TURTLE DOVE AND NEST
Photographed by the Author

A LABORATORY GUIDE

—IN—

ELEMENTARY ZOOLOGY

—BY—

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INTRODUCTION.

This guide is designed for use in my own classes, and it sets forth an outline of the work done in Zoology. No claim is made as to the originality of the subject matter except in the method of presenting it, and the order in which it is given. It has been in use in our laboratory for several years in mimeographic form. Type forms are taken of the different groups, and carefully studied. The classification of animals conforms to that of the "Manual of Zoology" by Parker and Haswell, which is used as a text for class work. Any other good text may be used. All instructions for the use of apparatus, etc., are left to be supplied by the teacher in charge.

Acknowledgment is here due Dr. W. F. Copeland, J. E. McDaniel, Ph. M., and A. A. Johnson, Ph. B., former assistants of mine, and my present assistants, J. A. Badertscher, and C. E. Hayden, for many valuable suggestions in the working of the manual before going to print.

—The Author.

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UNICELLULAR ANIMALS

PHYLUM PROTOZOA

I Rhizopoda

1. Amoeba

ANATOMY—The amoeba is so transparent that it is difficult to find without a great deal of care and some experience in the use of the microscope. After a good specimen is found note **size, shape,** and **structure.** Can it be seen without the aid of a microscope? Examine other specimens and compare as to size. What is the shape? Note any change in form that may occur. If there are any projections they will be called **pseudopodia.** Is the number of pseudopodia constant? Are they in the same position at all times? What is the meaning of the term **pseudopodium**? Sketch the animal in five different positions. Is there any difference in appearance in any part of the animal that would seem to indicate a differentiation in **structure**? If so an outer clear area will be seen, the **ectosarc.** Is this seen all over the body? Why? The inner granular portion is known as the **endosarc.** How does the quantity of this compare with that of the ectosarc? Is the endosarc uniform throughout? Do the granules always occupy the same position? A denser portion, the **nucleus,** will be seen in the endosarc. What is its size, shape, and position? Are these all constant? Do they vary in different specimens? If the nucleus is not visible run a drop of dilute iodine under the cover. What effect does this have upon the entire animal? If iodine has been used the slide must be carefully cleaned and a new specimen found for the completion of the work. Look for clear areas in the endosarc. If one is found that varies regularly in size it will be called the **contractile vacuole.** How many

are found? Make a careful drawing to illustrate all the structures of the amoeba.

PHYSIOLOGY—Describe the movements of the animal. Does the body change in shape as the animal proceeds? How does the movement seem to be brought about? How are the pseudopodia formed? Note the method of taking food. If your specimen is not taking food add a little ground carmine to the water under the cover. The animal will take this as food. What would be the natural food of the animal? The activities of the animal must necessarily produce waste matter. Are there any organs of excretion? Has your specimen cast off any waste matter at any time during your study? Remove the cover or mount a new specimen without a cover. While looking at the specimen touch it with a bristle or tap the slide. What effect does it have? Warm the slide to 45 degrees C. Note the effect. Touch the slide with a glass rod heated and note the effect. The amoeba reproduces by the simple method of fission. Some one in the class may be fortunate enough to find a specimen in the act of dividing. If so the attention of the whole class should be called to this specimen. Is there any way of knowing which is the parent in this simple method of reproduction?

II INFUSORIA

1. Paramoecium

ANATOMY—Compare this form with the amoeba as to shape and activity. What is the shape of this animal? Is it constant? If it changes compare with the change in the amoeba. Is there any way of determining an anterior and a posterior end? How does the paramoecium compare in size with the amoeba? Can you account in any way for its permanency in shape? Is there a cell wall? Does it extend over the entire surface? Is there an ectosarc, an endosarc, a contractile vacuole, or a nucleus? Compare in each case with the amoeba. In the paramoecium two nuclei may be found: a large one, macronucleus; and a small one near the large one, micronucleus. Look for cilia. Are they all over the body? Are they all alike? Kill a specimen with 1 per cent osmic acid. Study the cilia. Look for a row of striations under the cuticle, trichocysts. What is the position and shape of the mouth? Is it con-

stant? Compare with the amoeba. Look for a tube, the **oesophagus,** leading from the mouth to the interior. Are there any cilia here? What seems to be their function? During the study of a specimen it may be seen to eject waste material through an opening in the body wall, the **anus.** Is its position constant? When is it seen? Note the food particles filling into the spaces as the animal gathers food. Are these food **vacuoles** constant in number and size in all specimens? Make a large **drawing** showing all structures of the paramoecium.

PHYSIOLOGY—What are the motions of the body as a whole? What are the organs of locomotion? Are all the motions of the body caused by these organs? Study the motions of the cilia. Are they all used for the same purpose? Apply a drop of 1 per cent acetic acid and note the effect on the trichocysts. From this effect, what would be considered the function of the trichocysts? Study the contractile vacuole in a live specimen for several minutes and note any peculiarities in the movements of this organ. How does the motion of the food vacuoles compare with the motion in the contractile vacuole? How does the paramoecium take its food? Compare with the amoeba. Note the formation of the food balls in the food vacuoles. As they move about the body note any change in the size of the balls. How is this change accounted for? Stain with dilute iodine and ascertain what the paramoecium eats. Iodine stains starch blue and albuminous substances brown. Feed some live specimens some ground carmine as in the amoeba. Is there any concert of action on the part of the animal? Can the next movement be anticipated in observing him? Is there anything about the paramoecium that would lead one to think that it has any special senses? Darken one side of a dish containing large numbers of the animals and leave it four or five hours in a light place. Examine with a hand lens and find which side of the dish has the more of them. The paramoecium has two methods of reproduction by fission and by conjugation. Different specimens may be found representing each of these methods. Watch the process through in either case and observe the method in detail. Make a drawing on a large scale of the animal.

2. Vorticella

Review the directions for the paramoecium and answer the same questions in reference to the vorticella as far as they apply. Note the difference in shape. It will be noticed that this animal has a **stalk** and is regularly fastened to some support. What is the structure of the stalk? Study the **peristome** (rim of the body), the **disk** (within the peristome), **myophan layer** (striated base of body), and the **vestibule** (entrance to the gullet). Make a drawing on a large scale showing all parts. From the movements what would you consider the function of the stalk to be? Is the body always in connection with the stalk? If not, there must be some free swimming forms. In addition to the methods of reproduction in the paramoecium the vorticella has another method that is called **encystation**. Look for specimens of this type. Make a drawing representing all the stages of reproduction.

MULTICELLULAR ANIMALS

PHYLUM PORIFERA

PORIFERA (SPONGES)

1. Ascon Sponge

Leucosolenia.

This is a marine form found abundantly along the New England shores fastened to seaweed, submerged wood, etc., just below low tide mark. Note the difference in size of the specimens submitted for examination. Study them with the hand lens. Note the cylindrical **sponge body.** Do the two ends differ? Note the opening at one end, the **osculum**. Press the sponge lightly. Notice the flexibility of the wall. Note the buds on the larger specimens. Do the buds have oscula? Carefully cut a sponge from the osculum to the base. Lay the cut specimen open in water with the **cloacal surface** up. Does this chamber communicate with that of the buds?

Place one half of the specimen where it will dry, and the other half in borax carmine, from one to several hours. While the first specimen is drying draw a cluster of sponges, illustrating all the points considered up to this time. Examine the cloacal surface of the dry specimen

with the low power of the microscope. Note the multitude of small needle shaped bodies, the **spicules**. How many distinct forms appear? In what plane do all the prongs of the spicules extend? By careful manipulation a fourth prong on some of the spicules will be seen to project into the cloacal cavity.

Remove the specimen from the stain, wash in acid alcohol, 95 per cent, and absolute alcohol, clear, and mount in balsam, with the cloacal surface uppermost. Do not press the cover glass down. Use the low, and the high power of the microscope. A layer of cells whose nuclei are very prominent is above (inside) the spicules, the **entoderm**. Note the extent of this layer of cells. During life these cells are supplied with **flagella** and **collars**. The activity of these flagella keeps a current of water moving from the outside through minute pores in the wall into the cloacal chamber and out through the osculum. The pores may be seen as small clear spaces between the spicules. The **mesodermal** cells are located outside of the entodermal layer. This layer is not continuous, the cells are scattered somewhat. The **ectoderm** is not easily seen but is located outside the mesoderm.

Make a **drawing** representing all the points mentioned above.

Many of the larger specimens prepared as above will be found to bear **reproductive cells**. They will be seen as large, deeply stained cells in the mesodermic layer. Two kinds will be noticed, the **male** and the **female**. The former, spermatozoa, occur in spheres, each sphere containing hundreds of **sperm cells**. The nuclei of the sperm cells are much smaller than those of the mesodermal cells which give the spheres a dotted appearance. The spheres themselves are quite large. The **ova**, or **egg-cells**, are provided with but a single nucleus. Sometimes a nucleolus will be found imbedded in the nucleus. The egg cells are amoeboid, seldom regular in shape. Make a **drawing** representing the two forms of reproductive cells.

Prepared slides of cross, and longitudinal sections will be provided. Make a drawing to represent the cross section.

2. Sicon Sponge (Grantia)

Notice size, shape, and color. Is there any suggestion of a free and an attached end? How do the two ends differ? Are all the specimens the same shape? Look for projections on the sides of the different specimens. If there are any it is probably the beginning of buds (a process of reproduction). Measure several specimens and compare them. Is there any suggestion that these sponges ever may become of commercial value? Look for the **osculum** (the opening at the free end). Note the **spicules** about the osculum. Do they differ in any way from the spicules on the sides of the body? Is there more than one osculum on the specimen? If so, where located? Cut a budded specimen lengthwise and study the body cavity. How far does it extend? What relation does the cavity of the bud have to the cavity of the main part of the body? How does the thickness of the body wall compare with the diameter of the cavity of the body? Study a longitudinal section with the low power. Note the canals leading into the body cavity from the outside. Are the openings to these canals protected in any way? Compare the two ends of the radial canals in this respect. A slide of spicules will be supplied. Study them and decide how many forms there are. Treat some with dilute H Cl. What is the result? What is the composition of the spicules? Stained sections, both longitudinal and cross, will be supplied. Study them and make out the several layers of cells and the relation of the spicules to them. Try to find out if the radial canals lead directly from the outside to the body cavity or **cloaca**. Make drawings to show general appearance of the animal, also of longitudinal, and cross sections, both with and without the microscope. Compare the fresh water sponge (**spongilla**) in every respect with the Grantia.

3. Toilet Sponge

Study several specimens and detect any likenesses or differences in the specimens. What part of the animal is being studied. Note size, shape, color, and texture. Are there any suggestions as to why sponges will take up water? What is there about this sponge that is similar to the grantia? What is different? Point out the osculum or

oscula on the specimen in hand. Pull out a small piece and study the structure under the low and the high power. Make a drawing of the specimen as a whole. Make a diagram to illustrate the structure as seen under the high power.

PHYLUM COELENTERATA

I HYDROZOA

1. The Fresh Water Polyp or Hydra

Examine several specimens as to size, shape, and color. Decide whether the animal is free to move about or not. If it moves about, what is its method? Are there any specimens that seem to be double? If so, are there any suggestions as to how this might occur? Are all specimens the same color? Find the following parts of the body: The **foot** (attached portion); the **body proper**; the **body cavity** (enteron); the **mouth**, and the **tentacles**. What is the relation of the mouth and the tentacles? Study several specimens for the number and the variability of the tentacles. Make a drawing on a large scale showing all the parts studied thus far. Watch the Hydra in a jar for some time turning the jar so as to vary the light. Decide as to the method of locomotion and the changes in shape, and length of both body and tentacles. If the hydra are not inclined to move about they may be induced to do so by suspending a small piece of meat in the water by means of a thread quite near the animal. To observe the method of eating, place several good specimens in a watch glass and with them a few small bits of meat. Describe carefully what is observed. Is there any evidence that other things have been eaten? If so, what? Describe the action of the hydra when irritated. Test the effect of light upon the hydra by covering one side of a jar containing several specimens. Are there any evidences of co-ordination in the movements of the hydra? Study live specimens and stained sections under the high power. Determine the extent of the stomach cavity or **enteron**. Is there any opening (anus) for waste matter to leave the body? The body wall will differentiate into three layers, two of which are cellular; the outer (ectoderm), the inner (entoderm); the middle or supporting layer (mesogloea) is not cellular.

Cnidoblasts or thread cells will be found among the cells of the ectoderm. They contain **nematocysts** or capsules in which is a coiled thread. The cnidoblasts are terminated by a sharp point, the **cnidocil** or trigger hair. Are these cells uniformly distributed over the tentacles? Study the ectoderm and the entoderm for any difference in shape or size of the cells. What is the extent of the entoderm? Make a drawing of a cross section through the body and one through a tentacle. Does the hydra have any special sense organ? Run a drop of dilute acetic acid under the cover and note the effect on the nematocysts. Find a specimen that is budded and see what relation exists between the body cavity and the bud cavity. Make drawings to show parts referred to above. Under favorable conditions ovaries and testes may be found on the same specimen. The former are located near the base of the animal, the latter as small knob-like swellings near the tentacles. Spermatozoa may be demonstrated by crushing a specimen under the cover. If found, describe them.

2. Campanularian Hydroid

Alcoholic material as well as permanent stained mounts will be furnished. If possible get a specimen attached to some support. Examine the attached end, **hydrochiza**; the **stalk**, the **hydrocaulus**; and the branches with the **hydranths**. Would this cluster be considered a colony or a single animal? Note any differences in the hydranths. How are the branches arranged? Find a transparent covering, the **perisarc**. What is its extent? Is there any difference in arrangement at any point? Under this layer find the fleshy portion, the **coenosarc**. Compare with the hydra for the layers: the entoderm, the ectoderm, and the supporting layer. What is the extent of the body cavity? Look for two forms of **zooids**: the **feeding**, and the **reproductive** zooids. Note the extent of the **perisarc** in the former. Find the **nematocysts** (**lasso cells**) on the tentacles. How many tentacles are there? Compare them with those of the hydra. Note the mouth at the outer end, or the **manubrium**. How do the reproductive zooids compare with the ones just studied? Look along a central stalk (**blastostyle**) for the medusae which are finally to be shed. Make an enlarged drawing of the entire animal,

representing the forms of zooids. Can a feeding zooid be distinguished from a reproductive hydranth at this stage? From the study of the hydra one can get a good idea of the life process in this form. Several other forms of hydroids will be furnished for study and comparison.

PHYLUM ECHINODERMATA

Asteroidea (Starfish)

What is the general shape? Are there any variations in different specimens? The under surface is known as the oral, and the upper surface as the aboral surface. Make drawings of both surfaces. Whence the common name of the animal? Examine and compare several specimens for size and color. The central part of the body is called the **disk.** Find the **madreporic body** on one side of the disk. The **bivium** is formed by the two rays that touch the madreporic body. The other three form the **trivium.** The **anterior ray** is the one opposite the madreporic body. Note any differences in any of these rays. At this point soak a medium sized specimen in dilute KOH for a few hours and carefully clean the flesh off with a brush. This will leave the skeleton which will be left to dry for future use.

Examine the spines as to shape, and size. Are they movable? Note any differences in the spines around the mouth (**Mouth Papillae**). Remove a small portion of the skin and examine it under the microscope. Find the ciliated columnar epithelium. The **aboral tentacles** will be found at the base of the spines. Around the mouth find a membrane, the **peristome.** On the oral side of the rays extending the entire length will be found the **ambulacral grooves,** which contain the **ambulacral feet.** Pull off a foot, make cross and longitudinal sections, then examine each carefully for structures. Note the disk on the distal end, and the opening through the center. Note the arrangement of the muscles. Carefully pull off some of the feet and find a membrane stretched across the deeper part of the groove. Above this will be found the **radial water tube.** A demonstration of the water vascular system will be made on injected specimens.

It will be necessary to study well prepared cross sections of the rays in order to demonstrate the **nerve and the blood vessels** that run along with the water vascular system. Make a drawing of a cross section of a ray. Note the **eyes** in the ends of the rays. Examine for size, shape, and color. Are the eyes protected in any way? At the base of some of the spines branched jaw-like projections, the **pedicellariae,** may be found. These are best seen on sections. Study the skeleton already prepared. Are all the **ossicles** arranged alike? Cut across one of the rays. The **ambulacral ossicles** are found forming the roof of the **ambulacral groove.** What is the relation of the ambulacral pores to the ossicles? A single row of ossicles just outside of these form the **inter-ambulacral ossicles.** Note that these ossicles bear movable spines. In the middle of the floor of the ray will be found the vertebral ridge. Of what is it formed? Remove the disk. The mouth opening will appear. Note the partitions between the rays, **inter-radial partitions.** In these find the **reproductive orifice.** Treat some of the skeleton with dilute HCl and note results. From the effect of the HCl, what is the chemical composition of the ossicles? By means of a pair of scissors cut a slit from the tip of the rays of the trivium along the sides of the dorsal surface. This must be done with care so as not to injure the organs underneath. Turn back the cut portion to the disk. When this is done the digestive system can be seen. Note a thin membrane, the **mesentery,** which holds the large greenish bodies **(hepatic coeca)** to the dorsal surface as it is turned back. What is the size, the arrangement, and the attachment of the hepatic coeca? Demonstrate the tube or tubes, that lead from it to the **stomach** immediately under the disk. Note the two portions of the stomach: the central cavity, the **cardiac** portion; and the **pyloric** portion or pouches, that extend into each of the rays slightly. From the structure of the mouth and stomach what would be the conclusion as to the kinds of food adapted to the starfish? In some specimens the cardiac portion may be found protruding from the mouth. What does this indicate? What is the size and extent of the **oesophagus?** The **retractor and the protractor muscles** of the stomach will be seen as white shin-

ing strands. Note the number and extent of each. It will require careful work to demonstrate the short **intestine** leading from the top of the stomach to the **anal opening** in the disk. Look above the stomach for the **respiratory tree** attached to the disk. Make a drawing of the digestive apparatus. In fresh specimens the ovaries are pinkinsh, and the testes are yellowish white; both will be found in the axis of the rays. Settle whether both appear on the same specimen. Where do they open?

The hepatic coeca have been removed. Under these and on either side of the vertebral ridge, the **ampullae** or **water sacs** are found. Study injected specimens if possible. Tear one open. What is its structure? Press on the ambulacral feet. What effect has this on the ampullae? Are they connected?

Now carefully remove all the digestive organs of the trivium, including the stomach. Notice the **stone canal** leading down from the madreporic plate. Around the stone canal notice a thin membrane, the **pericardium**, which contains the supposed heart. Before tracing out the stone canal, remove the peristome and note the following: the **circum-oral water tube**; the **polian**, and the **racemose vesicles**. There is one less racemose than polian vesicle. Now trace carefully the stone canal and account for the difference in number of the vesicles. Make a drawing of the water vascular system.

The **respiratory** system may be demonstrated by showing the connection of the tentacles of the aboral surface with the body cavity. Small openings in the roof of the rays lead to the tube-like tentacles. Study sections to help decide this.

Demonstrate the nervous system by studying with a hand lens and also by the use of the microscope. The circum-oral nerve ring can be traced throughout in a gross way, but the radial nerve will need the microscope and well prepared sections for demonstration.

PHYLUM ANNULATA

Lumbricus (Earthworm).

Have at hand living specimens, as well as specimens preserved in alcohol or formalin. The tissues in the preserved specimens will be harder, and for that reason are

better for morphological work. Study specimen for a **right** and a **left** side; a **head** and a **tail**; a **ventral** and a **dorsal** surface. How are these details determined? Note color. Would its mode of life suggest any cause for the color? Into how many regions can the body be divided? Note the number of **segments** in each. The firmest part of the body will naturally be the most muscular. Which division is most muscular? Are the segments all alike? If not, where do they differ? Look for a protective covering (**exoskeleton**). Are there any special sense organs? Are there any jointed appendages or legs? Make an outline drawing of the first two divisions and put in the exact number of segments or somites. The light colored thickened division is called the **girdle** or **clitellum**. Note the number of segments in it, and whether they are complete rings or not. In numbering the segments from the anterior end, where do the segments of the girdle belong? From a preserved specimen strip off a little cuticle. Note its color and texture. Mount a small piece in water and study the structure with the high power. Note the striae and their direction.

By passing the thumb and finger over the sides of the animal, sharp projections or setae will be detected. Study with a hand lens and determine the direction and number in each segment. Note whether this direction is constant throughout the whole length of the animal. With forceps pull out a seta and study it with low power. Draw a seta.

The **prostomium** is a projection on the extreme anterior end of the animal, ventral to which the **mouth** will be found. In numbering the segments the prostomium must not be counted. Note the **anus** at the extreme posterior end. The **dorsal pores** may be demonstrated by peeling off the cuticle and examining it with the hand lens. How many are there on each segment? Are the segments alike in this respect? Look for a pair of openings external to the ventral **setae** on the fifteenth segment; the opening of the **sperm ducts**. Look for another pair in similar position of the fourteenth segment; the openings of the **oviducts**. Two pairs of openings will be found in line with the outer **setae** between segments 9 and 10, 10 and 11, one pair in each groove; the openings of the **seminal recep-**

tacles. Draw a ventral view of the anterior half, locating the openings referred to above. The capsulogenous glands will be seen to vary somewhat on segments 9 to 11 or 8 to 12, on the ventral surface. Does the number of segments containing the glands vary in different specimens?

Pin a large specimen out straight, dorsal side uppermost. Cover with water. With fine pointed scissors cut through the body wall along the mid-dorsal line. Note the membranous partitions, the **septa.** Cut these away and pin the specimen out in the tray. The tube extending through the body from the anterior to the posterior end is the **digestive tract.** Do the septa referred to above extend entirely across the body? Observe that the general formation of the body is a tube within a tube. The outer tube is known as the body cavity. Study a cross section of the earth worm and find the structure of the body wall. Note the layers of **muscle fibers.** In what direction do these fibers extend? Open the body cavity of a live specimen after giving it chloroform. Note a colorless fluid, the **peri-visceral fluid.** Examine some of this fluid with the microscope under both the low and the high power. Cells, **colorless corpuscles,** like the amoeba, will be found floating in the colorless fluid. Does the fluid coagulate when exposed to the air? What relation do the septa have to the constriction between the segments of the body? The **digestive system** referred to above is divided into several parts. The first two or three segments are occupied by the **buccal** cavity. Note the shape and how it is fastened to the body wall. Following the buccal cavity is the **pharynx.** How is this cavity separated from the first cavity? Note size, shape, and extent. Find the muscles that hold it in place. Leading from the pharynx is the **oesophagus.** How far does it extend? Are there any variations in its size? The **calciferous glands** are located in the 11th and 12th segments. From their position and connections what is their probable use? Examine some of the fluid in them under the microscope. What is found? Treat some of the gland in a test tube with HCl. Explain results. In about the 16th segment will be found a thin walled, sac-like expansion of the alimentary canal, the

crop. What does the crop contain? Make a drawing of some of the contents under the microscope. Just posterior to the crop will be found the **gizzard.** Compare with the crop. Leading from the gizzard will be found the **stomach-intestine.** The yellowish mass of cells on the dorsal surface of the intestine were formerly supposed to have the function of a pancreas, but now they are supposed to be connected with the process of excretion. Cut through the intestine a little to one side of dorsal line and find a longitudinal fold, the **typhlosole.** Examine the contents of the intestine in the posterior region with the microscope, and compare with that of the crop. Make an outline drawing of the body laid open on the mid-dorsal line and locate carefully all parts of the digestive apparatus in their proper segment or segments.

Carefully clean a live specimen and look for **circulatory system.** The dorsal blood vessel may be seen as a red line under dorsal surface. Carefully watch for pulsations in this vessel. By killing a specimen in alcohol the following vessels may be worked out under favorable conditions (the name will give the location): the **circum-oesophageal** blood vessel; the **supra-neural** blood vessel; the **lateral oesophageal** blood vessel. By the use of two pairs of fine-pointed forceps, a portion of a blood vessel may be removed without the blood getting out. Place this under the microscope and study the blood. What is its color? Are there corpuscles? How do they compare with those of the body cavity? Account for the color of the blood. Does it coagulate upon exposure?

To study the nervous system, remove the alimentary canal, from the pharynx back. Dorsal to the oesophagus the **supra-oesophageal** ganglia will be found. Leading ventrally from these ganglia on either side of the oesophagus, white threads, **circum-oesophageal commissures,** may be found joining the **ventral nerve cord.** What is the extent of the ventral nerve cord? Look for ganglia on the ventral nerve cord. What is the relation of the ganglia to the segments of the body? Make a diagram of the nervous system.

The **excretory system** is represented by a pair of organs, **nephridia,** in each segment except the first three. With the low power find the opening in the septum, and to the outside. Are both ends of the nephridial organ in the same segment?

The **reproductive system** is represented by the **seminal vesicles,** the **testes,** the **ovaries,** and the **spermathecae.** In the segments 9 to 12 find the large pouch shaped bodies (seminal vesicles). How many pairs are there? Note any difference in size. Remove the roof of the median vesicle and find the testes inside the vesicle. The sperm cells are shed into the vesicles in an immature stage and undergo their maturation there. The tubes leading from the vesicles unite to form the **vas-deferens,** whose opening is on the thirteenth segment. Look in segment 13 near the septum between that and the 12th segment for small rounded bodies, the ovaries. The oviducts pass through the septum and open on the 14th segment. The **spermathecae,** small globular bodies, are found in the 9th and 10th segments. Study a live worm, noting all the movements. Place some on a smooth surface and others on a rough surface. Note any differences in their movements on the different surfaces. Place some leaves on the surface of the dirt in a box containing earthworms and leave them several days. Note from day to day any change in the position of the leaves. Account for the same.

PHYLUM ARTHROPODA

Crustacea

Lobster or Crayfish.

The laboratory guide is especially adapted to the lobster, but will apply in general to the crayfish. With specimens before you study the general shape. How does it differ from anything studied before? Note the head covering, **exoskeleton.** Look for **bilateral symmetry.** Why is this animal called an arthropod? Note that the body proper is differentiated. How many distinct regions are found? How does the anterior region, the **cephalothorax,** differ from the posterior region, the **abdomen?** How many segments are found in the abdomen? How are the segments joined? Is there any suggestion of a joint? If so,

what kind of a joint? Note any differences in the different segments. On what abdominal segments are **appendages** (swimmerets) found? Note the **tergum,** the dorsal portion of a segment; the **sternum,** the ventral portion; the **epimeron,** the latero-ventral portion; the **pleuron,** the down growth of the sides. Note the parts of an appendage: the basal portion, the **protopodite;** the portion attached to the outer margin of the protopodite, the **exopodite;** that part attached to the inner margin, the **endopodite.** Make a drawing to represent a lateral view of a segment with its appendages.

Describe the cephalothorax from above and from the side. Are there any traces of segments? The **cervical groove** divides this region into a **cephalic** and a **thoracic** region. The **branchio-cardiac grooves** extend backward from the **cervical groove.** The heart lies under that portion of the carapace bounded by these grooves. Note the **rostrum** projecting in front. Describe it as to motion, appendages, size, and color. Examine the ventral surface of the cephalothorax. Are there any evidences of segmentation? With scalpel handle force out the margin of the carapace, the **branchiostegite,** and notice a chamber here called the **branchial chamber,** or **gill cavity.** Is there any suggestion here of segmentation? Compare with a single segment in the abdomen.

The last segment of the body is known as the **telson.** Describe and draw it after observing as to its appendages, form, etc. Note the **anal** opening on the ventral side. Beginning with the posterior pair of appendages disarticulate them on the right side of the abdomen, by cutting through the articular membrane with a sharp scalpel. This will require care in order to get them clear from the body and also entire. Study each appendage and note all the parts referred to above. In addition note that the protopodite consists of two segments: the **coxopodite,** the basal portion; the **basipodite,** the distal portion. What makes up the tail fin? Lay the appendages down in order with their posterior face uppermost and make drawings of same numbering them in order of segments. Remove the thoracic appendages in like manner, but study them as you proceed. Examine the last thoracic appendage and

note its direction. Has it an exopodite? Note the **male genital aperture.** On what segment does it open? Make a drawing of this appendage. Carefully remove the next appendage and compare it with the one just studied. Does it have a gill? An epipodite? In female specimens of lobsters, note the receptive apparatus near the base of the coxopodite. Make a drawing of this appendage. Remove the next appendage and compare with the one just studied. How does the distal end differ from the other? Note the **female genital pore** in the coxopodite. Draw as above. Compare the next appendage in every respect with the ones just studied. Remove the **great chela.** Compare with the other appendages and with each other on the same and different specimens. Is the distribution of hairs on both chelae alike? What differences are found? Note the teeth, are they alike on both jaws? Remove the next appendage; the third **maxilliped** or foot jaw. Compare with the great chela. Remove the next two appendages, the **second** and the **first maxillipeds.** In a review of all of the thoracic appendages note the two groups into which they naturally fall. The next appendages may be called the **head appendages.** Remove the next one, the **second maxilla.** Are there any modifications? The large plate like expansion is known as the **scaphognathite.** Remove the next appendage, the **first maxilla.** Compare with the preceding. Draw each of the maxillae. The **mandible** is the next appendage. Note the **palpus,** the **metastoma,** and the **labrum.** What is the direction of the mouth opening? Remove the next two appendages, the **antenna** and the **antennule.** At the base of the antenna note the opening of the **green gland.** Examine the antennule for the opening of the **auditory organ.** Compare these two appendages in every respect. The **eyestalk** is sometimes called an appendage. Make a review of all the appendages, noting any differences or likenesses. Decide as to the advantage of each to the animal. What constitutes the boundary of the **gill chamber?** The gills may be classed as **podobranchiae, arthrobranchiae,** and **pleurobranchiae.** What is the basis of this classification? How many of each of the classes of gills are there? Study a gill in water for its structure. Some of the gills referred to

above are rudimentary. Give reasons for calling them such. Make a drawing of a gill. Note in general the **exoskeleton.** Boil a piece of the exoskeleton. Place HCl upon another piece. What is its composition? Remove one of the eye-stalks. Study the surface of the eye. Note on the **cornea,** the flat areas, or **facets.** What is the shape of the facets? Make a longitudinal section of the eye, stalk and all. Study with low power. Note the **spindles,** the **crystalline cones,** the **optic ganglion,** and the **optic nerve.**

By the use of a bristle or pointed instrument find the opening of the auditory organ among the setae on the basal joint of the antennule. Now cut away the under side of the joint and find a transparent sac, the **auditory sac.** Study carefully with and without the microscope. Study the contents of the sac for sand-like grains, the **otoliths.** Note also the **auditory hairs.** The **olfactory organs** consist of setae on the endopodite of the antennule.

With strong scissors cut through the exoskeleton on the sides from the telson to the rostrum. Carefully lift it off beginning at the abdominal segments. Directly under the shell find the **epidermis.** Notice how it is attached. On either side of the mid-dorsal line of the abdomen directly beneath the epidermis find the **extensor abdominis** muscle. Note its origin and its insertion. To what are these muscles attached? Remove them. Find the **levator abdominis** muscle, whose origin is on the carapace just above that of the extensor abdominis. Find its insertion. The contraction of these muscles will produce what motion? The great muscle now seen to fill the greater part of the abdomen is the **flexor abdominis.** A deep groove runs through the middle of it containing the superior abdominal artery and the intestine. As far out to the side as possible cut these arteries, also cut the intestine in front of its dilated end, and turn both back to one side. Now work the muscle out of the shell, being careful not to injure the nerves underneath. Find **origin** and **insertion** of the muscle. What motion does this muscle produce? Why is it so large? The adductor muscle of the mandible has its origin on the carapace in front of the cervical groove. It is a fan-shaped muscle ending in

a long tendon extending obliquely downward to its **insertion** on the mandible. What motion is given to the mandible by this muscle? Look for small muscles extending to the antenna.

Remove the great chela from the body. Note the muscles of the basal joints. To what are they attached? With a pair of bone forceps cut around the edge of the pincher and lay off the exoskeleton on one side. Note the muscle contained in the cavity. Carefully dissect away the muscle and find its **origin** and its **insertion.** Note the **central tendon** and the direction of the muscle fibers. What motion does it produce? Notice another muscle just opposite this one and demonstrate its motion. Why should one be called the adductor and the other the abductor? Which is which? Study the muscle teased out in normal salt solution. Stain and note results. **Draw.**

At the anterior end of the superior abdominal artery, find the **pericardial sinus.** Note its shape and its size. Cut through the mid-dorsal line, fold the parts back, and find the **heart.** Note its size and shape. How is the heart fastened to the sinus? Look for openings into the heart on the dorsal, the lateral, and the ventral surfaces. How many are found on each? What connection does the superior abdominal artery have with the heart? The **ophthalmic artery** originates from the anterior end of the heart. Trace it towards the head. Does it have branches? The **antennary arteries** leave the heart, one on either side of the ophthalmic artery. Branches from these arteries supply what organs? The **hepatic arteries** arise from the antero-ventral part of the heart. The **sternal artery** arises from the posterior end of the heart, ventral to the superior abdominal artery. Notice that it divides soon after leaving the heart. What direction do the branches take? Sketch the circulatory system in an outline drawing of the animal. Kill a specimen and take some blood from the pericardial sinus and examine with the microscope. Note its color and account for the same.

THE DIGESTIVE SYSTEM—Dissect away the gills and other organs on one side to expose the **stomach.** What is its shape and position? Are there muscle fibers extending from the stomach to any other part of the body?

ıat is its relation to the mouth? Describe the **oesopha-**
ı, leading from the mouth to the stomach. Note the
diac and the pyloric regions of the stomach. With
ssors remove the wall of the stomach and note the
d portions or **ossicles**. Do they have any definite ar-
ıgement? How are they arranged? How many of them
there? The **gastric teeth** will now be seen: a pair of
eral teeth, and a **median** tooth. Demonstrate the motion
these teeth. Is there any division between the two
ions of the stomach? Trace the **intestine** from the
mach to the anus. Note an enlargement near the
sterior end, the **coecum**. Look for folds on the inside
the intestine. At the sides of the stomach will be found
obulated mass, the **digestive glands**. Try to find the
ct leading to the stomach.

The **excretory system** consists of the **green glands** or
lneys in the lower side of the head. Trace the duct
m these glands to its opening at the base of the antenna.
ıat name will be given to this duct?

THE REPRODUCTIVE SYSTEM—In the male the
ıtes will appear as tubular organs extending from the
eral angles of the stomach into the abdomen. In the
ıyfish they differ in being bilobed anteriorly. If a live
ecimen is at hand cut the testes and examine some
the fluid for sperm cells or spermatozoa.

Trace the tube (vas deferens) of the testes to its
ternal opening. In the female the **ovaries** compare in
ery respect with the testes of the male. Some may have
gs in them. Trace the oviduct to its external opening.

THE NERVOUS SYSTEM—To study this it will be
cessary to remove the muscles and viscera. Begin
th the **abdominal ganglia** and carefully trace the chain
phalad through the **thoracic ganglia** to the **sub-oesopha-**
al ganglion, thence by a pair of nerves around the
sophagus to the **supra-oesophageal ganglion**, or **brain**.
te the number of ganglia in each case and make drawing
show the nervous system. A living specimen should
w be at hand. Place it in a jar of water. Note its
ıvements. Does it swim? Tabulate the different move-
nts observed. Place some meat or bread in the jar of
ter some distance from the specimen and cause currents

of water to pass from it to the animal. Note any evidences that the animal knows of the presence of food. Draw a bristle over its back and note if one place is more sensitive than another. Pass your hand quickly by the jar. Does it see? From the study so far what can be said of this animal as to special senses? With a pipette place some carmine ground fine in water, close to the thorax. What becomes of it? This will demonstrate how the animal breathes.

II LOCUST.

EXTERNAL ANATOMY—Note the segmented structure. There are three main groups of segments: **head, thorax,** and **abdomen.** How many segments appear in the head, thorax, and in the abdomen? The thorax is distinguished by five pairs of appendages. What are they? Note the three divisions of the thorax. Compare the segments of the abdomen with those of the head, in reference to shape, structure, and distinctness.

BODY WALL—Note the hard covering, the **chitin.** The uneven distribution of the chitin produces the definite portions, the **sclerites.** Examine the surface of the specimen with hand lens. As the head is pulled note that the membrane that holds it in place has very little chitin, if any. Note the narrow furrows that separate the sclerites, the **sutures.** In many places the sutures are not distinct and the sclerites are fused.

THE HEAD—Two divisions of the head are readily distinguished: the fixed portion, the **cranium** and the movable portions, the **appendages.** The Fixed Parts of the Head: two large rounded bodies, the **compound eyes.** They occupy a large portion of the latero-dorsal portion of the head. Study the compound eyes with the microscope. Note the structure. Compare it with something you have already studied. Make drawing to illustrate the structure of one of these eyes. Cephalad of the dorsal half of each of the compound eyes find a small transparent body, the **simple eyes** or **ocelli.** In a pit in center of cephalic surface of head note a third simple eye. Note a large sclerite surrounding the compound eyes and bearing the simple eyes, the **epicranium.** A suture extends ventrad from the

eyes and separates the cephalic from the lateral parts of the epicranium. The epicranium is limited ventrally by a suture that connects the ends of the sutures just referred to. Mount the head on a pin. A ridge marks the caudal border of the epicranium. A well-marked suture forms the ventral border of the lateral part of the epicranium. Point out the **vertex,** the **front,** and the **genae.** A short but broad sclerite, the **clypius** occupies the ventral border of the epicranium. Note a movable flap, the **labrum.** Make a drawing of the cephalic aspect of the head. Note the parts. Locate the **post-genae** caudad of the genae on each side. Note that the post-genae are connected from side to side within the head by a strong membrane, the **tentorium.** Movable Parts of the Head: Antennae and the mouth parts; just cephalad of each compound eye note the attachment of the **antennae.** Each antenna is situated in a depression which is known as the antennary fossa.

Carefully remove the labrum. Now a pair of jaws, the **mandibles,** are exposed, which open by meso-lateral motion of each jaw. Each jaw consists of a short and a thick piece; the distal extremity of the latter is notched so as to form a series of teeth. At the base of the mandible between it and the gena, there is a small sclerite; this is the **trochantin** of the **mandible.** By the removal of the mandibles there is exposed a second pair of jaws, which like the mandibles open by a meso-lateral motion. These are the **maxillae.** Remove one of these and examine under the microscope. Make a drawing and name the parts, which are as follows: **Cardo** or hinge is the proximal part of the maxilla. It consists of two sclerites; the first is the larger and is triangular in outline. The **stipes** or foot stock is the large quadrangular sclerite which forms the central part of the maxilla. The **lacinia** articulating to the distal part of the stipes, is a large sclerite which tapers distad, is curved and is terminated with strong teeth. Joined to the lateral border of the stipes and between the cardo and proximal segment of the galea is a narrow sclerite, the **palpifer.** Attached to the distal end of the palpifer is a long slender organ consisting of five segments: the **maxillary palpus.** Note the parts of the **thorax.** The cephalic or first segment is named the **pro-**

thorax; the second or intermediate, the **mesothorax**; and the third or caudal, the **metathorax.** These divisions can be easily recognized by the appendages they bear. To the first segment is attached the first pair of legs; to the second is joined the second pair of legs and the first pair of wings; and to the third or metathorax, the third pair of legs and the second pair of wings. On the dorsal part of the prothorax note the sunbonnet shaped piece, the **pronotum** which covers the greater part of the sides as well as the dorsal part of this segment. Make a drawing of the lateral aspect of the pronotum. The two segments, known as the metathorax and the mesothorax, are firmly joined together forming a box to which two pairs of wings and the second and third pairs of legs are attached. The dorsal part of the mesothorax is termed the **mesonotum**, that of the metathorax the **metanotum.** Examine the vetral aspect of the first pair of legs. Each leg will be found to consist of the following parts: the proximal segment, the **coxa**; the second segment, the **trochanter.** This is smaller than the coxa. The third segment, the **femur,** is the principle segment of the leg. The fourth segment, the **tibia,** nearly equals the femur in length but is more slender. The **tarsus** includes all that part distal to the tibia. On the ventral surface of the tarsus note the series of cushions, the **pulvilli.** Make drawing of one of the legs. Name the parts.

The long parchment like wings are found on the mesothorax and are known as the **mesothoracic wings.** The large fan-shaped wings, folded under the mesothoracic wings are the **metathoracic wings.** and are the most important for locomotion. Compare the texture of these two pairs of wings. Make a drawing to represent one of each pair. What seems to be the function of the front pair of wings?

Note the number of segments in the abdominal region. Owing to the complexity of the caudal region, there is a difference of opinion as to the number of segments, but eight segments are readily distinguished in the female and nine in the male. On each side on the dorso-lateral region of the first segment find a large opening closed by a very delicate membrane. The whole is the **auditory or-**

gan and the membrane is the **tympanum**. The next seven or eight segments are very similar and without appendages. Note the **spiracle** or breathing pore on each. Also note the **sterna** and the **pleura** and how the two are united by a thin membrane. In the female specimen note the **ovipositor** consisting of four strong, curved, and pointed pieces which form the most caudal part of the body. How, and where does the locust lay its eggs? What suggestion do you get from the structure of the ovipositor? The opening of the oviduct is between the ventral pieces. Make drawings of the dorsal and the lateral aspect of this part of the body. In the drawing of the lateral aspect represent the entire abdomen. Make drawings of the dorsal and lateral aspect of the male also.

PHYLUM MOLLUSCA

I. THE PELECYPODA

Unio, or Anodonta (Fresh Water Mussel.)

Study the empty shell. What is its shape? Of how many parts or valves does it consist? How are they held together? How does the animal rest when alive? Point out the dorsal, and the ventral surfaces. Treat a small piece of the shell with HCl. What is the result? Draw a surface view of a single valve. What is the relative position of the valves after the animal is taken out? Why? How does the hinge act? Notice the lines of growth beginning with the **umbo** or **beak**. Note the **hinge teeth** (not present in anodonta). How do they fit when the shell is closed? How many forms are there? Does the color of the valve vary inside? Note the palial impressions, (the line of attachments of the mantle to the shell.) Note the scars for the attachment of the muscles. Examine the broken surface of a shell with a hand lens. What attachments does the body have to the shell? Study the texture of the mantle. Is it uniform in thickness? The **adductor muscles** hold the valves together. How many are there? How do they differ in size, and in shape? The scar for the **retractor pedis muscle** is at the upper margin of that of the adductor muscles. A little below the anterior retractor muscle scar will be found the scar

of the **protractor pedis muscle.** In marine forms the scars are not all distinct.

Note the **siphons.** How many are there? What is their shape, and size? Are they separate tubes? Turn back one of the lobes of the mantle and note the **palial cavity.** The large ventral cavity is the **branchial cavity,** and the small dorsal cavity is the **cloacal cavity.** What is the relation of the abdomen to the muscles and to the foot? Compare the texture of the foot with that of the abdomen. What direction does the foot take when extended? Note the **gills,** or **gill-plates.** How many are there? The **supra-branchial chamber** is laid open when a slit is made along the attachment of the outer gill and the mantle. Demonstrate the following in the structure of a gill: the **water tubes,** the **inter-lamellar junctions,** and the **inhalent apertures.** Sections will be needed. Study the **ciliary action** on the gill split open. Make a drawing to show the structure of the gill.

Find the mouth and note its size, shape, and position. How do the **labial palpi** compare with those on the lobster? Into which siphon does the **anus** open? It will require care and patience to work out the **digestive system.** From the mouth trace the **oesophagus.** What is its direction? The **liver** will appear as a dark colored mass around the **stomach** and the oesophagus. How is the stomach distinguished from the oesophagus? The **bile duct** opens into the oesophagus near the stomach. Trace the **intestine** from the stomach through the yellowish white **generative gland.** Note that the **rectum** passes through the pericardial cavity. Note the **typhlosole,** a prominent ridge on the ventral side of the rectum. Where has this organ been seen on previous specimens? Make an outline drawing of the body and place a diagram of the digestive system in the same.

THE CIRCULATORY SYSTEM—Carefully remove a living specimen from the shell. The movements of the heart may be observed. Open the pericardium and study the heart. Note the median **ventricle** and the two lateral fan-shaped **auricles.** The intestine was traced through the ventricle in the other specimen. Trace the **anterior** and the **posterior aorta,** the former above, and the latter

below the intestine. Compare the auricles and the ventricle as to structure.

THE NERVOUS SYSTEM—Preserved specimens are to be used here. Separate the palpi and find the **cerebral ganglia** just under the skin. Nerves may be traced to the adductor muscle and to the **pedal ganglia** in the foot. Separate the gills at the posterior end of the body and find the **visceral ganglia.**

THE EXCRETORY SYSTEM—Find the **kidney** as a dark colored tube with spongy walls under the pericardium. The **renal aperture** will be seen as a small pore at the anterior end of the pericardium. Find the genital aperture near the renal aperture. Study live specimens in an aquarium containing three or four inches of sand. There will thus be several interesting observations made on the habits of the animal. Specimens will be preserved in chromic acid and cross sections made for gross structure.

II. CEPHALOPODA

Loligo Pealii (Squid.)

The habitat of the squid usually corresponds with that of the larger number of salt water fishes. This is because he can thereby obtain his food to a better advantage. Fishermen often get large quantities of squid in their nets, and from them squid may be obtained during certain seasons of the year at a small cash outlay or by a little trouble.

For dissection squid should be preserved in formalin or alcohol, preferably the former. The can containing them should contain formalin 4 per cent, also some iron filings or old nails. Specimens thus preserved show good hardening and also the denser parts are colored a little darker than the others, thereby giving a better definition.

EXTERNAL FORM—What is the general form of the body? What is the shape of the animal as to anterior and posterior ends? Is the head movable? Notice the mouth in the space between the arms. How many arms are there? In some specimens a peculiar formation is seen projecting from the mouth. What is this?

Notice the **eyes.** Note their size. Compare them with those of the lobster or locust.

A crenated fold of membrane will be found just behind the eyes, the **olfactory organ.** What is its extent?

Notice the large triangular fin on the end of the body farthest from the head. Consider its use.

SURFACE—Dark brown pigment spots, **chromatophores,** will be found on the surface. These vary in shape, and number. Observe, with the hand lens, that some of these have blurred edges and others are clear cut. The chromatophores are very changeable during life. When the animal was killed the chromatophores were caught in the condition and shape in which they were at the time. The changes are interesting to observe for the chromatophores gradually fade in color and reappear so evenly that they present a blush of color gradually from one point to another over the entire surface. At times the color almost disappears and the animal is nearly invisible in the water.

PLACE IN ANIMAL KINGDOM—Does the external appearance suggest that this animal should belong in the same class as the clam? Explain.

Taking the DORSAL view of the head, is the animal bilaterally symmetrical? If so how many arms are found on each side? Are all the arms the same length? How many rows of suckers are found on the short arms? On the long arms? Draw the dorsal view.

Ventral View—What is the direction of the muscular bands that extend from the body to the fins? Notice the projections of the anterior edge of the mantle. Find the siphon projecting from under the mantle in the mid-ventral line. What is its shape, size, and the direction of its opening? Discuss the siphon as an organ of motion.

Examine one of the **grasping arms** (long arms). Examine closely one of the suckers on this arm. Does it have a stalk or is it sessile? Is there anything peculiar about the margin of the suckers or **acetabula**? Cut through the sucker and piston longitudinally. Note carefully and make drawing of the section.

INTERNAL STRUCTURE—Is the mantle fastened to the head in any way? If so at how many points? Notice mantle cartilage on the dorsal surface of the neck. What is its shape and extent? Are there any projections from

the margin of the mantle ventrally? Are there any indications of cartilage on the siphon? If so what is its use? Open the animal along the mid-ventral line. The two sexes differ in that the nidamental glands of the female, cover the other organs and give the appearance of a thick, granular substance. Notice four large muscles that attach the head to the mantle; two dorsal retractors of the head and two ventral retractors of the siphon. A pair of silvery cords will be seen extending from the neck, just posterior to the dorsal mantle cartilage, to the mantle. These are nerves which terminate in large ganglia on the inner surface of the mantle.

Are there any cartilage formations on the siphon? If so is there anything on the mantle corresponding to the same?

Note the two valve-like sacs lateral to the siphon sac which is on the mid-ventral line. Does their shape and position suggest their use?

Find the **rectum** and the **anal** opening directly posterior to the siphon. Is there a mesenteric fold to keep the viscera in place? Look for the **ink sac** immediately dorsal to the **intestine.** Find the duct and opening from this sac.

At the end of an elongated papilla which lies parallel to the intestine, and on the right side will be found the opening of the **male reproductive system.** Find a pair of papillae, about an inch from the anal opening, which are openings for the **renal organs.** Trace the ducts, if possible, posteriorly to the renal organs.

Look for the **gills** on either side of the mantle cavity. How many are there? How are they located as to the retractors of the siphon? Notice a vein running from the renal organ to the gill, (branchial vein). Find the **branchial heart,** a small, oval, white body at the base of each gill.

From a point midway between the branchial hearts notice a narrow membrane-like cord coming off and passing across the mantle cavity to the mantle. Does it have any branches after it reaches the mantle? This supplies the mantle with blood and is called the **median mantle artery.** Find the lateral mantle arteries. Posterior to these arteries find a large sac reaching to the posterior

end of the body. Make a drawing of the specimen as it now stands.

A pair of white granular bodies will be seen on either side of the intestine and extending posteriorly to about the region of the heart, **renal or nephridial organs.** Pick these away carefully after severing the mesentery, and the **heart** will be plainly brought to view. As the renal organs are taken out the intestine may be followed between the two cavities.

The **venae cavae** are thin, transparent vessels. The anterior cava runs back as far as the branchial heart and there unites with the posterior cava which at this point becomes nearly as broad as long. Sometimes these vessels contain blood so they may be easily traced in preserved specimens. Upon dissecting the posterior vena cava away the dorsal mantle artery is seen. Notice the branchial hearts are in separate pericardial chambers. Turn these hearts over. How many vessels open into them, and how many out of them? The blood is collected in the branchial hearts from the vena cava and forced to the gills, there collected again and brought to the systemic heart.

Lay the anterior end of the intestine back and find a pouch-shaped sac below the ink bag, the **spleen.** This receives a branch from the anterior vena cava.

THE SYSTEMIC HEART AND ARTERIES—What is the shape of the heart? How situated? Size? Is it placed directly on the median line? Is it placed with about equal portions on either side of the median line? How many vessels lead to or from the heart? Find the anterior, and the posterior aorta. Also the right and the left branchial veins. Trace the posterior aorta and notice the branches. The anterior aorta may be traced later to the head. Make a drawing of the circulatory system.

THE DIGESTIVE SYSTEM—Cut away the systemic heart with its arteries also the blind sac (a transparent membrane which contains the stomach.)

The **stomach** is a large muscular bag. Trace from the anterior end the intestine and the oesophagus side by side. Notice that the intestine takes a turn at this point and terminates in the **rectum.** Trace the oesophagus until

it enters the liver. A delicate duct will be found leading from the liver to the spleen and on to the stomach, on either side of the oesophagus as it enters the liver, hepatic duct. Describe the liver as to location, size, shape, and color. Now trace the aorta and the oesophagus through the liver and from there to the head. Watch for the salivary glands on the dorsal surface of the anterior end of the liver. Make a drawing of the digestive apparatus.

REPRODUCTIVE ORGANS—The testis or ovary according to sex, is a white dense mass under the stomach on the median line and extends posteriorly. Notice the accessory reproductive organ at the left. Notice on the left ventral arm of the male that the acetabula are modified so that the stalks are prolonged into blunt points. Compare these with those of the female.

No duct joins the testis with the vas deferens. Therefore the ripe spermatozoa pass through the cavity of the capsules into the excretory duct.

The reproductive organs of the female comprise the ovary, oviduct, gland of the oviduct, nidamental glands, and accessory nidamental glands.

Find the nidamental glands, upon opening the mantle cavity, in the region of the heart, as white laminated bodies. The capsules of the egg masses are excreted by these. The accessory glands are found in the region of the ink sac.

Look for the ovary in similar position as the testis of the male. The eggs escape from the capsule to be taken up by the oviduct. The oviduct, a long thick-walled tube, passes along the left side and opens in the region of the siphon.

The oviduct may be traced to a point below the left gill into the large oviducal gland, at the left of the posterior end of the nidamental gland. Look for eggs in varying stages of development in the ovary.

Carefully take away all the organs of the body cavity, turn the animal upon the ventral side, and cut through the integument along the mid-dorsal line. An elongated cartilaginous pen will be found here. Take it out carefully and make a drawing of it describing it in words as well. Does this pen suggest in any way, a shell? Is the pen

fastened in any way to the walls of the cavity? If possible find some communication of this cavity either with the interior or exterior of the body.

Divide the head vertically along the median line and find the following: the opening of the mouth, the horned beak, one part shutting under a larger. Which is dorsal? Which is ventral?

Notice the somewhat spherical buccal body. Of what is it composed? What is its use? Find the oesophagus running back through the buccal body. Find the **lingual ribbon.** Follow the oesophagus posteriorly through the head to the body. Which side of the liver does it pass?

Around the oesophagus posterior to the head, notice the cartilaginous **cranium.** What does this cranium contain? Are there any **ganglia** elsewhere around the oesophagus? Find the stellate ganglia referred to before. Trace the radiating nerves to the differnt parts of the mantle. The anterior branches may be traced through the retractors to the **infra-oesophageal ganglion.**

Find the large optic ganglia by removing the ventral side of the head. Look for the auditory chambers as the cartilage is cut away. The **pedal, the pleural,** and the **visceral ganglia** are fused and lie ventrally, between the optic ganglia. They together make up the **infra-oesophageal mass.** This mass is prolongated anteriorly into the **pro-pedal ganglia,** from these ten nerves pass to the arms. From the lower position of the infra-oesophageal mass the siphon nerves are given off. The **pleural** and the **visceral** nerves pass off further back.

Make a drawing of the free surface of a vertical section putting in all the mouth parts, the oesophagus, and the oesophagael nerve mass.

The study of **microscopic mounts** through the anterior part of the body will give better results than can be had by the dissection of a larger specimen, especially for the nervous system. Notice the following points under the microscope, they being the most important. The series of slides should be taken in order from the anterior toward the posterior part of the head.

1. Cut surface of five pairs of arms.
2. Nerve ganglia near center of each arm.

3. In center of section a large oval body, the buccal mass.

4. The mouth on the ventral surface.

5. Small dorsal beak, dorsal to the mouth.

6. The large mandible and the muscle which moves it.

In section through the eyes:

1. The small oesophagus near the center of the section.

2. Pedal ganglia on the middle line of the body.

3. Eyes on the side of the head.

4. Anterior chamber of the eyes. The posterior chamber. The line between the two.

5. The cornea. The central opening, the pupil.

The posterior chamber is filled in the living animal with **vitreous humor.**

6. The retina on the back of the eye; examined under high power, rods between the lines of pigment will be found.

7. Layer of cartilage outside of the retina.

8. Optic ganglion outside of the cartilage.

Section posterior to the eyes:

1. Cerebral ganglia dorsal to the middle line.

2. Optic ganglia on each side of the head.

3. Pedal ganglion on the ventral surface of oesophagus

4. Head cartilage outside of the brain.

5. Upper end of siphon ventral to the head.

Study a section through the base of the head.

Make a drawing of each section studied as above.

The living animal is a very interesting one to study. His motions are quick. He moves in any direction by means of the fin and the siphon. His movements backward are exceedingly swift, being brought about by the action of the water as it is thrown out of the siphon. The blind sacs, spoken of above, act as valves that allow the water to enter the mantle cavity, but as the mantle contracts to send the water out they close and the water is forced out through the siphon in jets. He has the power to vary the direction of the jet by moving the point of the siphon to various positions.

His color is constantly changing as explained above.

The tentacles are in constant motion, in search of food.

Upon being irritated he quickly projects black ink, which is secreted in the ink sac, through the siphon and he is suddenly enveloped in a cloud of black fluid which affords him an easy means of escape from his enemy.

His large eyes, his great variety of motions of tentacles and body, and his change of color, give him on the whole a very odd appearance.

PHYLUM CHORDATA

ELASMOBRANCHII

The Dog-fish (Mustelus canis)

EXTERNAL FORM—What is the general form? Does it belong to the fishes? Why? (See Herwig, page 557). Can you determine divisions: **head, body, and tail?** Note the **rostrum** or beak, anterior to the mouth and eyes. Note the position and shape of the eyes. Are there **eyelids?** With the tenaculum hook up the membranous fold under the eye, and draw it up over the eye. This is the **nictitating membrane.** Has it an analogue among the higher types? Immediately posterior to the eye note a small opening, the **spiracle.** Posterior and somewhat ventral to the spiracle you will see five slits which are the **gill clefts.** Is there an arrangement by which they may be closed? Lift up the flap of skin covering them and notice the **gills** or branchial apparatus. Can you demonstrate the connection of the gill-clefts and the spiracles with the pharynx, and mouth? What would you infer as to the function of the spiracles from the derivation of the word? What reasons would you give that water goes from the mouth through the spiracles and the gill-clefts instead of in the opposite direction? On the ventral side of the head, some distance from the front of the beak, note the triangular-shaped **mouth.** Are the teeth placed in rows? Look at them with the hand lens. How would the fish seize food thrown upon the surface of the water above it? Open the mouth and examine the **tongue.** Is there any connection between the size, length, and shape, and the absence of molar teeth as found in the higher forms? Can you assign any reason for the flat surface of the underside of the head and the rostrum?

How many paired fins has the fish? How many unpaired? Have the paired fins any relation to the limbs in the higher forms? By working the anterior pair of paired fins, see if you can determine something of the mode of connection with the body. By pressing on the skin ventrally and dorsally see if you can determine the presence of the **pectoral arch.** In the same way try to determine the **pelvic arch** in connection with the hind pair of ventral fins. Immediately posterior to this latter pair in the angle formed by their approach to the body the anal or **cloacal opening** is found. If the fish is a male you will observe that the inner part of each of these fins is specialized to form a **pair of sexual organs.** Note the opening of the **sperm duct,** Where is it found? The cloacal or tail fin is heterocercal. (See Kingsley, page 229). On each side of the fish extending from near the spiracle to the tail note the **lateral** line. (See Weidersheim and Parker, page 191 and Weysse, page 275). By pressing on the skin of the fish taken from the preserving fluid one may demonstrate the **pores** of the skin. They are especially noticeable on the head near the spiracles. Examine the skin with the hand lens. It seems to be covered with fine teeth. Which direction do they slant? Look up the word "shagreen". These scales are of the placoid form. (See Kingsley, page 228). Make a drawing of the external appearance. Make a drawing of the musculature on the side after the skin has been removed.

DIGESTIVE SYSTEM—Open the abdominal and the thoracic cavities by a median cut extending from a short distance in front of the anal opening to a point opposite the posterior corner of the mouth. The body is lined with a silvery membrane, the **peritoneum.** In the abdominal cavity note the large **bi-lobed liver.** Between the lobes of the liver note the **stomach** connected by a short **gullet** or oesophagus to the back part of buccal cavity or **pharynx.** By pushing a scalpel handle or other blunt instrument down the oesophagus demonstrate the connection with the stomach. The stomach is V-shaped, the large anterior end being known as the **cardiac** and the posterior end as the **pyloric** stomach. Attached to the posterior end of the cardiac stomach and extending around the angle of the V

and along the entire length of the pyloric stomach is a large, reddish organ, the **spleen.** Is it continuous? Posterior to the opening of the stomach into the intestine, lies a small, flattish, irregular body, the **pancreas.** Demonstrate. Is there a small intestine? Open the stomach along its ventral edge until you demonstrate the pyloric opening. Note the contents of the stomach. Wash the stomach clean and examine its mucous lining carefully with the hand lens for the openings of the **stomach glands.** Note differences in the lining of the stomach in the different parts. Open the intestine and note the peculiar membranous folds in the interior of the posterior portion, the **spiral valve.** Is the name justified? What might have been its origin? What the use now? Extending from the dorsal wall of the intestine near the posterior end notice a small diverticulum-like gland, the **anal gland.** The intestine opens into a short chamber common to it as well as to the ureters. This is the **cloaca.** Make a drawing of the digestive apparatus. Show the spiral valve in a separate drawing.

CIRCULATORY AND RESPIRATORY SYSTEMS—The heart lies in the **pericardial cavity** in the mid-ventral line, just under the pectoral girdle. The posterior wall of the pericardial cavity has the appearance of a diaphragm. The heavy, thick-walled middle portion of the heart is the **ventricle.** Anterior and connected to this note the **conus arteriosus,** which is developed from the ventricle as is indicated from the striped muscle fibers of which it is composed. Posterior and dorsal to the ventricle lies the thin-walled atrium or **auricle.** Posterior and dorsal to this lies the **sinus venosus,** which is developed as a part of the vein ending, and has the appearance of a thin membrane. This is determined by the smooth muscle fibers of which it is composed. From the anterior part of the conus arteriosus trace forward the **ventral aorta.** This gives off an afferent branchial artery to each **gill-pouch.** They enter the gills from the ventral side. Demonstrate each one by the proper longitudinal cuts at the ventral ends of the gill-clefts. Carefully dissect off the skin from the roof of the mouth and expose the efferent branchial arteries, then trace them until they converge to form the

dorsal aorta. The one arising from the posterior gill-cleft unites with the one in front of it. Open the spiracle and see if you can demonstrate that it is a rudimentary gill-cleft. From the first or anterior pair of **efferent branchial arteries** trace forward the two **common carotid arteries.** Note that each one of these divides into two branches; an external which goes to the eye and surrounding region, an internal which, approaching its mate from the opposite side, pierces through on the median line and supplies the brain. Trace the dorsal aorta posteriorly. Note and trace the first branches, the two **subclavian arteries** to the pectoral fins. Posterior to the subclavian arteries the first median or **coeliac axis** is given off.

Trace this through its first branch, the **anterior gastric,** to the front part of the stomach, and through its second branch, the **hepatic,** to the liver. The second median artery, the **anterior mesenteric** sends a branch, the **lineo-gastric,** to the posterior part of the stomach and another to the spleen. Demonstrate this. The third median artery, the **posterior mesenteric,** supplies the rectum and the rectal glands. Trace these points out. The dorsal aorta also gives branches to the genital organs, the kidneys, and the pelvic fins. It continues into the tail as the **caudal** artery.

The venous system can be traced from the sinus venosus by three veins which lead into it. A pair of smaller ones, the **hepatic** veins, come from the liver. The larger, a short trunk directed anteriorly and ventrally, the **pectoral sinus** or ductus Cuvieri, receives the subclavian veins. The **ductus Cuvieri** is formed by a pair of jugular or **anterior cardinal** veins returning the blood from the head region, and a pair of **posterior cardinals** bringing the blood from the posterior regions. Each anterior cardinal has an expansion, the **orbital sinus,** which surrounds the eye. The veins entering the kidneys from the tail are often called caudal veins, but may be considered as the posterior cardinals which, after performing the portal circulation of the kidneys, collect and empty into the ductus Cuvieri. The hepatic portal vein is formed by the junction of veins from the intestines, pancreas, and the spleen. The lateral vein brings blood from the femoral and some

of the cloacal veins to the ductus Cuvieri. It runs parallel but ventral to the dorsal aorta. Open the heart through all of the chambers by a ventral cut. Demonstrate the valve between the ventricle and the auricle. Demonstrate the pocket valves in the conus arteriosus. How many transverse rows of valves and how many valves in each row in your specimen? Open the nasal cavity. Where does it open posteriorly? Note carefully the lining of the nasal cavity. Make a drawing of the circulatory system. Expose the internal gills and make a diagram showing the circulation in the gills.

THE EXCRETORY AND THE GENERATIVE SYSTEMS—The **kidneys** lie in the posterior part of the body cavity on each side of the spinal column and may be exposed by carefully cutting away the peritoneum covering them. They are long, flattish, lobulated organs composed of bunches or lobes of tubules. The tubules forming the hinder portion of the kidneys are called the **metanephros** or true kidneys. The tubules from these lobes unite to form about six branches. These join one another to form a duct, the **ureter**, which opens directly into the cloaca in the female and in the male into the paired uro-genital sinus which empties into the cloaca. Demonstrate. The anterior part of the lobulated mass is known as the **mesonephros**. This is rudimentary in the female. In the male the tubules serve to carry the spermatozoa. Find in the male, in the dorsal part of the dorsal cavity, two long flattish bodies united with one another posteriorly. They are the **testes** and are connected anteriorly by slender tubes, the **vas deferens** which leads to the cloaca. Demonstrate. The posterior end of the vas deferens is dilated forming the **vasicula seminalis.** In the female look for the single **ovary** in the dorsal part of the body cavity suspended in folds of the peritoneum. Back of the viscera, extending from a position near the posterior end of the heart to the cloaca, are the two oviducts united in front and opening by a single large aperture into the body cavity. Notice an enlargement of each duct, the **shell gland.** How do the ova get into the oviducts? Draw the uro-genital apparatus.

THE NERVOUS SYSTEM AND THE ORGANS OF SPECIAL SENSE—The central nervous system consists of the **brain** and the **spinal cord**. Open the dorsal part of the skull, cutting and picking away the cartilage of which it is composed with the scissors and forceps until the brain is entirely uncased. This will necessitate careful work, especially where the **olfactory lobes** are continued forward; the **pituitary body** downward, and the **pineal body** upward. Cut the **cranial nerves** as far from their attachment as possible. Are there sutures in the skull? When you are picking away the skull investigate the structure, first of the nostrils. Where do they open posteriorly? Are they functional as organs of smell? Second, the structure of the eye. Note the muscles. How many pairs are there? Are they fastened to the thick outer coat or sclerotic? In what direction does each move the eye? Take the eye from the socket cutting the optic nerve close to the eye ball. Open the eye. What is the comparative shape of the lens? Is it different from the shape of the lens in the higher forms? What is your conclusion from the shape as to the range of vision? Divide the two lenses. What is the comparative size of the space filled with the **vitreous humor**? Note the black inner coat, the **choroid**, and interior to this the **retina**. Does the optic nerve enter the posterior part of the eye? Posterior to the eye carefully dissect out the mucous sac constituting the **ear**. Does it have a connection with the pharynx? With the external surface? With the brain? Find the ossicles. Test with HCl. What is their composition? Use? Trace the auditory nerve. What are the essential conditions of hearing? Does it function as an organ of hearing? What other function beside hearing has the ear in the higher forms? Work out the muscles, using the frog for comparison.

Find the olfactory lobes as the foremost part of the brain. Note the connection with the sensory membrane of the nostrils. The short stem connecting these with the body of the brain is the **olfactory tract**. It is connected with the **prosencephalon**, a part of the fore-brain. On the dorsal side, back of the fore-brain, constituting a part of the 'twixtbrain, note an upward and forward tube-like

projection, the **epiphysis** or **pineal gland.** (On the function of this gland see Weidersheim and Parker, page 155). Anterior to the base of this tube remove a little of the membrane and find the **third ventricle.** The posterior part of the fore-brain is called the **thalamencephalon.** On the ventral side of the brain back of the thalamencephalon find the **optic nerves.** On the dorsal and the lateral side of the brain back of the **diencephalon** or the **mid-brain** are the two optic lobes. Partly overlapping the optic lobes and extending backward is the **cerebellum** which constitutes the anterior part of the hind-brain. The tapering part of the brain back of the cerebellum is the **medulla oblongata.** The cavity in the dorsal part of this is the **fourth ventricle.** Running forward from this demonstrate the narrow passage, the **iter** or aqueduct of Sylvius. From the third ventricle demonstrate the passages into the lateral ventricles and into the olfactory lobes. The side walls of the third ventricles are the **optic thalmi.** On the ventral side of the brain posterior to the optic nerves note the hollow outgrowth from the floor of the third ventricle. This is the **infundibulum** on the end of which is situated the **hypophysis** or pituitary body. Note the cranial nerves coming from the medulla. Make a drawing of the dorsal and the ventral views of the brain. Open the vertebral column carefully and expose the **spinal cord.** Note how the nerves are given off. Demonstrate the posterior and the anterior nerve roots. Dissect out a vertebra. Notice particularly the character of the articulating facets. Dissect out the pectoral arch and note the character of the articulating facets between the arch and the fins.

TELEOSTOMI.

Teleost (perch).

NOTE—In working out this animal keep constantly in mind the corresponding parts in the dog-fish and compare them point for point.

EXTERNAL FEATURES—How does the general form compare with that of the dog-fish? Is it bilaterally symmetrical? What are its dimensions? (Length of fish is measured from tip of snout to base of tail fin. Length of head from tip of snout to the posterior edge of oper-

culum). Can you distinguish the divisions, head, body, and tail? How? What are **cervical vertebrae**? Would you expect to find them in a fish? Do you find a lateral line? Note the position of the mouth. Open it and find the teeth on the upper jaw. They are on the **premaxillary** bone. How is it fastened to the skull bones? The paddle-shaped bone back of it is the **maxillary**. Those constituting the sides of the lower jaw are the **dentary bones**. Do they bear teeth? In the front of the roof of the mouth is situated the patch of **vomerine teeth**, so called from the bone upon which they are placed. Extending back from these teeth on each side of the roof of the mouth are two rows of teeth situated on the palatine bones. Are the teeth placed in regular rows? Look at them with the lens. What is their shape, their slant, and their function? Back of the premaxillary bone note a pocket-like flap or valve with the opening turned backward. What is its use? Is there a tongue?

Examine the position and general appearance of the **eyes**. From a superficial examination of the eyes in how many respects do they differ from the eyes of the dog-fish? Do you think that the nictitating membrane in the dog-fish is an organ in the process of evolution or of degeneration? Why? Press on the roof of the mouth and note effect on the eyes. Was this effect possible in the dog-fish? Anterior to the eye is situated a thin triangular bone, the **ante-orbital** bone. Note a pair of openings in front of each eye, the **nostrils**. Do they open into the mouth? Do they communicate with each other? Are there any valves for closing them? Compare their situation, with reference to the mouth, to those of the dog-fish. Can you find a **spiracle**? How many external gill openings are there? Find the **operculum** or gill covering and note that it is composed of over-lapping parts the posterior of which is called the **opercle**. Over-lapping the opercle in front is the **pre-opercle**. This generally has a serrated hinder edge. The **inter-opercle** lies within its dorsal edge under the opercle and the pre-opercle and over the **sub-opercle**, which is ventral. Considering the fact that there are a number of gill-clefts in the embryo of this fish, what do the parts of the operculum mean? Is the arrangement a better pro-

tection to the gills than the dog-fish has? Make a drawing illustrating the parts of the operculum. Raise the operculum and examine the gills. There is a double row of gills on the posterior edge of each gill arch and a single row of gill rakers on the anterior edge. How many gill arches and gill-clefts are there? Depress the tongue with the fingers and note the effect on the gills. What is the meaning? On the inside of the operculum find a fleshy projection, the false gill. Dorsal to the attachment of the pectoral fin, note a sort of rudimentary operculum.

How many paired and unpaired fins has this fish? Are the paired fins much developed? Notice the difference in the character and the placing of the pelvic fins as compared with those of the dog-fish. Make the same observations with regard to the other paired fins. From these observations do you think that this fish should be placed higher or lower in the animal scale than the dog-fish? Are there modifications of the fins by which the sex may be known? In this regard which seems to be higher or lower in the scale? Determine something of the manner of the articulation of the paired fins by working them. Can you detect the presence or absence of pectoral and pelvic arches? Note the difference between the dorsal and the pectoral fin rays. The tail is homocercal. What does that mean?

Are the scales imbricated or are they tessellated? Raise a scale carefully and note the thin epithelial membrane reflected from its hinder portion to the scale underneath. Note the pigment granules in this membrane. Remove a patch of scales and examine the flesh underneath to determine the method of attachment. Examine a number of scales under the hand lens. Make an enlarged drawing of a typical scale, showing the shape and markings. Imbricated scales are either cycloid or ctenoid; ctenoid if the hinder edge is toothed or spiny. Do the scales covering the lateral line differ from those found elsewhere on the body? How?

In front of the ventral anal fin demonstrate the opening of the urinary and the reproductive organs. Do they open together? Locate the anus. Is this arrangement typical of the higher or of the lower forms? Do you find

skin pores about the head of this fish? Make a drawing of the lateral surface of this animal locating the different external features.

THE VISCERA—Cut away carefully one side of the body wall from a short distance in front of the anal opening to the pectoral fins and from the ventral line as far dorsally as you can without injuring the viscera especially the air bladder. Note the **peritoneum.**

In the fore part of the body cavity lying mainly in the left side is the **liver.** How many lobes has it? Is it larger in size compared to the bulk of the body than it is in the dog-fish? Demonstrate the gall bladder and the hepatic veins passing forward from the liver. Demonstrate the **oesophagus** and the **stomach** by passing a probe down the throat. From the anterior part of the stomach find the opening of the **intestine.** This form of stomach is called coecal. About a half inch from the anterior end of the intestine find projections from it, the **pyloric coeca.** How many of these are there? Cut off the end of one of the coeca. Where does it lead? What is its use? Is the intestine convoluted? Trace it to the anal opening. If the stomach of the dog-fish is of the more primitive type from which the Teleostian type is a development, how may the opening of the intestine from the anterior end be accounted for? Do you find a pancreas? (See Shipley and McBride, page 381). Observe that the viscera are held in place by a thin membrane, the **mesentery.** Notice how the blood vessels are contained in it. Find a reddish body near the intestine. This is the **spleen.** Dorsal to the intestine in the female find a long granular yellowish body, the **ovary.** This may be very large at certain times of the year, when the eggs are ripe. Trace the **oviduct.** Does it open into a cloaca? Does this reproductive apparatus indicate an advance in the scale above the dog-fish? Why? If the fish is a male notice the two white bodies, the **testes.** Trace the **vas deferens.** Find a **urinary bladder** posterior to the reproductive organs. Where is its external opening? In the dorsal part of the body cavity find the **air bladder.** What is its use? Trace carefully its anterior end to see if it has a communication with the alimentary canal. Open the oesophagus, stomach, and the intestines,

and note the differences in the character of the mucous membrane lining them. Find the **pyloric valve**. Do the pyloric coeca open into the intestines? In front of the liver find a false diaphragm. Remove this and observe the **heart**. The part most ventral and posterior is the **ventricle**. The part above the ventricle is the **auricle**. Dorsal to the aorta is a large thin-walled **sinus venosus**. Anterior to the ventricle find the **bulbus arteriosus**. Is this composed of different material from the ventricle? Trace the ventral aorta leading from this forward until it divides into two branches one going to each branchial apparatus. Observe along the dorsal part of the body cavity under the peritoneum, the **dorsal aorta**. How many branches does it give off to the viscera? Can you find the long **kidney** on each side of the spinal column? Where do the **ureters** leading from them go?

Separate the lower jaws by a cut along the medial line. Turn the sides back and notice how the gill rakers fit into each other. Is the anterior row of gill rakers different from the others? How? Observe where the gill arches meet dorsally a large flat prominence constituting the dorsal part of the **pharynx**. This is covered with numerous fine teeth. Opposing these on the ventral side is a smaller patch of teeth. These are called the superior and the inferior **pharyngeal teeth**. Do the gill arches have joints? The bones supporting these are the **pharyngeal bones**. Carefully pick away the flesh from the inside of the pectoral and the pelvic arches so as to expose the bones constituting these arches. The largest bone of the pectoral arch is the **clavicle**. It projects a little above the base of the pectoral fin. Above this is the **supra-clavicle**. The **post-temporal** connects this latter with the skull. The bones connected with the ventral fins may be considered as the **pelvis**. Observe that they are directly connected with the pectoral arch. How does this compare with the dog-fish? With the higher forms? What would this indicate as to the place of the Teleostomi in the evolutionary scale? Make a drawing of these bones together and one to show the method of articulation between the fins and these bones. Is this joint different from that of the higher forms?

Remove the skin from the whole side of the fish by cutting along the back near the dorsal fins, taking care not to injure the musculature beneath. Roll the skin lengthwise to see the arrangement of the rows of scales in that direction, and roll it crosswise to see the arrangement of the scales and the epidermis. Look at the lateral line from the inside of the skin with a hand lens. Is there any indication of a lateral line on the musculature? Look on the inside of the skin and on the body under the skin with a lens for pigment cells.. In what are they situated? Make a drawing of the muscle arrangement on the side of the fish. Carefully pick and scrape the muscles away so as to expose the skeleton. Take out a few vertebrae and attached bones over the visceral cavity. Does the fish have ribs? What peculiarity is there in the articulation of the vertebrae? The largest and ventral part of a vertebra is called the centrum. Is it hollow? Notice the canal traversed by the spinal cord. This is called the **neural cavity,** and the bones forming it the **neural arch.** The **neural spine** projects dorsally from the neural arch. Do the neural spines connect directly with the dorsal fins? Sketch a dorsal vertebra and the connecting bones side view, also end view. Take out a few vertebrae from near the tail. How do they compare with the dorsal vertebrae? On the ventral portion note the **haemal arch,** for the passage of the **dorsal aorta,** and the ventral spine projecting ventrally. Observe how the blood vessels are given off. Sketch a caudal vertebra from the side, also from the end.

Dissect out the brain with much care by commencing on the dorsal anterior portion. Note the nasal sacs and the nerves leading to them. Trace the two **olfactory nerves** back to the two olfactory lobes. How do they compare with those of the dog-fish? Back of the small olfactory lobes find the cerebral hemispheres constituting the **cerebrum.** Observe the immense advance of the cerebrum here over the dog-fish. Back of the cerebrum note the two round, paired **optic lobes** constituting the largest and the widest part of the brain. Back of these is the **cerebellum.** Beneath the cerebellum and extending backward is the **medulla oblongata.** From the under side of the brain

observe the optic and the auditory nerves. Can you distinguish an epiphysis and a hypophysis? Sketch the brain from the top, also from the bottom. Open the optic lobes and the cerebrum. Are there cavities in them? Where do they lead to? Back of the eye and lateral to the optic lobes find the cavity of the ear and the ear stones. Open the eye and find the aqueous humor, lens, vitreous humor, retina, choroid coat, sclerotic coat, and the cornea. How does the lens compare with that in the dog-fish? Dissect out the eye, commencing first in the roof of the mouth. Between the membrane of the roof of the mouth and the roof find the levator muscle. From the internal posterior part of the optic cavity as an origin, to the sides of the eyeball, find four recti muscles. The two oblique muscles of the eye have their origin at the internal anterior part of the orbit and extend to the upper and to the lower parts of the eyeball. Note the way in which the optic nerves cross, that from the left eye going to the right side of the brain, etc.

AMPHIBIA

FROG (Rana)

Material is best found during the early spring months. Search the shallow ponds and the grass adjoining them for good sized frogs. Rana catesbina (bull frog) may be obtained, at small cost, from the dealers in zoological material. Frogs can be kept alive for long periods with very little care. It is necessary to have a wire cage, with or without running water. If running water is not to be had put some sods with growing grass in the cage and keep them moist. Place a vessel of water in the cage. This water must be changed frequently. The frogs will need no care as to food, as they will not eat anything except the frogs of smaller size that may be in the cage with them. On this account it is well to sort them as to size and to keep them separate. If they should freeze no injury is done for if left to themselves they will gradually thaw out and be as active as ever.

In studying the frog both living and preserved specimens should be at hand. Formalin, four per cent. makes

a good preservative for frogs. The abdominal wall must be cut to allow the liquid to gain access to the viscera.

EXTERNAL ANATOMY—Notice the general shape and attitude of the live specimen. Compare with a preserved specimen. Notice the color. Is there any variation in color on the same or different specimens? Reflect on the mode of the frog and decide whether he is well adapted in form for his mode of living. In what respect would the variations in color aid him in his life struggle?

GENERAL STRUCTURE—The body as a whole consists of an **axial portion, head, and trunk**; and an **appendicular portion, the legs.** What is the texture of the skin? Notice whether or not the skin fits closely to the body. Note the surface of the skin. Study the dorsal, ventral, and lateral views of the head. Can you locate the dividing line between the head and the body? Compare the mouth of the frog and that of the lobster, as to position, shape, and breadth of opening. Locate the eyes. Note color and shape. Are the eyelids all alike? Note the differences if any. Has the frog the power to depress the eyes? Keep this in mind and see if you can explain it later. The **brow-spot** is between the eyes on a line connecting the anterior borders of the eyes. The **nostrils** will be found anterior to the eyes. Notice the position and shape. Can they be closed? Is there any modification of the skin around them? The **tympanic membranes** are found posterior to the eyes. What is their shape? Do they vary in size or color? Notice the tension of this membrane. To what is it fastened? Study the dorsal and the ventral surfaces of the **trunk** to note any difference in shape and in color. By pressing the body between the thumb and fingers note the hard parts or the **skeleton.** Observe the hump that appears near the middle of the back. By pressing your fingers posteriorly from this point three hard ridges will be noticed. The two lateral ones are the parts of the **ilium.** The middle one is the **urostyle.** Find the anal opening at the posterior end. What is its relative position to the posterior end of the urostyle? Notice carefully the anterior **legs.** What is their direction? Can the frog reach his nose with his hand? Does

the diameter of the leg vary greatly throughout its length? Note the upper arm, **brachium**; the forearm, the **antibrachium**; the hand, the **manus**. What is the relative proportion of each of these parts to the length of the leg? How many digits on the manus? Do you find a thumb, **Pollex**? Note the number of joints in each digit. Would you judge these legs to be good organs of locomotion in the water? Why? In the posterior legs note the **thigh, leg, crus,** and **foot**. How do these parts compare with those of the anterior leg? Do you find a great toe, the **hallex**? Make a **sketch** of the frog, side view as seen alive.

INTERNAL ANATOMY—**The Skeleton.** Study skeleton prepared in Wickersheimer's fluid. Note the **axial skeleton, consisting of skull; vertebral column; appendicular skeleton,** and limb **girdles**: anterior, the **pectoral girdle**; posterior, the **pelvic girdle.**

The Vertebral Column—Of how many parts does it consist? What is the general shape of each part? How does the urostyle compare in shape and structure with the anterior part of the vertebral column? Near the anterior end of the urostyle find two openings, **foramina** for nerves to enter. Draw the urostyle from the side. The anterior part of the axial skeleton is made up of parts called **vertebrae.** How many do you find? Study them for differences. Examine one, the third as a type, and note that it is a bony ring with several projections. Note the ventral portion, the **body.** What is its structure? On the dorsal side is the **neural arch.** Note the shape as seen from the end. Find the **spinous process.** On dorsal side of each, the **transverse process** on the side of the neural arch. Note their shape, size, and direction. Find the anterior and the posterior **articular processes.** Why are they called articular processes? Are there any ribs? Draw end and side view of a vertebra. Compare carefully the first vertebra, the **atlas,** and the last, the **sacrum,** with the one just studied. Can you find all the processes mentioned above? Do you find any modifications of these processes? Find the **odontoid process,** a projection on the body of the atlas. The **intervertebral foramina** will be noticed, by studying the entire column, on the lateral area just below the articular process. Note the direction

of movements possible in the vertebral column as a whole.

The Skull—Describe its shape from below, above, and from the side. Locate the **eye sockets.** Notice the **auditory capsule** just back of the eye socket. What is the relation of the tympanum to this capsule? Note the lower jaw, the **mandible.** What is its shape? Look for teeth. Find whether it is made up of one or of several parts. **Meckel's cartilage** will be found in a groove on its upper edge. Note the extent of this cartilage. Find the **foramen magnum** in the posterior end of the skull. The neural canal is a continuation of this foramen. What is the relation of the cranial cavity to this foramen? What is the shape of the **condyles** which are the projections on either side of the foramen magnum? Note the surface of the condyles. With what bone do they articulate? Find the cartilaginous ring upon which the tympanic membrane is stretched. Note the nasal bones near the anterior part of the head. Find the **premaxillae** just in front of the nasal bones. The **maxillary** bones extend backward from the premaxillae. How are the teeth arranged? How many are there? Find the **palatine** bone just under the nasal bone. Describe this bone. The **vomers** are found in front of the palate bones. Do you find teeth here?

The Pectoral Girdle—Is made up of the **clavicle, scapula,** and a **sternum.** What attachments to the axial skeleton do you find? What is the relation of the scapular portion (dorsal) and the coracoid portion (ventral) each to its neighbor on the right or the left side? Note that the scapular portion is made up of a cartilaginous and a bony part. The former is the **supra-scapula,** the latter is the **scapula.** Note the **coracoid bone** and the **clavicle.** Compare them in form. The part of the girdle that makes up one side of the shoulder joint is the **glenoid cavity.** What bones go to make up this cavity? Note the manner in which the clavicle is attached to the scapula. The **coracoid foramen** is between the coracoid and the clavicle. The **sternum** consists beginning in front, of the **omosternum, episternum, epicoracoids, sternum proper,** and the **xiphisternum.** Make a careful comparison each

with the others and note whether they are bones or cartilage.

The Fore Limb—Notice that it is made up of four parts; the **humerus, radio-ulna, carpus, and manus.** Make a drawing of the humerus after making a careful study of it. The proximal end of the humerus is enlarged to form the head and articulates with the pectoral girdle at the glenoid cavity. Observe a prominent ridge, the **deltoid ridge,** on the dorsal side. How do the two ends of the ridge differ? Are both ends of the humerus alike? What is the shape of the radio-ulna? What would suggest this name for the bone? The **olecranon process** is back of the elbow joint. What movements are possible in the elbow joint? How many, and what is the arrangement of the **carpal bones?** Note the position of the hand on a living frog. Compare the movements possible in the wrist of the frog with those of your own. Examine the **metacarpals.** Study the **phalanges.** Notice carefully the **pollex** or thumb, and point out any differences between this and the fingers.

The Pelvic Girdle—Compare this with the pectoral girdle, in shape, and the direction in which it extends. What is its attachment to the axial skeleton? Make out the following bones which are more or less fused to make up the girdle: the **ilium,** which runs nearly parallel to the urostyle, the **ischium,** which forms the greater part of the posterior half, and the **pubis,** which forms the ventral portion. Note carefully the shape of each of these parts. Find the **acetabulum,** the cavity into which the femur fits. Make a drawing showing a side view of the girdle.

The Hind Limb—In what way does the **femur** differ from the humerus? Compare the range of motion of the femur with that of the humerus. Give your reasons for any difference. Compare the **tibio-fibula** with the corresponding parts in the fore limb. Find the **tarsus.** Note the **astragulus,** and the **calcaneum.** Note the direction of motion possible in the bones of the hind foot. Do you find a patella? Make a drawing of the bones of the hind leg. Compare the skeleton of the frog with as many other skeletons as you have at hand.

MUSCULAR SYSTEM—**Muscles of the Ventral Body Wall**—Remove the skin of the ventral surface of the body and find a long muscle extending from the pubis to the sternum, **rectus abdominis.** It is divided on the median line by the **linea alba,** and transversely into several divisions. How many?. The **pectoralis** is a fan shaped muscle having its origin along the entire length of the body to the pubis. It may be considered in at least two parts, the thoracic and the abdominal, from the points of origin. Trace it to the insertion on the deltoid ridge of the humerus. Just in front and partly covered by the pectoralis is the **sterno-radialis.** This is a triangular shaped muscle with its origin on the sternum and its insertion after ending in a very long tendon, is on the radio-ulna. The **external oblique** arises on the surface of the ilium and the aponeurosis of the back and spreading out in a thin sheet, ends in an aponeurosis ventral to the rectus abdominis. Its insertion is in the linea alba. What is the direction of the fibers? The **internal oblique** lies under the external oblique. It has its origin on the vertebrae and the ilium and is inserted on the sternum and the linea alba.

The Muscles of the Back—The **depressor mandibuli** is a triangular muscle posterior and partly covered by the tympanic membrane. Its origin is on the suprascapula and the fascia of the mid-dorsal line, and it is inserted into the angle of the jaw. The contraction of this muscle would do what? The **cucullaris** is a small muscle arising from the middle line of the exoccipital and inserted into the dorsal border of the suprascapula. What is its direction? The **infra-spinatus** is a large triangular muscle overlapped anteriorly partly by the next muscle. Its origin is on the suprascapula and its insertion is on the deltoid ridge of the humerus in common with the latissimus dorsi. The **latissimus dorsi** is a triangular shaped muscle posterior to the depressor mandibulae. It has its origin in the dorsal fascia and is inserted on the deltoid ridge with the infraspinatus. The **extensor dorsi communis** is the large dorsal mass of muscles. It arises from the urostyle and is inserted into the ilium, transverse processes of the vertebrae. and into the posterior end of the skull.

What is the direction of the fibers? The **intertransversales** are small muscles between the transverse processes of the vertebrae. They lie beneath the preceding muscle. The **gluteus** arises from the outer side of the posterior two thirds of the ilium and is inserted into the trochanter of the femur. What is the direction of the muscle?

The Muscles of the Ventral Surface of the Head—The **mylohyoid** covers the entire ventral surface of the head just under the skin. The fibers meet on the mid-ventral line, and have their origin on the inner superior border of the mandible. In the anterior angle of the mandible note the **submentalis**, a short muscle dorsal to the fibers of the mylohyoid. The fibers have their insertion on the inner superior border of the mandible. On either side of the mid-ventral line is a broad, thin muscle, the **geniohyoid**, just dorsal to the mylohyoid. Its origin is at the anterior end and on the inner superior border of the mandible. The posterior end is divided and inserted on the hyoid apparatus. The **sternohyoid** is really a continuation of the rectus abdominis. The inner fibers have their origin on the sternum and the outer ones are continuous with the rectus abdominis. It is inserted between the ends of the geniohyoid. Dorsal to the mylohyoid and the geniohyoid is the **hyoglossus**. Its origin is on the hyoid apparatus. This muscle can be traced to a point anterior to the larynx, into the tongue, and backward to the tip of the tongue. The **petrohyoids** are a group of four muscles with their origin in the auditory capsule. Extending ventrally they pass around the oesophagus, spread out in a fan shape upon reaching the floor of the mouth, and are inserted upon the hyoid apparatus. Between the tympanic membrane and the eye find the **temporalis**, whose origin is on the dorsal surface of the head and the auditory capsule, and whose insertion is on the outer surface of the posterior end of the mandible. What is the function of this muscle? Partly under the temporalis is found the **pterygoideus**, a slender muscle with its origin on the side of the skull and its insertion on the mandible back of that of the temporalis very near the joint. The **masseter** is a small muscle behind the temporalis and inserted just in front of the joint on the outer surface of the mandible.

Figure I.

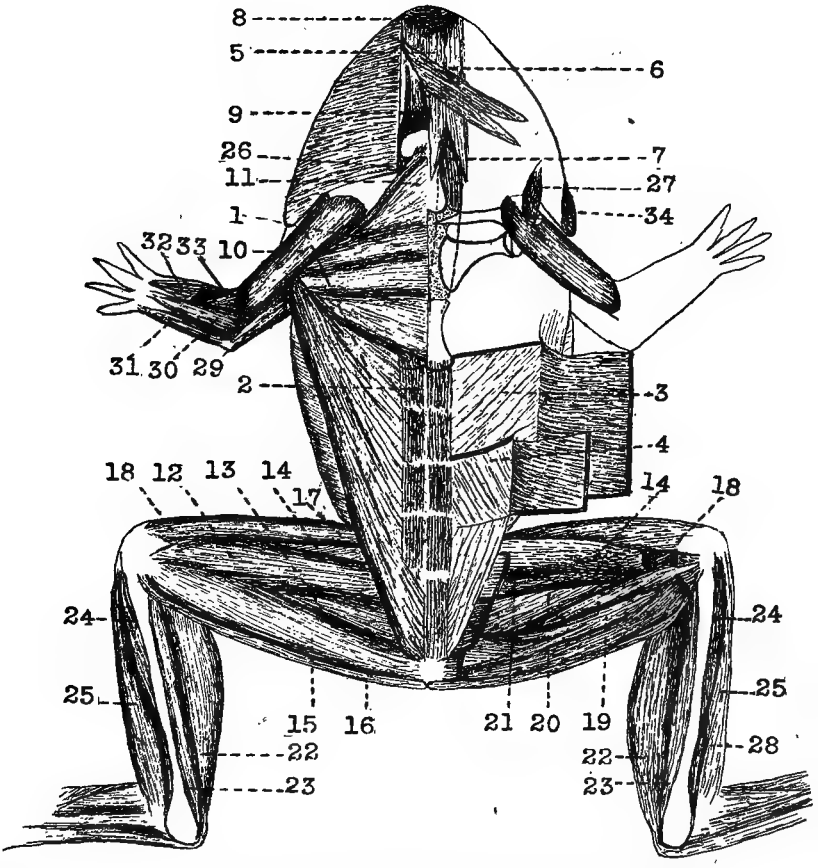

FIGURE I.—**1**, Pectoralis; **2**, Rectus Abdominis; **3**, External Oblique; **4**, Internal Oblique; **5**, Mylohyoid; **6**, Geniohyoid; **7**, Sternohyoid; **8**, Submentalis; **9**, Hyoglossus; **10**, Deltoid; **11**, Sternoradialis; **12**, Sartorius; **13**, Adductor Magnus; **14**, Adductor Longus; **15**, Rectus Internus Major; **16**, Rectus Internus Minor; **17**, Rectus Anticus Femoris; **18**, Triceps Extensor Femoris; **19**, Semitendinosus; **20**, Adductor Brevis; **21**, Pectineus; **22**, Gastrocnemius; **23**, Tibialis Posticus; **24**, Extensor Cruris Brevis; **25**, Tibialis Anticus; **26**, Episternodeltoid; **27**, Levator Clavicula; **28**, Flexor Tarsi Anterior; **29**, Posterior Division of the Triceps; **30**, Pronator; **31**, Anterior Extensor; **32**, Anterior Flexor; **33**, Supinator; **34**, Masseter. (After W. F. Copeland.)

Muscles of the Eye Ball—The **levator bulbi** is a thin sheet of muscle ventral to the eye ball. What is its function? The **recti muscles** consist of four separate muscles with their origin on the inner posterior angle of the eye socket and their insertion on the eye ball. Locate each: **rectus superior, rectus inferior, rectus externus,** and **rectus internus.** The **oblique muscles** are two in number with their origin on the palatine bone at the anterior end of the orbit and with their insertion on the eye ball; **superior oblique** is inserted on the dorsal surface of the eye ball in front of the rectus superior; **inferior oblique** passes under the rectus internus and is inserted between it and the rectus inferior. The **retractor bulbi** has its origin on the parasphenoid embracing the optic nerve to the eye ball where it is inserted. Look for it from below after removing the recti muscles.

The Muscles of the Fore Limb—The **sub-suprascapula** has its origin on the ventral surface of the proximal end of the suprascapula and its insertion on the upper anterior surface of the scapula. The **subscapula** is similar in shape but much larger than the former. Its origin is on the greater part of the inner posterior surface of the scapula. Its insertion is on the head and the proximal half of the postero-inferior surface of the humerus.

Separate the suprascapula from the scapula and reflect it; find two broad muscles inserted on the under surface of the suprascapula near its ventral margin. The anterior one, which is the smaller, is called the **levator anguli scapulae.** The posterior division is called the **retrahens scapulae.** This latter corresponds to the serratus magnus in the higher forms. It has its origin on the second transverse process and on the dorsal surface of the third, fourth, and fifth vertebrae. What is the origin of the levator anguli scapulae? After the viscera have been removed find an oblong muscle, the **trapezius,** dorsal to the oesophagus and ventral to the extensor dorsi communis. Its origin is on the exoccipital and its insertion is on the proximal half of the ventral surface of the suprascapula. Press apart the deltoid muscle and the mandible and find a cylindrical muscle, the **levator clavicula;** its insertion is the middle of the anterior border of the

Figure II.

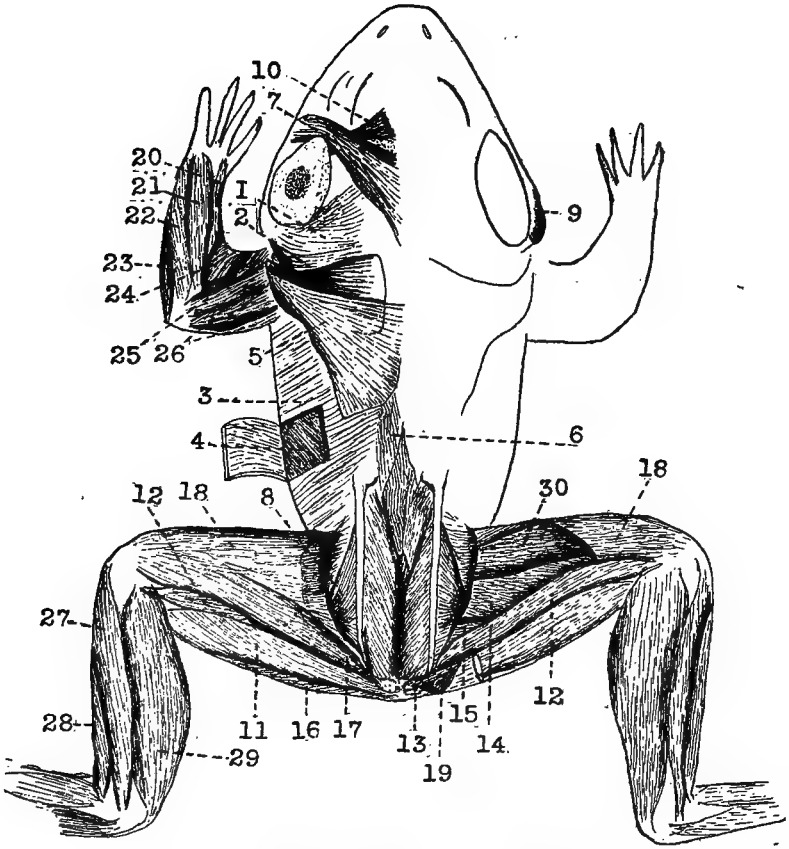

FIGURE II.—**1**, Depressor Mandibuli; **2**, Infra-Spinatus; **3**, External Oblique; **4**, Internal Oblique; **5**, Latissimus Dorsi; **6**, Extensor Dorsi Communis; **7**, Temporalis; **8**, Gluteus; **9**, Masseter; **10**, Pterygoideus; **11**, Semimembranosus; **12**, Biceps Femoris; **13**, Pyriformis; **14**, Iliopsoas; **15**, Obturator; **16**, Rectus Internus Minor; **17**, Vastus Externus; **18**, Triceps Extensor Femoris; **19**, Quadratus Femoris; **20**, Anterior Flexor; **21**, Middle Flexor; . **22** Posterior Flexor; **23**, Posterior Extensor; **24**, Supinator; **25**, Deltoid; **26**, the three Triceps; **27**, Peroneus; **28**, Tibialis Anticus; **29**, Gastrocnemius; **30**, Vastus Internus.

(After W. F. Copeland.)

scapula. What is its origin? Ventral to the latissimus dorsi and posterior to the scapula find a muscle, the **opponens levator clavicula,** similar in shape to the former. Its origin is on the outer end of the third or fourth transverse process, and its insertion is on the posterior border of the scapula. Immediately antero-external to the sterno-radialis find a narrow muscle, **episterno-deltoid.** Its origin is on the outer edge of the episternum and its insertion is on the posterior surface of the deltoid ridge near the distal end of the humerus. Note the relation of the muscle to the sterno-radialis. The **deltoid** is located dorsal to the episterno-deltoid and ventral to the infraspinatus. Its origin is on the anterior edge of the scapula, and its insertion is on the deltoid ridge, almost its entire length. Three muscles comprise the group known as the **triceps brachia.** They are all inserted in one tendon on the olecranon process of the radio-ulna. Trace each division to its origin. Two thick muscles invest the insertion of the deltoid. They may be called the **pronator,** and the **supinator.** Trace out both the origin and the insertion of these muscles, and decide why these names are given to them. The **extensor muscles** are located on the externo-ventral surface of the radio-ulna. Two divisions of these muscles may be made, an anterior and a posterior. On the anterior dorsal surface of the radio-ulna or ante-brachium are found the **flexor muscles.** Three divisions of these muscles may be made. From their position and direction what would be the result of their actions?

Muscles of the Hind Limb—In the act of swimming or jumping the frog extends his hind legs backward until they occupy a position parallel to the longitudinal axis of the body. Specimens that have been preserved in alcohol or formalin are not usually found thus, but for purposes of description this longitudinal position will be assumed. The surface along which lie the extensor muscles of the legs, the patellar surface of the knee, and the upper surface of the foot, will be called the outer or external surface. The surface opposite along the bend of the knee and covered by the flexor muscles, will be called the inner or internal surface of the leg. Concerning the surfaces

Figure III.

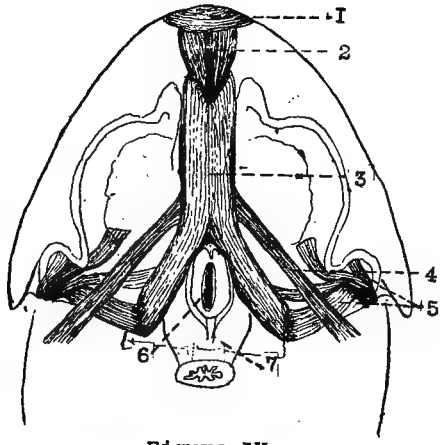

Figure IV.

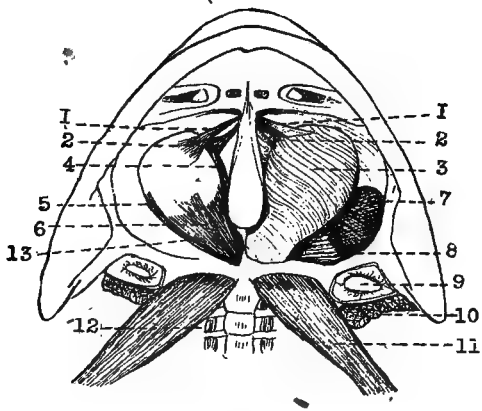

FIGURE III.—**1**, Submentalis; **2**, Tongue; **3**, Hyoglossus; **4**, Levator Clavicula; **5**, Petrohyoids; **6**, Glottis; **7**, Oesophagus.

FIGURE IV.—**1**, Inferior Oblique; **2**, Superior Oblique; **3**, Levator Bulbi; **4**, Rectus Internus; **5**, Rectus Externus; **6**, Rectus Inferior; **7**, Temporalis; **8**, Pterygoideus; **9**, Auditory Capsule; **10**, Petrohyoids; **11**, Cucullaris or Trapezius; **12**, Intertransversalis; **13**, Retractor Bulbi. (After W. F. Copeland.)

separating these two surfaces, the upper is the dorsal or superior, and the under is the ventral or inferior surface.

The Superficial Muscles of the Ventral Surface—The **sartorius** extends along the entire length of the femur external to the middle of the ventral surface. Its origin is on the symphysis of the ilium and it is inserted on the inner tuberosity of the tibio-fibula and in the aponeurosis of the knee joint. One of the largest muscles of the thigh is the **adductor magnus.** It runs along the inner border of the sartorius under which it dips at the distal end. It originates on the pubis and the ischium and is inserted on the distal end of the femur together with the **adductor longus.** External to and mostly covered by the sartorius is the **adductor longus.** It is a ribbon shaped muscle between the sartorius and the vastus internus. Its origin is on the ilium anterior to the acetabulum and it is inserted with the preceding muscle. The **rectus internus major** is a large muscle situated internal to the origin of the adductor magnus and the insertion of the sartorius. What is its origin and its insertion? The **rectus internus minor** lies internal to the rectus internus major on its ventral border. Its origin is on the symphysis of the ischium and is inserted on the inner side of the tibio-fibula just below its head.

Deep Muscles of the Ventral Surface of the Thigh—The **semitendinosus** arises by two heads, one on the symphysis of the ischium and the other on the symphysis pubis. The two heads unite near the middle of the femur and are inserted into the knee joint and the proximal inner surface of the tibio-fibula. The **pectineus** has its origin on the symphysis pubis and is inserted on the proximal half of the posterior border of the femur. This muscle is dorsal to the vastus internus and the adductor magnus. Internal to the pectineus and dorsal to the adductor magnus is a short broad muscle, the **adductor brevis.** Its origin is on the symphysis pubis and the ischium posterior to that of the pectineus.

Superficial Muscles of the External Surface of the Thigh—The **triceps extensor femoris** lies on the external surface of the thigh. It originates by three heads: **vastus externus, vastus internus,** and the **rectus anticus**

femoris. These three heads unite near the middle of the thigh into the tendon of the patella, whose insertion is on the ventral proximal end of the tibio-fibula. The vastus externus is the most dorsal of these three heads, with its origin on the posterior surface of the ilium. The vastus internus lies nearer the ventral surface, ventral to the rectus anticus femoris and external to the sartorius with its origin on the anterior surface of the head of the femur and the acetabulum. The rectus anticus femoris is the middle head with its origin on the ventral posterior border of the ilium.

The Superficial Muscles of the Dorsal Surface of the Thigh—The **gluteus** is a thick muscle with its origin on the outer posterior surface of the ilium, and with its insertion on the posterior surface of the cartilage about the head of the femur. The largest muscle on the dorsal surface is the **semimembranosus.** It is bounded by the vastus externus and the rectus internus minor. It originates on the ischium and is inserted on the knee joint in its aponeurosis. The long spindle shaped muscle with two bellies with a common tendon at the proximal end is the **biceps femoris.** It is bounded by the triceps femoris and the semimembranosus, and has its origin near the dorsal edge of the acetabulum. A part of this muscle is inserted on the dorsal proximal half of the femur and another part is inserted on the knee joint and the dorsal part of the proximal end of the tibio-fibula. The **pyriformis** is a small muscle with its origin on the posterior end of the urostyle and its insertion on the shaft of the femur.

Deep Muscles of the Dorsal Surface of the Thigh—After removing the vastus externus, the semimembranosus, and the biceps femoris, the **ilio-psoas** will be seen in contact with the ventral border of the gluteus. Remove the gluteus and find the origin of this muscle on the inner posterior surface of the ilium internal to the acetabulum. Follow it around the ventral border of the ilium, anterior to the acetabulum, to its insertion on the dorsal border of the femur. Ventral to the origin of the semimembranosus and dorso-posterior to the obturator find the **quadratus femoris.** It originates on the ilium near the acetabulum and is inserted on the proximal third of the femur.

The **obturator** has its origin on the symphysis of the ischium and its entire lateral surface and is inserted above the head of the femur.

Muscles of the Leg—On the dorso-posterior surface of the tibio-fibula note a large muscle, the **gastrocnemius.** It has its origin by two heads passes around the calcaneum and is inserted in the fascia of the plantar surface of the foot. This is the tendon of Achilles. The **tibialis posticus** is a slender muscle between the tibalis anticus and the gastrocnemius. It has its origin along the entire inner surface of the tibio-fibula, and is inserted on the dorsal proximal end of the astragalus. The **tibialis anticus** is a muscle opposite the gastrocnemius. It has its origin on the femur near the knee joint, divides near the middle of the leg, and is inserted by two tendons, one on the astragalus and the other on the calcaneum. The **peroneus** is a long muscle extending the whole length of the tibio-fibula between the tibialis anticus and the gastrocnemius. Its origin is on the distal end of the femur and it is inserted on the calcaneum. Between the tibialis anticus and the tibialis posticus find a small muscle, the **flexor cruris brevis.** Its origin is by a long tendon which lies in a groove on the surface of the tibio-fibula. It is inserted along the shaft of the tibio-fibula. The smallest muscle of the leg is the **flexor tarsi anterior.** Its origin is on the anterior part of the distal half of the tibio-fibula and its insertion is on the proximal end of the astragalus.

DIGESTIVE SYSTEM—**The Buccal Cavity**—Open the mouth as wide as possible. Note the **maxillary teeth** on the upper jaw, two small patches of teeth in the middle line, the **vomerine teeth.** Look for two small holes lateral to and slightly in front of the vomerine teeth, the **posterior nares.** Is there any connection of the nostrils and the posterior nares? In the posterior part of the mouth two larger holes are found one on either side, the **eustachian tubes.** What relation do these tubes have to the tympanic cavity? Demonstrate with a bristle. How do the eye balls effect the shape of the roof of the mouth? Are there any teeth on the lower floor of the mouth?

What is the shape and the attachment of the **tongue?** Locate the **glottis** or the opening into the **larynx.**

The Abdominal Viscera—Lay the frog on its back and open the body cavity. On the mid-ventral line is found the **heart** inclosed in the **pericardium.** Behind the heart find the **liver.** What is its color? What is its size as compared with the other organs in sight? Note its shape. Dorsal to the liver and often hidden by it are the **lung sacs.** Demonstrate the connection of the lung with the larynx. Behind the **large intestine** note the convoluted tube, the **small intestine.** Find the **bladder,** a thin walled, bilobed sac in the posterior end of the body cavity. In the female two large bodies consisting of a mass of eggs are the **ovaries.** Trace the **oviducts** from these. In the male two yellow bodies fastened to the dorsal wall, the **testes,** will be found. Examine in detail the **alimentary canal.** The **duodenum** opens from the **stomach** and continues into the small intestine which opens into the large intestine. Notice the **pyloric constriction** between the stomach and the duodenum. Notice the manner in which the small intestine opens into the large intestine. Follow the large intestine to the **cloaca.** Note the openings into the cloaca: the **renal,** the **genital ducts,** and the **bladder.** Between the left and the right lobes of the liver, find the **gall bladder;** from this trace the **gall duct** to its opening into the duodenum. This opening will be found about one half inch beyond the pylorus. Locate the **pancreas** in a loop between the stomach and the duodenum. The ducts from the pancreas open into the bile duct on their way through the pancreas. In the dorsal body wall close to the middle line will be found two flat, oval bodies, the **kidneys.** Note a white tube leading from each kidney to the cloaca, the **ureter.** Near their opening into the cloaca find two pouch like sacs, the **vesicula seminalis,** on each ureter in the male. Note small red patches on the ventral surface of the kidney, the **adrenal bodies.** The **fat bodies** are seen as two bright yellow tufts fastened to the dorsal wall and appear on the surface just behind the liver. In the mesentery near the commencement of the large intestine find a dark red body, the **spleen.** Make

a sketch of the alimentary canal with all of its accessory organs.

THE CIRCULATORY SYSTEM—Pith a frog. Lay him on his back and open the ventral wall to expose the heart just under the sternum. Study the beat of the heart. Do all parts of the heart beat at the same time? Describe the heart beat. Note the four divisions of the heart: the anterior part, the **auricles**; the **ventricle**; the **truncus arteriosus.** How many auricles? What is the relation of the ventricle to the auricles? The truncus arteriosus arises from the right anterior border of the ventricle. Trace this across the auricles. Dorsal to the heart find a thin walled sac, the **sinus venosus.** How many vessels open into it? These are called **venae cavae.** Note the **pericardium.** What is its relation to the heart? To what is it fastened? What does it contain? Dissect the veins first on account of their being filled with blood; this gives them a dark color. Dissect from the ventral surface being careful not to injure the veins. Clean and pin them out carefully as you go along.

Veins Opening Into the Sinus Venosus—Into the right side opens the **right anterior vena cava.** This carries the blood from what region? It is formed by three veins: the **external jugular,** the **innominate,** and the **subclavian.** The first receives blood from the tongue through the **lingual vein** and from the lower jaw through the **mandibular vein.** The second gets blood from the interior of the skull by the **internal jugular** and from the arm by the **subscapular vein.** The third gets blood from the fore leg by the **brachial vein,** and from the skin and back by the **musculo-cutaneous vein.** Compare the left anterior vena cava with the right.

The **posterior vena cava** may be traced from between the kidneys forward and dorsally to the liver, and finally to its opening into the posterior end of the sinus. It receives blood from the **hepatic veins.** How many are there? Trace the **renal veins.** Into what do they empty? Trace also the **ovarian,** and the **spermatic veins.** Locate the **pulmonary vein.** Note that it is formed by two veins, one from each lung, and that it empties directly into the left auricle.

Make a diagram representing the venous system as far as studied.

What is meant by a portal system? It will be noted that the frog has two portal systems: the **renal** and the **hepatic**. Trace back the anterior abdominal vein to the posterior part of the body and find that it receives blood from the **femoral veins**. It will be found that the femoral vein branches, one branch going to the kidney; this is the **renal portal vein**. The **hepatic portal system** is formed partly by the anterior abdominal vein, and partly by veins returning blood from the alimentary canal. Look for the **hepatic portal vein**. Near the point where the branches of the anterior abdominal veins go off to the liver, look for the **gastric vein**, the **intestinal veins**, and the **splenic vein**. Make a diagram of the portal system.

Arteries—Distend the oesophagus with a roll of paper or with a pencil. Clear off the arteries as in the case of the veins. Note the division of the **truncus arteriosus** into two branches, each of which subdivides into three arches: the **carotid arch**, the **systemic arch**, and the **pulmo-cutaneous arch**. The most anterior of the three arches is the carotid arch. It gives off a branch to the tongue, the **lingual artery**. Find the **carotid gland** on this branch. Trace the carotid artery around the oesophagus to its dorsal surface and thence to the skull where it divides into two branches, the **external** and the **internal carotid arteries**. The middle of the three arches is the systemic arch. Trace this around the oesophagus and note that it joins with its fellow from the opposite side in the region of the kidneys to form the **dorsal aorta**. Note four branches given off before this union: the **lingual artery**, which supplies blood to the larynx, the **oesophageal**, the **occipito-vertebral**, and the **subclavian artery**. Follow it back of the union to the dorsal aorta and find four branches: the **coeliaco-mesenteric**. It supplies with blood the **urogenital arteries**, the **lumbar arteries**, **hemorrhoidal artery**. Note the division of the aorta into the great arteries, the **iliac arteries**. These supply blood to what? The most posterior of the three arches is the **pulmo-cutaneous arch**. It divides at about the level of the carotid

gland into two branches, the **cutaneous artery,** and the **pulmonary artery.** To what do they supply blood? Make a diagram of the arterial system.

Heart—Cut off the blood vessels some distance from the heart. Insert bristles of different color into the carotid arch, the aortic arch, and the pulmonary arch. Pin the heart down dorsal side up. Dissect under water, cutting through the ventricle and other parts of the heart to expose their cavity. Study the **ventricle.** What is the thickness and texture of its walls? Compare with the **auricles** and the **truncus arteriosus.** Is the ventricle divided? Look for the **auriculo-ventricular aperture** on the right of the specimen. Are there **valves** here? How many? Name them. Notice their connection with the ventricles. Notice the **inter-auricular septum.** What is its structure, direction, and position with reference to the truncus arteriosus and the auriculo-ventricular aperture? Locate the opening of the sinus venosus, in the right auricle, the **sinu-auricular aperture.** Find the opening of the pulmonary veins, close to the septum, near the top of the left auricle. What relation does the truncus arteriosus have with the ventricle? Notice the **longitudinal valve** in the truncus. Notice the relation of the carotid, the aortic, and the pulmonary arches of the truncus. Make a diagram of the heart, and its connections. On a live frog notice the **posterior lymph hearts** on either side of the urostyle. Study the meaning of the lymphatic system, what it consists of, and what relation it has to the circulatory system. Make a mount of frog's blood in normal salt solution. Note the two kinds of corpuscles. How do they compare in number? What is their shape? Run some acetic acid under the cover glass. What is the effect? Make a mount of human blood as above; compare the corpuscles in every respect with those of the frog. Pith a frog and prepare the web of his foot for the microscope stage. Study the circulation of the blood. Can you distinguish arteries, capillaries, and veins? Study carefully with the high power, if you have to use the mesentery, the corpuscles and their movements. Are they all in closed vessels? What exceptions do you find? Make a drawing representing the corpuscles of the frog and those of man.

THE NERVOUS SYSTEM—Cut away the muscles on both sides of the spinal column. Cut off the dorsal portion of the skull and the vertebrae, being careful not to destroy the contents of the cavities exposed. Notice that the nervous system consists of two parts: the **central** and the **peripheral** portions. The central portion consists of the **brain** and the **spinal cord.** Examine carefully the dorsal surface of the brain. Note the **olfactory lobes,** the most anterior portion; **cerebral hemispheres,** immediately posterior to the olfactory lobes; the **thalamencephalon,** posterior to the cerebrum and between its diverging ends; the **optic lobes,** two oval bodies posterior to the former; note the pigment in the **pia mater** over the optic lobes; the **cerebellum,** a narrow strip or band posterior to the optic lobes; the **oblongata,** immediately posterior to the cerebellum and continuous with the spinal cord. Locate the **choroid plexus,** a thick membrane covering the thalamencephalon. Locate the **pineal body.** The **optic thalmi** are the thickened sides of the thalamencephalon. Slice off the top of the brain without removing it from the skull, thereby exposing several cavities, the **ventricles.** The most anterior and lateral cavities are the **lateral ventricles.** What is their extent? The cavity in the thalamencephalon is the **third ventricle.** Note its connection with the lateral ventricles through the **foramina** of **Monro.** Locate the **infundibulum** and the pineal body. The **aqueduct** of **Sylvius** leads from the cavity known as the third ventricle to the **fourth ventricle.** Notice the cavity in the optic lobes. Cut the medulla at the level of the posterior part of the skull and carefully remove the brain, keeping in mind that there are a number of important things on the ventral surface that may be easily destroyed. Find two large nerves that appear to cross, the **optic chiasma.** Notice a depression just posterior to the optic chiasma, which causes a swelling on each side, the **tuber cinereum.** If the **pituitary body** has been left in the skull in taking out the brain, the torn end of the infundibulum will be seen in connection with the posterior part of the tuber cinereum. Find the **crura cerebri** at the base of the optic lobes. Notice a fissure continuous with the ventral fissure of the spinal cord, the **ventral fissure** of the **brain.** Is the spinal cord uniform

in size? Notice several pairs of nerves coming off from the spinal cord. How many are there? What makes up each pair of spinal nerves? The spinal nerves may be seen better by cleaning the ventral cavity. They will appear as white cords extending to different parts of the body. Work them out carefully and note that there are ten of them. Work out the spinal column and locate the **spinal ganglia.** Upon which root do you find them? Locate the **sympathetic nervous system.** Is there any connection with the spinal nerves? Note, locate, and name the ten pairs of **cranial nerves.** Study prepared slides of nerve tissue, spinal cord, and isolated nerve cells for the microscopic structure of the nervous system. Distinguish between **medullated** and **nonmedullated** nerve fibers. Note the **axis cylinder, nodes,** and **internodes.** Pick out several cells in the slide and compare them in shape. In the spinal cord note the position of the **gray** and the **white matter.** What constitutes each? Study a section of the spinal ganglion. Of what does it consist? What membranes cover the central nervous system? Make a drawing of the dorsal and one of the ventral surfaces of the brain.

THE EYE—Note the following structures before making any dissections. The **shape,** the **sclerotic coat,** the **cornea,** the **iris,** the **pupil,** the **optic nerve.** With a sharp knife divide the eye ball into an anterior and posterior half. Note the **lens** in the anterior portion. Locate the **anterior chamber.** What does it contain? The **vitreous humor** fills the **posterior** chamber. Describe the vitreous humor. Locate the **choroid coat** as a lining for the **sclerotic coat.** What is its color? Note a transparent membrane lining the eye ball, the **retina.** At what point is it attached to the eye ball? Dissect an eye of a sheep or of an ox and compare in every respect with that of the frog as above. Make a diagram of the antero-posterior section of the eye and name all of the parts. Study prepared slides of the anterior and the posterior quarters of the eye. Work out the meaning of all the parts shown, especially the **ciliary muscles,** the **iris,** the **cornea,** the **coats** of the eye, the **optic nerve.** Note carefully their structure.

THE EAR—Study a series of sections of the frog's head through the ears, made by decalcifying, embedding

in paraffin, and cutting in a microtome. Stain "in toto" in borax or para carmine. Note the following: the **periotic capsule**, the **vestibule**, the **ductus endolymphaticus**, the **semicircular canals**, the **auditory nerve**, the **eustachian tubes**, the **tympanic membrane**, the **columella**.

THE REPRODUCTIVE SYSTEM—In a male specimen locate the **testes** as a pair of yellow, oval bodies, on the ventral surface of the kidneys. The **vasa efferentia** are several tubes leading from the testes to the kidneys. They carry the sperm cells into the kidneys from which they pass through the ureters which act as **vas deferens**. They finally open into the cloaca. Locate the **vesicula seminalis** as a large pouch on the vas deferens before they open into the cloaca. Note the following openings into the cloaca: the large intestine, the ureters, and the **bladder**. What is the nature of the bladder? Are there any openings out of it? Compare the female frog with the above. Locate the **ovaries**. Trace out the **oviducts**. Does the female frog have ureters as well as oviducts? Compare with the male. Note the openings into the cloaca: the bladder, the oviducts, the ureters. How does the number of openings compare with those in the male?

REPTILIA

The Turtle.

NOTE—The work on the turtle should be one of continuous comparison with the lower forms, especially with the frog.

EXTERNAL STRUCTURES—The shell of the turtle consists of a dorsal part, the **carapace**, and a ventral portion, the **plastron**. These are united at the side by the **bridges**. The carapace is made up of a definite number of central plates surrounded by a regular border of smaller ones. What is the number of each kind? How many plates in the plastron? Is it divided into distinct parts? Is it movable? What is the purpose of the shell? Can the head, tail, and legs be entirely drawn into the shell? Make a sketch of the ventral surface of the animal. Note the general shape of the head. Find the **nostrils**. Into what do they open? Note the size, shape, and position

of the eyes. Do they have eyelids? Is the iris colored? Is there a nictitating membrane? Do you find indications of ears on the outside of the head? Open the mouth and notice the beak. Do you find any teeth? Find the opening into the trachea and the posterior part of the floor of the mouth. Behind this find the opening into the oesophagus. Notice how the head and the neck can be withdrawn into the shell and become encased in folds of skin surrounding the neck. How does the length of the neck compare with that of the animals already studied? Note the cavities in the sides of the body into which the legs and the tail may be drawn. Do you find scales on the legs, neck, or tail? Find well developed claws on each digit. How many are there on each foot? Are they web-footed? Cut through the bridges with a bone forceps. Cut the plastron loose from the skin and other attachments. After removing the plastron notice the arrangement of the muscles attached to its under side. Separate them carefully and observe that they are arranged in pairs and determine the action of each pair as nearly as possible. Dissect them away so as not to disturb the underlying structures. Over the ventral part of the body the peritoneum will be found. Observe that the pectoral girdle seems to be separate along the mid-ventral line. Dissect away the muscles covering them. Then putting the thumbs under them and twisting the fore legs at the same time, they may be turned forward out of the way without injuring them. Back of the posterior edge of the pectoral arch a little to the right of the medial line find the heart, inclosed in a tough membrane, the pericardium. Open this and observe the large ventricular part of the heart, anterior to which is a pair of distinctly separate auricles. From the antero-ventral part of the ventricle observe the arteries passing between the auricles. Notice that what appears to be the main trunk given off from the ventricle is in reality composed of a number of distinct arteries bound together. By careful dissection demonstrate this point. Is there any indication of a conus arteriosus? Dorsal to the auricles is the sinus venosus. Remove the heart by severing the arteries about one eighth of an inch from the heart, and the veins immediately back of the sinus.

Preserve the location of the arteries and veins by putting bristles in them. How many arteries do you find? Cut off the end of the ventricle of the heart. Is there evidence of two chambers? Open the sinus and note the manner in which it opens into the auricles. Is there an opening from the sinus into each auricle? Are there valves there? Put bristles into the stumps of the arteries leading into the heart, and then dissect along them until you find where they lead. Open the ventricle and see if you can find any evidences of a partition there. Is it complete? Are there any valves between the auricles and the ventricles? Sum up the differences between the heart of the turtle and that of the frog. Are there any evidences of a **diaphragm** in the turtle? Beneath and to the side of the heart find the large **liver.** With bone forceps remove a part of the carapace until the viscera is more accessible. How many lobes has the liver? On which side is the gall bladder? How does the liver compare in shape and in position with the other forms that you have studied? How do you account for any differences? Begin at the edges of the liver and carefully pick it away, noticing to what it is fastened, and also the large **hepatic veins,** one from each lobe of the liver leading into the sinus. Remove the skin from the front part of the neck and find the **trachea.** Down which side of the neck does it go? Working from the side and being careful not to cut veins and arteries, trace it down a short distance. Does it branch? Note the manner in which it enters the lungs and the very peculiar structure of the lung. Trace the arteries leading from the heart. The one lying on the left is the **pulmonary artery.** The one next to this is the **right aorta,** and the one farthest to the right is the **left aorta.** The two aortae cross one another a short distance from the heart. The right aorta, close to the heart, gives off the **innominate artery,** which almost immediately gives off the right and the left **subclavians,** and then divides into the **carotids.** These latter pass into the skull through a foramen. Trace all these points out. Trace the right, and the left aorta, noticing that they pass backward over the right and left **bronchi** respectively and communicate with one another. From this point they become the **dorsal**

aorta, which, after giving off branches to the kidneys and the reproductive organs, branches into the right and left **common iliacs**. Before joining the right aorta the left gives off branches to the stomach, the pancreas, and the mesentery. The pulmonary artery divides near the ventricle into a right and a left branch. Trace these branches to the lungs. Notice that they run along by the side of the **pulmonary veins**, which open into the left auricle. If the specimen is a female a large **ovary** with eggs in various stages of development will be found immediately dorsal and posterior to the liver. Are there any indications of two ovaries? Can you find a way by which the eggs might escape from the body? About how many eggs are there? On each side of the ovary notice curiously folded bodies. These are the fimbriated ends of the **oviducts**. Trace them backward. Where do they open? How do the eggs get into them? How are they fastened to the body wall? Have they any connection with each other? Slit open the oviduct to near its posterior end and note the character of its mucosa. The **oesophagus** lies back of the trachea and is inclined somewhat to the left of the median line. How does it compare in length with that in the frog? Beginning near the mouth, slit open the alimentary canal, in situ, until you are convinced by the character of the mucous membrane that you have passed through the oesophagus and the stomach into the small intestine. Compare the mucosa so far with that in the two fishes and the frogs you have examined. Which is the better way to determine the extent of the stomach, the external form or the internal structure? What is the shape of the stomach? How does it compare with the dog-fish? The perch? The frog? In which of these forms is the pyloric valve most highly developed? Where would you look for the **pancreas** in any vertebrate? Carefully dissect it away from the intestine to find the opening of its duct. How are the intestines held in place? Trace back the small intestine, unraveling and slitting it open, until you pass into the large intestine. Could you tell by the character of the mucosa the limits of the small intestine? Trace back the large intestine by slitting it open until you come to the **cloaca**. Now open the cloaca along one side.

Find the opening from it into the large intestine. Find the opening into the **urinary bladder** ventral to this. In a female specimen the openings into the **oviducts** will be found in the top of eminences on each side. In male specimens slits in the same relative position mark the openings of the **vas deferens**. Put bristles into them and trace them back to the **testes** which lie a short distance in front of the pelvis. Attached to each of the testes is a dark colored mass, the **epididymis**. Attached to the inner ventral side of the cloaca is to be found the external generative organs of the male. Along its dorsal border is a deep groove, the **urethral groove**. Make a diagrammatic sketch of the **digestive**, the **urinary**, and the **reproductive** systems, showing the general form and relations. Near the junction of the small and the large intestine find the small roundish **spleen** suspended in the mesentery. Underneath the posterior end of the lungs on each side of the median line find the lobulated **kidneys**. Trace the **ureters** leading from their ventral surface. Do they lead into the bladder?

Pull out the head and notice the large muscles attached to it. Find their origins and insertions. Cut them from their attachments to the head. Note the manner in which the neck is bent if the animal was killed with the head retracted. How would the muscles act in order to protrude or retract it? Break the spinal column as far back as it is free. Cut all attachments and remove the head. Posterior to the angles of the mouth you will find the **tympanic membranes**. How do they compare with those of the frog? Remove the skin over them. Notice the white cartilaginous ring inclosing a round opening over which is stretched a cartilage-like membrane which seems to be more dense in the middle and membranous at the edges where it attaches to the white ring. Cut around the inside of the ring so as to free the tympanum. Pull up one edge of it and notice a slender column leading from it back into the ear cavity. The column and its outer expanded tympanic part are together called the **columella**. At the lower edge of the cavity will be found the very narrow **eustachian tube** leading to the back part of the side mouth cavity. Demonstrate this by working both from the mouth and the ear side. Follow carefully the columella,

breaking through the floor of the bone cavity of the middle ear. The inner end of the columella expands into a small disk, which fills the **foramen ovale**, which leads into the vestibule of the inner ear. Enlarge this opening very carefully and you will find the **semicircular canals.** Dissect out the eye, noting the following points: the **nictitating membrane**, the **lachrymal gland** ventral to the posterior angle of the eye in the orbit (what is its position in man?), the colored **iris**, the transparent **cornea**, which is surrounded by a peculiar cartilage-like differentiation of the **sclerotica.** Open the cornea carefully and observe the **aqueous humor** and how the iris is spread out. Take out the lens. How does it compare with that in the fish and in the frog? Back of the lens find: the **vitreous humor**, the **retina**, the **choroid coat**, and the entrance of the **optic nerve.** What separates the two eye orbits? Open the **olfactory cavities.** Are they lined with any sort of epithelium? How do they compare with that in the dog-fish and in the teleost?

Dissect out the brain very carefully, beginning with the already exposed ends of the olfactory nerves. Note on the dorsal aspect the **olfactory lobes**, the comparatively large **cerebral hemispheres**, the **pineal gland**, or epiphysis, the **corpora bigemina** (optic lobes), the **cerebellum**, the **medulla oblongata**, and the **fourth ventricle.** On its ventral aspect note the **olfactory lobes**, the **optic chiasma**, the **optic nerves**, the **optic tracts**, the **pituitary body**, the **infudibulum**, the **thalamencephalon**, the **crura cerebri**, and the **anterior pyramids** of the medulla oblongata. Make drawings of the dorsal and of the ventral parts of the brain to show the preceding points.

Dissect out a portion of the **spinal cord.** How does it compare with the other forms? How many neck vertebrae are there? Dissect out and clean all of the neck vertebrae noting particularly the manner of their articulations. Make a note of the different ways they articulate. Dissect out some of the caudal vertebrae and note their manner of articulation. Dissect out the pectoral girdle. Note the **glenoid fossa** at its outer extremity for articulation with the head of the humerus. Articulating with this latter are the **radius** and the **ulna.** Are they separate bones? How

do they compare with those in the frog? Dissect the pelvic girdle. Find the **femur**. Are the **fibula** and the **tibia** distinct? Find the **astragalus** and the **os calcis**.

AVES.

English Sparrow (Passer domesticus.)

EXTERNAL FEATURES—Take some time to note all the ways that come to you readily in which the bird differs from other forms studied. This should be a test of your powers of observation and comparison, and should be done before your attention is called to the differences and the likenesses. Note the **beak**, composed of the upper and lower **mandibles**, at the front part of the head. Is there any resemblance to that of the turtle? Find the **nostrils**. How is their external opening protected? Do they open into the mouth? In front of the eyes at the base of the beak find the **rectal bristles**. Note the position of the **eyes**. Can a bird see an object with both eyes at once? Demonstrate the **nictitating membrane** by working with a tenaculum in the anterior corner of the eye.

Associate the following names, much used in the description of birds, with the appropriate parts of the body. The front part of the head is the **forehead**, the top, the **crown**, the back part, the **occiput**, the back part of the neck, the **nape**, the front part, the **throat**. In the male the throat is black. Between the corner of the eye and the corner of the mouth is the **lore**. At the base of the lower mandible is the **chin**. Find the **ear**. Are the feathers covering it different from the others? The dorsal portion of the bird is the **back**. The narrow portion in front of the tail is the **rump**. The large, stiff tail feathers are the **rectrices**. Overlapping them dorsal are the upper **tail coverts**, and ventrally, the under **tail coverts**. The posterior ventral part of the body is the **belly**, and the anterior, the **breast**. Stretch out a wing. How many general divisions can you feel? The long feathers on the most distal portion are the **primaries**. On the middle portion are the **secondaries**. The short feathers overlapping the primaries and the secondaries are the primary and secondary wing **coverts**, upper and lower. At the angle of the outer joint is a little bunch of feathers on the **pollex** or

thumb. On the under part of the wing near the junction with the body are the soft **axillar** feathers. Work the wing back and forth and note the way in which the feathers overlap the large surface of the expanded wing and its compactness when folded. From the inside the toes are numbered as first, second, third, and fourth. The first opposing the other three. How many joints are there in each one? A sparrow when standing rests on its toes. Its heel is at the joint between the scaly and the feathered portions. The scaly part extends from the toes up to the tarsus. The next section is the tibia and corresponds to the leg in the higher forms, while the proximal section corresponds to the thigh. Does the scale-covered foot suggest a close relationship to such reptiles as the snake? Does the beak suggest the beak of the turtle? Look up the meaning of the word **sauropsida.** Are all parts of the foot covered with scales? Extend the limb at the heel joint and notice the position the toes take. Now flex the same joint and note the position they take. Could the bird fly from the place upon which it was perched when this joint was flexed? How does it sleep on its perch without falling off? Make a drawing of the side view of the bird naming all the parts indicated.

Examine one of the large feathers. The tubular portion inserted in the skin is the **quill.** The long, four-sided part distal to this is the **rachis.** On the other side of this is the **vein** or **web.** The vein is composed of filament-like barbs lying close together side by side. On the sides of the barbs are the barbules. Pull off a few barbs and soak them in 95 per cent alcohol, and then examine them under the low power. On the under side of the rachis note a narrow groove running lengthwise. With a pin follow it towards the proximal end until you come to a little hole leading into the quill. This is the **umbilicus.** In the end of the quill you will find an opening. What is the use of this?

Pluck a feather from the back or breast and note the peculiar difference between it and a large feather. Examine the rictal bristles under the low power. Examine a hair from your head. What is your conclusion as to the rictal bristles? Beneath the body feathers you will find downy filament-like feathers. Look at these under

the microscope. Are there any true hairs on the bird? Pluck a part of the body bare. Are all parts equally covered with feathers? Is there any regular arrangement of feathers to be deduced from the appearance of the plucked portion? Remove the upper tail coverts and note the large **oil gland.** What is its use? Slit open the skin from the chin to the cloacal opening, and carefully remove it. Down the front of the neck note the **trachea.** To the right of this find the **oesophagus.** Open the mouth and inflate the **crop,** a bag like expansion of the oesophagus by blowing into the oesophagus with a blow pipe. What is the use of the crop? Find the **jugular veins** and the **vagus nerve** in the neck. In the median line of the chest find the keel of the **sternum.** The sides of this serve as attachments for the **pectoralis major and minor muscles.** Are they much developed? Where are they inserted and what is their use? Sever them from their attachment at the keel and dissect them away. Scrape the flesh carefully from the large sternum and connected bones. Note a V-shaped bone, the **furculum** or wish bone, with the apex attached to the most ventral and interior part of the keel. This bone is composed of the two **clavicles** grown together at their sternal ends. The pair of bones attached to the antero-lateral angles of the body of the sternum at their proximal, and to the shoulder at their distal ends are the **coracoids.** Note the **ribs** attached to the sides of the sternum. Remove the sternum very carefully by disarticulating it from the furculum and the coracoids and by cutting the ribs on each side. Inflate the **lungs** and the air sacks in the body cavity by blowing into the trachea. How does the bird breath? Is there any residual air left in the lung between breaths? The temperature of the blood is higher in birds and the pulse more rapid than in other animal forms. From the structure of the breathing apparatus, would you expect this? Why? Trace the trachea to its division into bronchi. Near the division on the trachea note a swelling. This is the **syrinx,** or voice organ of birds. Notice the **heart and the pericardium.** Slit the latter open. Cut off the posterior end of the heart. Are the two **ventricles** separated? Which is the stronger? What is the shape of each? How many **auricles** are there?

Three veins enter into the right auricle, two **precavae** and one **postcava.** From the right ventricle arises the **pulmonary artery** which divides near the heart into two branches which lead directly to the lung. From the lungs the blood returns to the left auricle by two distinct **pulmonary veins.** One large artery, the **aorta,** comes off from the left ventricle. Inflate it through the left ventricle with the blow pipe and trace it out as far as possible. Demonstrate these points and also the **valves** between the auricles and the ventricles. Trace the digestive system from the mouth through the **oesophagus,** the **crop,** the **oesophagus,** the **proventriculus** or fore-stomach, the **muscular stomach** or gizzard, the **duodenum,** the **small intestine,** the **large intestine,** to the **cloaca.** The muscular stomach is the most noticeable part of the system. The expansion of the oesophagus leading into it is the proventriculus. The loop posterior to the gizzard, holding between its folds the long light-colored **pancreas,** is the duodenum. About an inch from the cloacal end of the intestine are found two little bud-like diverticula which mark the junction between the large and the small intestine. Emptying into the cloaca from the dorsal side, is a bag-like diverticulum, the **bursa fabricii** of unknown function. Cut the alimentary canal open longitudinally and note differences in the mucous membrane. Note the contents of the gizzard, the muscular structure of the mucosa, and the teeth. Above and overlapping the sides of the gizzard is the **liver.** How many lobes has it? Is there a gall bladder? Beneath the gizzard find the **spleen.** Sketch the digestive system diagrammatically. Dissect out the lungs. Note how they are related to the ribs. In the dorsal-posterior part of the body lie the lobulated, brownish **kidneys.** How many lobes have they? How are they related to the skeleton? Ventral to these in the male lie the two round, light-colored **testes** connected to the cloaca by the two **vas deferens.** In the female, in place of the testes lies the **ovary.** Leading back to the cloaca find on the left side a single **oviduct.** How does this compare with the turtle? The oviduct secretes the **white** of the egg, the **enveloping membrane,** and the **shell.** Trace the ureters from the kidneys to the cloaca. Make a diagram of the urinary and the

generative systems. Dissect away the lower jaw by breaking it down and cutting carefully. Note the ball and socket articulation and the openings into the **larynx** and the oesophagus. How does the tongue compare with the tongue in the other forms? Pass a bristle into the nostril and notice where it enters the mouth. Note the median fissure in the roof of the mouth and the little papillae fringing its edge. Which way do they slant? What is their use? Dissect out the ear noting the outer **ear drum** composed of an inpocketing of the skin. Back of this find the **middle ear.** Pass a bristle into the lower opening leading inward from this and find where it leads. By carefully breaking away the bone find the **inner ear** with its **semicircular canal.** Remove the upper mandible by bending it upward and breaking it off. Dissect out the eye, noting the four **recti,** and the two **oblique muscles** attached to its surface. Note the cartilaginous ring surrounding the cornea. Compare this with the turtle. Open the cornea and note in order the **aqueous humor, the iris, the crystaline lens, the vitreous humor, the retina, the choroid, and the sclerotica.** Make a sketch of the front and also one of the side view of the lens. Which side is more convex? Compare its shape with that of each form studied. Dissect out the brain by picking away the thin bone covering it. Note the small conical **olfactory lobes,** the **cerebral hemispheres,** the **pineal body,** the transversely **grooved cerebellum,** the round **optic lobes,** the **medulla,** the **infundibulum,** and the **optic chiasma.** Note especially the very large **cerebrum.** Compare this brain in every point here named with that of the forms studied before. Make a sketch of the upper and one of the under surface of the brain. Dissect away and scrape clean the wing and attached scapula. Make a drawing and name on it the following parts: **scapula, humerus, radius** and **ulna, carpal** bones, **carpo-metacarpus,** and **phalanges.** Dissect away and scrape clean the bones of the leg. Make a drawing of this and name the parts; **femur, tibia, fibula, tarso-metatarsus,** and the **phalanges.** How do the tibia and the fibula compare with those in the forms studied before? Dissect out some cervical **vertebrae and note** the method of articulation.

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