small bundle medial to the ventral border of the superior peduncle. These constitute the mesencephalic root of nerve V. Try to distinguish the rather large rounded cells near the ventricle from which these fibers originate, the mesencephalic nucleus of nerve V. What is there peculiar about its position for a nucleus whose axones pass outside the central nervous system? What conclusions might be drawn as to the character of this nucleus? Note the "principal sensory nucleus" of nerve V. What is its relation to the nucleus of the spinal V and to the afferent trigeminal fibers? Look for any evidences of a secondary trigeminal tract (what is meant by "secondary tract"?) passing across near the floor of the ventricle. Note the disappearance of the abducens nucleus. Is there any portion of the root fibers of nerve VII present? Reconstruct the whole central course of the motor root of nerve VII and especially its position with reference to the nucleus abducentis. Note the disappearance of all vestibular nuclei.

Note the nuclei fastigii in the cerebellum. Is there any nucleus dentatus present? What fibers do these nuclei receive and originate? Of what paths are they a part? Note that the pyramidal tracts in the pons are now broken up into a number of bundles. By what? Note the nuclei pontis and the perpendicular and transverse fibers of the pons, the latter no longer passing into the cerebellum. Note the medial lemniscus, lateral lemniscus, medial longitudinal fasciculus, reticular formation and its nuclei and the central tegmental tract. About at this level the ventral spinocerebellar tract passes dorsally and assumes a position external to the superior cerebellar peduncle. What tract or tracts are here left in the continuation of the lateral column? Draw as directed in 1.

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31. Similar section of the adult rhombencephalon. Weigert's myelin stain.

Observe the points mentioned in 30, noting any difference.

32. Similar section of the rhombencephalon. Nissl's stain.

Study the cell groups mentioned in 30. If a drawing is made, draw as directed in 3.

33. Similar section of the rhombencephalon. Cajal's silver stain.

Study the various points mentioned in 30, 31 and 32.

34. Vertical section through the cortex of the cerebellum and subjacent white matter. Cut transversely to the cerebellar folia or laminæ. Nissl's stain.

Naked eye, ocular and low power. Note the pia mater enveloping the branching laminæ. In each lamina note an external lighter layer (molecular or plexiform layer), an inner darker layer (granular or nuclear layer) and a lighter core (the white matter). On examination with the ocular or low power note the single row of widely spaced, large pear-shaped cells between the molecular and granular layers, the cells of Purkinje. The three layers (molecular, Purkinje and granular) constitute the external gray or cortex of the cerebellum.

Low power and high power. Note that there are comparatively few nuclei in the molecular layer, the nuclei of the stellate cells. The cytoplasm, especially of the inner, larger stellate (basket) cells is distinguishable. Study carefully the Purkinje cells, their nucleus, cytoplasm and chromophilic bodies. Are the latter like those in the lower motor neurones? Study the cells of the granular layer. Note the two kinds of nerve cells, the caryochrome granule cells and a few large somatochrome cells, Golgi type II or the van Gehuchten cells. What is the difference between these two types? Note that the granule cells are not uniformly distributed but that there are numerous small spaces free from them, the "glomeruli." Distinguish the somewhat larger nuclei of the neuroglia cells, especially at about the level of the cells of Purkinje. In the white matter note the nuclei of the neuroglia cells. Everywhere note the blood-vessels both within the nervous tissue and the pia.

Make a drawing of a portion of a lamina showing the distribution of the cells in the different layers and a high power drawing of each kind of cell.

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35. Similar section. Weigert's myelin stain.

Naked eye, ocular and low power. Note in each lamina the deeply stained core of white matter (why so deeply stained?), next a lighter layer, principally the granular layer (why stained more lightly?), and an external pale layer, most of the molecular layer (why pale?). Under low power note the arrangement of the medullated fibers in a single lamina. What is the arrangement? Are there any medullated fibers in the molecular layer? Where?

Make a drawing of a single lamina showing the arrangement of the medullated fibers in each layer.

36. Similar section. Cajal's silver stain.

Naked eye, ocular and low power. Select a place where the stain is good and the section vertical. Identify the molecular, Purkinje and granular cortical layers and the white matter. Study the Purkinje cells, note the extent of their branching dendrites. Identify the basket fibers and study the pericellular baskets formed by their collaterals around the bodies of the Purkinje cells. What is their origin? Note the fibers in the granular layer and try to identify an axone of a Purkinje cell.

Draw a small vertical portion of a lamina, sufficient to include one Purkinje cell and its basket.

37. Similar section, showing the climbing fibers. Cajal's silver stain.

Low power and high power. Examine the dendrites of the Purkinje cells for the appearances mentioned below. Study under high power the pale coarse dendrites with fine black fibers in apposition with them, the climbing fibers.

Draw a few dendritic branches (high power) with their climbing fibers.

38. Similar section, showing the mossy fibers. Cajal's silver stain.

Low power and high power. Select portions of the granular layer which have a rather faintly mottled appearance. The small darker areas producing this appearance are the glomeruli. Examine (high power) and note the fibers, with thickenings or excrescences as they pass through or end in the glomeruli. These are the mossy fibers. What structures are interlaced and terminate in the glomeruli?

Draw (high power) some of the mossy fibers.

39. Similar section. Golgi's chrome-silver impregnation.

Low power. Find dendritic arborizations of Purkinje cells or a whole cell if possible, also look for granule cells

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and neuroglia cells, the latter both in cortex and white matter. Look in the white matter for glia cells whose processes adhere to the walls of blood-vessels (the latter usually stained brownish). Note the epithelial or spongioblastic character of the glia cells whose processes extend through the molecular layer (fibers of Bergmann).

High power. Note the excrescences ("gemmules") on the finer dendrites of the Purkinje cells and study further the above structures.

Draw the above structures.

40. Demonstration. Vertical section cut longitudinally through the laminæ. Golgi's chrome-silver impregnation.

Note the granule cells, their short dendrites and their axis-cylinder extending into the molecular layer and there bifurcating into two longitudinal fibers (the "parallel fibers"). Are the axones of the granule cells myelinated? Reason for answer?

In the previous sections which are the fibers which terminate in the cerebellar cortex? From what cells do they arise? Of what paths are they a part and what is their functional significance? Which are the cells which send their axones out of the cerebellar cortex? Where do these axones end? Of what path are they a part and what is their functional significance? Which of the neurones studied are the association neurones of the cerebellar cortex and what are the possible functional connections which they may make? What light is thrown upon cerebellar function by the nature of the cerebellar connections and the cortical integrating mechanisms? Do the nature of the cerebellar connections and the structure of the cortex favor or contradict localization of function in it? What points require further investigation?

41. Vertical section of an infant's cerebellar cortex. Nissl's or Weigert's stain.

Note the presence of an external granular layer in the outer part of the molecular layer. What embryological significance has this? What is its significance as to the development of cerebellar functions?

42. Transverse section of an infant's rhombencephalon through the isthmus and emergence of the trochlear nerve. Weigert's myelin stain.

Naked eye, ocular and low power. Note the general shape of the isthmus. What is the trigonum lemnisci? Why so called? Note the small size of the fourth ventricle,

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now passing into the iter. Distinguish the roof or superior medullary velum, the tegmentum and pons. Compare with a brain, brain model or illustrations of the brain. Note the decussation of the root fibers of nerve IV in the superior medullar velum and their emergence. What do they innervate? Note the various structures in the tegmentum. Has the medial lemniscus changed its position? The lateral lemniscus? In what respect? Note the nucleus of the lateral lemniscus. Note the beginning decussation (commissure of Wernekinck) of the superior cerebellar peduncle or brachium conjunctivum. Identify the medial longitudinal fasciculus (what fibers compose it here?), the central tegmental tract and the mesencephalic root of the trigeminus. Try to locate (high power) its nucleus, also the locus cæruleus and the positions of the rubro-spinal and lateral spino-thalamic (and spino-tectal) tracts. In some sections superficial fibers may be seen passing around outside the medial lemniscus. These may be the ventral spino-cerebellar fibers which loop back into the cerebellum outside the superior peduncle. Note the presence of small lightly stained bundles of fibers in the medial lemniscus. These are aberrant pyramidal fibers. What is their probable source and destination? Note the nuclei reticularis.

In the pons distinguish the pontile nuclei and the transverse, longitudinal and perpendicular fibers of the pons. In the infant the pyramidal fibers alone are well stained. Why? In some sections fibers may be seen proceeding from pons to medial lemniscus. These are other aberrant pyramidal fibers. What is their source and destination? What are the connections and paths of the nuclei and tracts studied in this section?

Draw as directed in 1.

43. Similar section of adult isthmus. Weigert's myelin stain.

Note the points mentioned in 42 and compare the myelinization of the various fibers in the pons with those in the infant.

44. Similar section of the isthmus. Nissl's stain.

Study the cell groups mentioned in 42. If a drawing is made, draw as described in 3.

45. Similar section of the isthmus. Cajal's silver stain.

Study the various points mentioned in 42, 43 and 44. Note the large rounded cells of the mesencephalic trigeminal nucleus.

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**G. Mesencephalon (Colliculi or Corpora Quadrigemina, Tegmentum, a portion of the Pons and Basis Pedunculi or Crus).**

1. Transverse section of an infant's mesencephalon through the inferior colliculi (posterior corpora quadrigemina). Weigert's myelin stain.

Naked eye, ocular and low power. Note the general shape of the section, the external eminences of the inferior colliculi, the trigonum lemnisci and the cavity of the brain, the iter or aquæductus Sylvii (or cerebri). Distinguish the roof part or colliculi, the tegmentum and the pons. Compare with a brain, brain model or illustrations of the brain. Note the inferior colliculus and distinguish the large oval gray mass, the nucleus of the colliculus, external to which, dorsally, is the cortex of the colliculus. Note the commissure of the colliculi. Note the lateral lemniscus fibers entering the nucleus of the colliculus. What are the principal connections of the inferior colliculi and their general functional significance?

In the tegmentum note the medial lemniscus, the lateral spino-thalamic and spino-tectal or spino-collicular tracts, the decussation of the superior cerebellar peduncles, and try to locate the rubro-spinal tract. In some sections the superficial pes-lemniscus bundles (an aberrant pyramid tract) may be seen medial to the medial lemniscus. In the central gray note the root fibers of nerve IV in its outer portion, sometimes visible as they are leaving their nucleus. Identify the nucleus of nerve IV, indented in the dorsal surface of the medial longitudinal fasciculus. Reconstruct the central course of nerve IV. Note the mesencephalic root of nerve V, always bordering the central gray. Try to identify its nucleus (large rounded cells); also the locus cæruleus and nucleus tegmenti dorsalis. The central tegmental tract is difficult to distinguish among the decussating fibers of the superior cerebellar peduncle. In the pons note that the pontile nuclei and transverse fibers have diminished and the longitudinal fibers (only the pyramidal fibers being stained in the infant, why?) are being massed together. In some sections the anterior foramen cæcum may be present in the median line between pons and tegmentum and laterally to it the interpeduncular ganglion or nucleus. What are the connections, paths and functions of the above nuclei and tracts?

Draw as directed in F. 1 (rhombencephalon).

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2. Similar section of the adult mesencephalon. Weigert's myelin stain.

Note the points mentioned in 1. Compare the myelinization of the fibers in the pons with those of the infant.

3. Similar section of the mesencephalon. Nissl's stain.

Study the cell groups mentioned in 1. If a drawing is made, draw as directed in F. 3 (rhombencephalon).

4. Similar section of the mesencephalon. Cajal's silver stain.

Study the various points mentioned in 1, 2 and 3. Note the large round cells of the mesencephalic trigeminal nucleus.

5. Transverse section of an infant's mesencephalon through the superior colliculi (anterior corpora quadrigemina) and emergence of the oculomotor nerve. Weigert's myelin stain.

Naked eye, ocular and low power. Note the eminences of the superior colliculi and the crusta or pes pedunculi and interpeduncular space. In the higher levels note the two lateral prominences, the medial or internal geniculate bodies. Note the emergence of the oculomotor nerve. What does it innervate? Note the aquæductus Sylvii. Compare with a brain, brain model or illustrations of the brain.

Distinguish the roof or superior colliculi, the tegmentum and the basis pedunculi, the latter replacing the pons and consisting of the substantia nigra and the pes pedunculi (crusta). The tegmentum and basis pedunculi are sometimes collectively called the crura cerebri.

In the colliculi note the various layers and if possible distinguish the alternating gray and white layers (stratum cinereum, stratum opticum, stratum lemnisci and the deep white layer next to the central gray composed of efferent collicular fibers from the preceding layers). What are the afferent and efferent connections of the superior colliculi and what is its general functional significance?

In the central gray note especially the nucleus of the oculomotor nerve. Distinguish the lateral large-celled, and, if possible, the medial portions. In the higher levels identify the small-celled Edinger-Westphal nucleus, more dorsally located. What is probably the functional difference between the large- and small-celled portions of the nucleus? What fibers probably terminate in this nucleus? What are their functional significances? Trace the course of the root fibers to the surface. Note the brachium of the inferior

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colliculus. Why so called and what does it connect? Functional significance? Note the lateral spino-thalamic (and spino-tectal or spino-collicular) tract, here quite distinct. Functional significance? Has the medial lemniscus changed in shape or position? Note the large nucleus ruber. The emergence from it and decussation of the rubro-spinal tract (ventral tegmental decussation of Forel) has taken place in somewhat lower levels. Look for the decussation of the colliculo-bulbar and colliculo-spinal fibers (dorsal tegmental decussation of Meynert). It may take place in a somewhat lower level than the section. Are there any decussating fibers of the superior cerebellar peduncle present? What are the various probable connections of the nucleus ruber?

Locate the central tegmental tract in the gray reticular formation. Where does it terminate? Is its exact origin known?

Note the substantia nigra. Why so called? Ventrally, note the mass of fibers known as the pes pedunculi. What fibers compose it? Origins? Terminations? Paths? Functional significance? Note that in the infant only the fibers of the middle portion of each pes is medullated. What fibers are these? What are the non-medullated fibers? (Compare section 6 below.) In many sections of the higher levels note the fibers from the pes passing into the lateral part of the substantia nigra, the deep (or lateral) pes-lemniscus fibers. What is the source and destination of these aberrant pyramidal fibers? Function? In some sections (not constant) fibers pass from the pes around its outer side to take a position medial to the medial fillet, the superficial (or medial) pes-lemniscus bundle. They are also aberrant pyramidal fibers. Source? Destination? Function?

If the medial geniculate body be present, note the lateral lemniscus fibers entering it.

What are the connections, paths and functional significance of the nuclei and tracts in this section?

Draw as directed in F. 1 (rhombencephalon).

6. Similar section of the adult mesencephalon. Weigert's myelin stain.

Observe the points mentioned in 5. Compare especially the myelinization of the fibers of the pes with those in 5. What general method does this comparison illustrate?

7. Similar section of the mesencephalon. Nissl's stain.

Study the cell groups mentioned in 5. If a drawing is made, draw as directed in F. 3 (rhombencephalon).

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8. Similar section of the mesencephalon. Cajal's silver stain.

Study the various points mentioned in 5, 6 and 7. Study especially the nucleus of the oculomotor nerve.

**H. Prosencephalon (Diencephalon [Epithalamus, Thalamus and Hypothalamus] and Telencephalon [Rhinencephalon, Corpora Striata and Pallium]).**

1. Transverse section through the junction of midbrain and forebrain. Weigert's myelin stain.

Naked eye, ocular and low power. Note the dorsal eminences of the superior colliculi still present, between which may be, if not detached in preparation, the pineal body. Laterally is the overhanging pulvinar of thalamus which in turn passes laterally into the cerebral hemisphere. Ventro-laterally is the protruding lateral or external geniculate body, more medially the pes and, between the two pedes, the interpeduncular or posterior perforated (why so called?) space. In the latter the root fibers of the oculomotor nerve may be seen emerging. Compare with a brain, brain model or illustrations of the brain.

Distinguish in the section the lateral portions belonging to the telencephalon, the portions belonging to the diencephalon (pulvinar, medial and lateral geniculate bodies and pineal body) and the parts belonging to the mesencephalon (superior colliculi, tegmentum and basis pedunculi, the latter composed of substantia nigra and pes). Note the aquæductus Sylvii.

Midbrain. Note the central gray and within its ventral portion the oculomotor nuclei. Identify the Edinger-Westphal nucleus, if present. Trace the root fibers of the oculomotor nerve to their exit. Note the colliculi and their commissure. In higher sections the posterior commissure may be present. In the tegmentum note the large nucleus ruber with fibers within and on its medial aspect. What are these fibers, in part at least? Note the nuclei reticularis and fiber bundles in the gray reticular formation which is still present. Note the medial lemniscus, now showing signs of dispersion. Dorsal to it is the lateral spino-thalamic tract. Note that the medial longitudinal fasciculus is diminished. Laterally to it is the nucleus of the posterior commissure which, with other larger cells of a motor appearance (in Nissl preparations) in the reticular formation (interstitial nucleus), is believed to give rise to descending fibers from the midbrain forming part of the medial longitudinal fasciculus. Note the substantia nigra. It may con-

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tain aberrant pyramidal bundles (subthalamic bundle and deep pes-lemniscus bundle). The large mass of fibers forming the pes is unaltered.

Thalamus. Identify the medial geniculate body and note the fibers accumulating on its lateral aspect. Where do they probably go? What fibers does this body receive? General functional significance? Note the lateral geniculate body. What are the fibers on its ventral aspect? Their origin? Dorsally may be seen the field of Wernicke composed of fibers curving dorsally towards the pulvinar (collaterals of the optic tract?), crossed by fibers of the thalamic radiation. Functional significance of the lateral geniculate body? Note the large pulvinar and the fibers radiating from it (part of the thalamic radiation), traversing the retrolenticular portion of the internal capsule and entering the corona radiata of the pallium. What three great sensory paths undergo relays in this part of the brain? What is the significance of these thalamic relays?

Draw as directed in section F. 1 (rhombencephalon).

2. If No. 1 is a section of the infant's brain, study a similar section of the adult brain. Weigert's myelin stain, and compare with 1.

3. Similar transverse section. Nissl's stain.

Study the cell groups mentioned in 1. If a drawing is made, draw as directed in F. 3 (rhombencephalon).

4. Transverse section of the diencephalon through the optic chiasma. Weigert's myelin stain.

Naked eye, ocular and low power. Note the optic chiasma and tuber cinereum on the ventral aspect. Note the third ventricle and (usually torn away) its roof, the tela chorioidea. In more frontal sections the sulcus hypothalamicus may be seen on the inner, ventricular wall of the diencephalon. Note the optic tract passing to about the location of the lateral geniculate body in the preceding level. Compare with a brain, brain model or illustrations of the brain.

Epithalamus. Note the habenula and its nucleus and, if the section is at the right level, the habenular commissure. Note the beginning of the fasciculus retroflexus of Meynert. Where does it originate? Where terminate? Of what path is it a part? Note the tænia thalami and near it the bundle of fibers known as the stria medullaris, terminating partly in the nucleus habenulæ. Note the stalk of the pineal body.

Thalamus. Note the lateral and ventro-lateral nuclei, more medially the arcuate nucleus and the median center of

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Luys. Note that the medial lemniscus has disappeared in the ventrolateral nucleus. In higher sections the medial thalamic nuclei are separated from the more lateral by the medial medullary lamina (of medullated nerve fibers). What is the general difference between the medial and lateral nuclei in respect to their connections with the ascending tracts and cortical connections? What is its probable functional significance as regards sensation? From the lateral portions of the thalamus note the fibers of the thalamic radiations passing dorso-laterally to the lateral border of the thalamus, forming there the lateral medullary lamina and thence passing obliquely across the internal capsule into the corona radiata. What are the connections of these fibers? Functional significance? Note the small bundle of fibers at the junction of caudate nucleus and thalamus, the stria cornea (stria semicircularis, from primary olfactory cortex to nucleus amygdalæ). In the ventral part of the thalamus note the tegmental area H of Forel which replaces the nucleus ruber (present in some of the sections). Laterally from this proceed the fibers of the tegmental radiation (field H1 of Forel, representing connections of nucleus ruber with pallium?). Ventrally is the gray zone incerta and ventrally to this a bundle of fibers, the lenticular bundle (field H2) of Forel, a part of the ansa lenticularis system. These latter fibers can be seen passing through (fibræ perforantes) the adjacent lenticulothalamic segment of the internal capsule to the globus pallidus (see below) from which they originate. They pass to the corpus subthalamicum of Luys (see below), to the tuber cinereum, also probably to the nucleus ruber and possibly to the substantia nigra. Ventrally to this bundle note the corpus subthalamicum of Luys.

Hypothalamus. Note the tuber cinereum and the mammillary bodies. In the lateral portion of the latter note the termination of the descending anterior pillar of the fornix (connections?). From the medial part of the mammillary body note the fasciculus mammillaris princeps, a part of which higher forms the mammillo-thalamic bundle of Vicq d'Azyr. What are the paths of which these connections are a part?

Telencephalon: Corpus striatum. Note, at the dorsolateral border of the thalamus, the tail of the caudate nucleus. Externally to the internal capsule (pes) note the lenticular nucleus. Distinguish its lateral part, with comparatively few medullated fibers, the putamen, and its medial part, the globus pallidus, with radiating medullated

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fibers. Why are these various names appropriate? Note that the globus pallidus is both subdivided and separated from the putamen by laminæ of medullated fibers (probably principally fibers of passage).

Internal capsule. Note that a considerable portion of the pes is now between the thalamus and lenticular nucleus, constituting the posterior or lenticulo-thalamic portion of the internal capsule. Note also that the fibers of the dorsal part of the capsule are, in company with the fibers of the thalamic radiation, passing into the corona radiata of the pallium. Correlate the portions of the internal capsule seen in these sections with the various portions of the capsule seen in horizontal (frontal) sections.

Draw as directed in F. 1 (rhombencephalon).

5. If the preceding is a section of the infant's brain, study a similar section of the adult brain, Weigert's myelin stain, and compare with 4.

6. Similar section. Nissl's stain.

On comparing with the cell groups as seen in myelin-stained sections it will be observed that the various thalamic nuclei do not each always have their own peculiar type of cell. Most nuclei have small cells, presumably many with axones confined to the thalamus or to the nucleus itself. Some nuclei have only small cells, other nuclei have in addition other larger types of cells more peculiar to them. The ventro-lateral nuclei have scattered very large cells, possibly those cells sending fibers to the primary sensory cortical areas. There are no cells of the "premotor" type in the thalamus proper. If a drawing is made, draw as directed in F. 3 (rhombencephalon).

7. Similar section. Cajal's silver stain.

Note, as far as possible, the features observed in 4, 5 and 6.

8. Transverse section of the thalamus, internal capsule and corpus striatum through the anterior cerebral commissure. Weigert's myelin stain.

Naked eye, ocular and low power. Distinguish the thalamus, corpus striatum and internal capsule.

Thalamus. Note the medial nucleus separated by the medial medullary lamina from the lateral nucleus. Note the mammillo-thalamic bundle beginning to disperse in the medial nucleus and the fibers connecting the medial nucleus with the nucleus caudatus and globus pallidus (part of the ansa lenticularis in a broad sense; here forming a part

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of the inferior thalamic peduncle). Note the fibers passing from the lateral thalamic nucleus, forming the lateral medullary lamina and passing through the internal capsule into the corona radiata.

Corpus striatum. Note the globus pallidus and putamen. Note the anterior commissure connecting the corpora striata. Dorsal to it note the descending anterior pillars of the fornix. Note the internal capsule, its dorsal part continuous with the white matter of the pallium. This section is near its genicular portion. What fibers in it are here passing into the corona radiata? Origin? Destination? Path? Function? Effects of injury to this part of the internal capsule?

Draw as directed in F. 1 (rhombencephalon).

9. If the preceding is a section of the infant's brain, study a similar section of the adult brain, Weigert's myelin stain, and compare with 8.

10. Similar section. Nissl's stain.

Study the cell groups of the thalamus and corpus striatum. Note in the latter the large cells, principally found only in the globus pallidus. What is their probable significance? If a drawing is made, draw as directed in F. 3 (rhombencephalon).

11. Similar section. Cajal's silver stain.

Note, as far as possible, the features observed in 8, 9 and 10.

12. Transverse section of the olfactory bulb. Weigert's myelin stain.

Compare with illustrations of preparations by Golgi's chrome-silver method.

Distinguish: (*a*) The external layer of olfactory fibers (from what cells?); (*b*) the glomerular layer (constituents of the glomeruli?); (*c*) the molecular or external plexiform layer (dendrites, collaterals and axones from mitral and granule cells); (*d*) the mitral layer (bodies of the mitral cells); (*e*) internal plexiform layer; (*f*) central white substance (axones of mitral and other cells, secondary olfactory tract, also some fibers to the bulb), mingled with granule cells.

Draw, showing the above layers.

13. Demonstrations, as far as possible, of above and also of the olfactory cells of the mucous membrane. Golgi's chrome-silver impregnation.

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14. Vertical section of the area calcarina (visual area) of the cortex pallii. Nissl's stain.

Ocular and low power. Distinguish the following layers: (1) The zonal or molecular layer, with very few nerve cells; (2) the external granular layer (small pyramidal cells); (3) the pyramidal layer (medium and large pyramidal cells); (4) the internal granular layer, here subdivided into the external sublayer of large granule cells and the internal sublayer of small granule cells; (5) ganglionic layer (internal layer of pyramidal cells) and (6) the multiform layer of triangular and fusiform cells. How does the above differ from the typical cortex?

Draw a thin vertical strip indicating the above cell layers (cytoarchitecture).

Study and make a high power drawing of each of the different types of cells showing shape, nucleus and especially the arrangement, etc., of the chromophilic bodies.

15. Similar section. Weigert's myelin stain.

Naked eye, ocular and low power. Note the three general categories of fibers, (*a*) tangential fibers running parallel to the surface of the brain. These may be superficial or deep. (*b*) fibers passing obliquely and (*c*) radial fibers, arranged in bundles. In certain layers the tangential and oblique fibers, especially the former, may be especially numerous giving rise to the various lines or striæ.

Distinguish the following layers: (*a*) The tangential layer of superficial tangential fibers, corresponding to (1) in 14; (*b*) a layer with few medullated fibers (dysfibrosa); (*c*) the suprastriate layer (separated from (*b*) often by the Kaes-Bechterew line or stria); (*d*) external line or stria of Baillarger, here the line of Gennari; (*e*) infrastriate layers. (Where there is also an internal line of Baillarger, this and an interstriate layer are added.) In general, layers (*a*), (*b*) and part of (*c*) are also termed the supraradiary layers and the remaining layers the radiary layers, according to the absence or presence of the radiations.

Note especially in this section the clearly marked limits of the line of Gennari. What area is thus distinguished by the presence of this line? Note also where the radiations end and any sublayers of the zonal layer.

Draw a thin vertical strip of the cortex showing the arrangement of the above myelinated fibers (myeloarchitecture).

16. Similar section. Cajal's silver stain.

Study the cells and fibers composing the various layers.

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17. Demonstrations of Golgi preparations showing the shapes and processes of the various types of cortical cells and especially the course of their axones. Note the prevailing type, the pyramidal cells with long apical and shorter basal dendrites, the former usually directed towards the periphery. Note the axones, usually directed towards and into the white matter. Note, if present, inverted cells in which the opposite obtains and also pyramidal cells with axones which turn upward toward the periphery. Note the collaterals. In the granule or stellate cells the dendrites pass off equally in all directions, the axones may pass into the white matter or they may be short axones, often directed upward. Other modifications of these types are present. The polymorphous cells of the sixth layer usually send their axones into the white matter. Fibers from elsewhere (what sources?) terminate in all layers and especially in the line of Gennari. What is the probable origin of some, at least, of the latter?

Correlate this picture with that obtained by the myelin stain. What are the fibers of the radiations and the fibers of the striæ?

18. Vertical section of the precentral (motor) cortex pallii. Nissl's stain.

Ocular and low power. Distinguish, as far as possible, the same cell layers as in 14. Note, however, that the internal granular layer is practically indistinguishable. Note also the presence of the giant cells of Betz in the ganglionic layer.

Make a drawing of a thin vertical strip of the cortex, indicating the arrangement of the cells, their sizes, etc.

Make a (high power) drawing of a cell of Betz. What type of cell does it resemble with respect to its chromophilic bodies? What are the destinations of the axones of these cells? About what percentage of all the cells in the section are cells of Betz? What is probably the general nature of the connections of the other cells?

19. Similar section. Weigert's myelin stain.

Distinguish the various fibers as in 15. Note the great abundance of medullated fibers, the great thickness of the cortex and the absence of striæ.

Draw a thin vertical strip of the cortex showing the fiber arrangement.

20. Similar section. Cajal's silver stain.

Study the cells and fibers of the various layers.

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21. Demonstration of Golgi preparations as in 17.
Correlate the various pictures obtained from different preparations.

Construct a general conception of the cortical connections: The afferent fibers from other parts of the brain (sources and functional significance?), fibers to (and from) other parts of the cortex (functional significance?) and fibers to other parts of the brain (functional significance?).

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# CHAPTER XVIII.

## ORGANS OF SPECIAL SENSE.

1. Eye of sheep. Gross preparation.

With razor or sharp knife bisect eye, being sure that section passes through optic nerve. Examine carefully under water. Identify: (1) Anterior chamber filled with aqueous humor. (2) Lens. (3) Posterior chamber filled with vitreous (glassy) humor. The vitreous humor is surrounded by a delicate hyaloid membrane attached to the retina and to inner surface of lens. (4) Sclera and cornea forming the outer coat. How does the latter differ in the gross preparation? (5) Chorioid, ciliary body and iris. What is the color of the chorioid? Separate chorioid from sclera and note the loose lamina fusca. In ciliary body identify ciliary folds and ciliary processes, and note delicate suspensory ligament which attaches ciliary body to lens. (6) Retina. What is its color? Note that the optic part of the retina is bounded by a ragged line, the ora serrata, beyond which it is continued as the ciliary and iridic portion. Note the optic disc and its central excavation. How is the disc formed? What is its physiological significance? What is the blind spot? Fovea centralis? Significance? Is part of the optic nerve present?

Make drawing showing all parts seen.

2. Section through eye. Microscopic study.

Under ocular and low power identify again the following structures: Anterior and posterior chambers, lens, cornea, sclera, chorioid, ciliary body (ciliary folds and processes), retina (optic, ciliary and iridic portions), optic disc, optic nerve. Draw.

Under high power study and draw strip through the three coats of the eye.

Make out the following:

(*a*) Sclera, noting the dense fibrous tissue of which it is composed. What is the direction of the fibers? Distribution of cells? Where the optic nerve enters the sclera is broken up forming the lamina cribosa. Note pigmented layer of flat cells (lamina fusca) separating sclera from chorioid.

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(*b*) Chorioid. Make out the four layers (lamina supra-chorioidea, Haller's layer, capillary layer, vitreous membrane). What is the structure of each? Is pigment found? Where most abundant? Note the blood-vessels in Haller's layer. What is their arrangement? In capillary layer note the dense net work of capillaries. Where are they most abundant? The seemingly structureless vitreous membrane separates the chorioid from the retina.

(*c*) Retina. Make out: (1) Layer of pigmented epithelium; (2) neuro-epithelial layer consisting of layer of rods and cones, outer limiting layer and outer nuclear layer; (3) ganglionic layer consisting of outer molecular layer, inner nuclear layer, inner molecular layer, layer of nerve cells, layer of nerve fibers and inner limiting membrane. Study carefully structure of each layer. How many cell layers in retina? Relative number of rod and cone cells, bipolar cells and large nerve cells? Significance? Reconstruct the cellular elements of the retina showing the relation to each other.

(*d*) Cornea. Study and draw. Make out anterior epithelium, anterior elastic membrane (membrane of Bowman), substantia propria, posterior elastic membrane (membrane of Descemet), posterior endothelium (endothelium of Descemet). Which is the chief epithelial layer? What type of epithelium? Can you distinguish conjunctival from corneal epithelium? Is the cornea vascular?

(*e*) Iris and ciliary body. What coats contribute to their formation? Note pigmented epithelium lining the inner surface of the ciliary folds and ciliary processes. This is the ciliary part of the retina. Make out ciliary muscle. What type of muscle? Disposition of fibers? The ciliary body is attached to the sclero-corneal junction by an elastic ligament (ligamentum pectinatum) in which endothelial spaces (spaces of Fontana) may be seen. Draw. In iris note again the inner pigmented layer formed by iridical part of retina. Outside of this layer study structure of anterior epithelium, stroma and vitreous

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membrane. Is smooth muscle found? Where? Draw strip through iris.

(*f*) Study carefully structure of sclero-corneal junction. Note canal of Schlemm and attachment of ligamentum pectinatum. Significance of canal of Schlemm and spaces of Fontana? Draw.

(*g*) Study optic nerve. Note the nerve fibers, the dural, pial and arachnoid sheaths, the subarachnoid space. Are the nerve fibers medullated? Do they possess a neurolemma? Note that where the nerve passes through sclera the connective tissue of the latter is broken, forming a lattice work (the lamina cribrosa). Can you find central blood-vessel? Study the optic disc. Of what does it consist? Are the fibers myelinated? Are rods and cones present in region of disc? Draw.

3. Study demonstration preparation through fovea centralis. How does it differ from other portions of the retina?

4. Study demonstration of retina with injected blood-vessels.

5. Study Golgi demonstration of retina, showing relation of various cells.

6. Section through cochlea.

Study with ocular and low power. Identify the central bony axis (modiolus), the bony spiral lamina and the canal of the cochlea. In latter note Reissner's membrane and the basilar membrane dividing canal into three parts, an upper (scala vestibuli), a lower (scala tympani) and a middle (scala media, cochlear duct). In cochlear duct note organ of Corti resting on basilar lamina, spiral ligament, spiral crista, spiral prominence, spiral limbus and tectorial membrane. Note spiral ganglion in bony lamina sending out peripheral processes through bony sulcus to organ of Corti. Low power drawing indicating parts seen.

Under high power study carefully and draw organ of Corti. Identify the following kinds of epithelial cells and study their shape, cytoplasmic structure, position of nucleus and distribution in organ of Corti,—pillar cells, auditory (hair) cells, Deiters's cells, Hensen's cells. Distinguish between inner and outer hair cells? Function of the various cells? What is meant by Corti's tunnel? Study struc-

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ture of tectorial membrane. Where is it attached? What is its shape? In membrane note the fine radial striations and absence of nuclei. Function of tectorial membrane? Study spiral ganglion. What type of neurones compose it? Trace peripheral fibers from ganglion to hair cells. Where do central fibers go? Of what cranial nerve are they a part? Study carefully the basilar lamina, the spiral limbus and spiral ligament, noting their structure and relation to organ of Corti.

7. Study Golgi demonstration showing termination of nerve fibers in organ of Corti.

8. Section through crista of semicircular canal.

Study under high power. Identify sustentacular cells, hair cells, otolithic membrane. Note that the epithelium rests on a connective tissue stroma which is attached to the bony capsule. Nerve fibers run through stroma to termination among hair cells.

9. Study demonstrations of macula acustica of utricle and saccule and compare with crista.

10. Section through olfactory mucosa.

Under low power identify the neuro-epithelial coat and the underlying stroma of fibro-elastic tissue. Are glands present? What type? Under high power study the olfactory epithelium. Identify the sustentacular and olfactory cells, and the layer of flattened basal cells. Compare sustentacular and olfactory cells with regard to position in mucosa, shape of nucleus, character of cytoplasm and cell processes. What is there unique about the olfactory cells? From what structure are they derived? What forms the olfactory nerve? Draw strip through olfactory epithelium.

11. Study Golgi demonstration showing the olfactory cells.

12. Section through taste bud.

Under low power identify taste bud and gustatory pore. What tissue surrounds the taste bud? On what does it rest?

Under high power study shape and structure of (*a*) sustentacular cell. (*b*) Gustatory cell. Compare with similar cells of olfactory mucosa. Draw.

13. Study Golgi demonstration showing nerve terminations in taste bud.