ZOOLOGY

A LABORATORY MANUAL

THEO. H. SCHEFFER.

THE LOOSE LEAF SYSTEM OF LABORATORY NOTES

FOR GUIDANCE IN THE DISSECTION AND ELEMENTARY STUDY OF ANIMAL TYPES

PREPARED BY

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PREFACE.

Instructors in biology very generally direct the laboratory work by means of written or printed guides placed in the hands of the student. These are sometimes hastily prepared for the occasion, and come from the mimeograph or typewriter abounding in misprints and various other errors.

If more carefully elaborated, the sheets furnished the student at various times are not uniform in size and will not fit in with any system of notes which he may be keeping.

The Loose Leaf guides are the results of several years' experience in directing zoölogical work in high school and college laboratories. The sheets outlining the work on each type of animal are separate, so that they may be incorporated with the student's drawings and notes on that particular type. The recorded information on the subject is thus collected together, not only simplifying at the time the work of studying the specimen, taking notes, and indexing the drawings, but making future reference to the records an easy matter. Then, too, the laboratory guides being thus bound in with the student's notes, do not become scattered or lost.

The instructor who has mastered his subject only fairly well might easily dispense with the use of a regular text book of zoölogy in connection with these guides. We should study things, not about things. Collateral reading assigned by the instructor and simple lectures or talks on various phases of the particular type of animal life in hand will, however, stimulate and encourage the student to investigation on his own account. The field, the brook, the woods have attractions more for the average student of zoölogy than any text book on the subject. But he must be so directed or trained that he will learn to see what he looks at and interpret correctly what he sees. A biological survey—classes in botany cooperating—of a small selected area is an excellent plan for developing nature students. As a matter of course, aquaria and terraria ought to form part of the equipment of every zoölogical laboratory.

The twenty-one types of animal life herein treated give the student a brief general survey of the field from Protozoan to Vertebrate. Similar treatment is accorded each type. It will be noted that the zoölogical position of each animal is given (Parker and Haswell's classification), that its habitat receives attention, and that there are hints on collecting the material for class study. Details of structure that are very obscure are either omitted, or, if essential, attention is called to them without any attempt at demonstration.

The author is constrained to believe that by reason of their special advantages and a simple and rational treatment of the subject in general, these Notes will commend themselves to teachers of zoölogy.

At this point I desire to thank Dr. C. E. McClung of Kansas University for his kindness in reviewing the manuscript and giving helpful suggestions.

THEO. H. SCHEFFER.

MANHATTAN, KANS.

PREFACE TO SECOND EDITION.

The favorable reception accorded these Notes by teachers of zoölogy has necessitated and warranted the printing of a second edition. This edition includes notes on three more types of animal life and is bound in a still more convenient form than was the first edition.

THEO. H. SCHEFFER.

MANHATTAN, KANS.
October, 1908.

LIST OF CONTENTS.

TO THE STUDENT.

It will be well to read the following suggestions concerning the use of these Guides and the make-up of your note book:

1. Remember that the drawings are only the means to an end—not the end itself—so do not hurry over the detailed study of the specimen before you in order to take up the drawing.

2. Make your first draft of all but the simplest sketches on scratch paper, so that the instructor may have a chance to offer suggestions, or to make corrections without making erasures in your note book.

3. Jot down on scratch paper the results of your observations as they occur to you. If you postpone writing up your notes until you have finished the type many details will have been forgotten or overlooked.

4. All notes and indexing should be in ink. Use hard pencil only (No. 4 to No. 6) for the drawings.

5. Number each separate sheet of drawing paper (plate) with a Roman numeral. Use the Arabic numerals for the several figures on a plate and the small letters of the alphabet for the detail of each figure. Mark off a border three-fourths of an inch wide on the perforated side and one-half inch wide on the other margins of the plate.

6. Do not write any words on the drawing sheet, but explain details of drawings on a sheet of note paper facing the plate.

7. In the make-up of your note book put first the printed sheets on the particular type, then your notes on the same, and finally the drawings. Do not write any notes on the side of the index sheet facing the plate. Printed notes on types not taken up in your course may be placed in the last part of the completed note book.

8. Thirty-five to fifty sheets of note paper and about the same number of sheets of drawing paper will be required for the course based on these printed Guides. Any local printer can usually cut and perforate the paper to fit these covers. Unruled note paper is preferable. A border, similar to that on the plates, will look well on the note paper.

AMŒBA.

Phylum I, PROTOZOA; class I, RHIZOPODA; order I, LOBOSA.

HABITAT.—The Amœba is a minute, jelly-like speck of protoplasm found on submerged weeds and leaves in pools and ditches, or in the slime at the bottom. Amœbæ also occur in damp places not under water.

Technical Note. With a pipette or the point of a scalpel, place on a slide a little of the water and slime from the surface of objects submerged in an aquarium jar containing Amœbæ. Cover, and study with a moderately high power of the microscope.

APPEARANCE.—The Amœba will appear as a small, semi-transparent object of irregular outline. As the individuals vary much in size, some will not be seen without a high power of the microscope, while others may almost fill up the field. The larger specimens will be best for study.

DETAILS.—You should be able to make out a clear outer layer of the protoplasmic body—**ectosarc**—and an inner, more granular mass, the **endosarc.** There is, however, no true cell wall. The granules of the endosarc are merely the products of certain life processes. Watch for movements of the animal—simple outpushings of the ectosarc into which granules of the endosarc slowly stream. These blunt projections from the central mass of the Amœba are called **pseudopods** or false feet. Within the endosarc note the **contractile vacuole,** a clear globule that slowly increases in size and then suddenly disappears only to reappear shortly and repeat the action. This performance is supposed to represent the excretion of waste matter which is gradually accumulated and then suddenly squeezed out into the surrounding water by the globule's collapsing near the periphery of the body. Try to time the so-called pulsations of these vacuoles.

If opportunity offers, study the Amœba's method of taking food and of excreting the indigestible portions of the same. Around each particle of food which you may see imbedded in the body protoplasm is a quantity of liquid filling what is called the **food vacuole.** This liquid is largely water with perhaps the addition of some ferment to assist in digestion.

Under favorable circumstances, the Amœba's method of reproduction by **fission** may sometimes be observed. Look for individuals that show a constriction dividing the body approximately into halves.

If the water in the aquarium containing the Amœba be allowed to evaporate slowly, encysted forms may also be found. In this condition the form of the Amœba is more globular, the pseudopods being withdrawn. Surrounding the protoplasm is a tough cell-wall or **cyst,** from which the former will emerge to resume active life again when conditions become favorable.

A denser portion of the inner protoplasm, called the **nucleus,** is present in all Amœbæ, but it cannot usually be distinguished without staining. Run a little methyl green, or blue, under the cover-glass and note results. If properly stained the nucleus will appear as a comparatively large mass of globular form imbedded in the endosarc.

Exercise 1. *Make drawings of the Amœba at intervals, showing the changes of shape. Also sketch any individuals feeding, undergoing fission, or encysting. Index all the parts shown in the exercise.*

Hints on Collecting.—The collector should carry several small pails, filling each with the various water plants found in ponds or quiet stretches of running streams. When the laboratory is reached pack the contents of each pail firmly in a glass dish about 3 to 4 inches deep and two or three times that in diameter. Add enough water to just cover the crushed mass of plants, and cover the dish with a glass plate. Label each dish with place where the material was obtained and the date of starting the culture, then set it in a warm and well lighted part of the laboratory.

PARAMŒCIUM (Slipper Animalcule).

Phylum I, PROTOZOA; class 5, INFUSORIA; order 1, CILIATA.

HABITAT.—Paramœcia are fairly common in stagnant pools, but become noticeably abundant only when putrefaction of contained organic matter sets in. They may be secured for laboratory purposes by partly filling a glass jar with hay or dead leaves, covering it with water and allowing it to stand in a warm room for several days. The appearance of a scum and the characteristic odor of decaying organic matter indicate the probable presence of Paramœcia. A jar of water that has contained clams soon swarms with Slipper Animalcules.

APPEARANCE.—An individual Paramœcium is just on the limit of unaided vision, appearing as a minute white speck moving about in a drop of water that is held against a dark background. When properly magnified it is seen to be slipper-shaped, the rounded end corresponding to the heel and the more pointed end to the toe. The typical specimens are more or less cylindrical.

Technical Note. With a pipette or camel's hair brush, place on a clean glass slide a drop of water containing a little of the scum from a jar prepared under conditions suggested above. Cover, and study first with a low power, later with a higher power of the microscope. If the animalcules dart about too rapidly to be readily followed, their movements can be retarded by adding a thin mixture of cherry gum and water. A few fibers of cotton enclosed between the cover and slide will serve both to hinder free movement and to prevent excessive cover-glass pressure.

MOVEMENTS.—Study their movements until you can answer the following questions: Which end of the body is directed forward in progression? Does the animal ever move backward? Is there any other motion? Does the shape of the body ever change?

STRUCTURE.—Note the following relations and parts:

a) An anterior and a posterior end, determined by the student in the observations suggested in the preceding paragraph.

b) The **buccal groove** running from the rounded end obliquely or spirally back for about two-thirds the length of the body.

c) The buccal groove ends in a funnel-shaped pocket, the **gullet,** leading into the interior protoplasm. This pocket is usually hard to distinguish.

d) A dorsal and a ventral surface, determined by the position of the buccal groove which occupies the latter.

e) An inner, semi-fluid and more granular portion of the body protoplasm, the **endosarc** or **medulla,** a firmer outer layer, the **ectosarc** or **cortex,** and a thin **cuticle** closely applied to the latter. This differentiation may not be readily observed unless the student has good typical specimens.

f) The **cilia,** hair-like projections of the ectosarc through minute perforations in the cuticle. Note that they are of about equal length and are distributed pretty evenly over the surface of the body and down the buccal groove. They function as organs of locomotion and also induce food-bearing currents of water.

g) The **contractile vacuoles,** two clear globular bodies near the respective ends of the body. Note their gradual increase in size and sudden collapse. How frequently does this action repeat itself. These vacuoles are organs of excretion, being accumulations of water and waste material resulting from metabolism which is periodically squeezed out of the body by the highly contractile surrounding protoplasm.

h) **Food vacuoles,** particles of ingested food enclosed in a globule of water which is thought to contain some digestive ferment. The food particles are swept down into the gullet by the action of the cilia, and, accumulating in pellets or balls, pass into the interior protoplasm. Portions of indigestible matter are forced out through the body wall at a temporary **anal spot** below the interior end of the gullet. The feeding process may sometimes be observed if a little powdered carmine be added to the drop of water containing the Paramœcia.

i) The **trichocysts.** These are little oval sacks lying side by side in the ectosarc giving it a striated or granular appearance. They contain coiled threads of protoplasm which can be projected to a greater length than the cilia. It will require close focusing and decreased light to make out either trichocyst threads or cilia. A weak solution of some irritating fluid, such as osmic or acetic acid, will cause the Paramœcium to discharge the trichocysts.

j) The **nuclei—macronucleus** and **micronucleus.** These are brought out by running a little stain, such as iodine or methyl green, under the cover-glass. Look for the macronucleus near the center of the organism. The micronucleus is much the smaller and is attached to the side of the macronucleus. It is very difficult to observe.

REPRODUCTION.—Look for specimens undergoing **fission.** They will be more or less constricted in the middle and finally will divide on this line of constriction into two halves, each a new Paramœcium individual. Specimens may also be observed in the act of **conjugation.** They will be temporarily attached one to the other, buccal groove to buccal groove. After an exchange of nuclear substances, they will separate and each individual will undergo fission.

Exercise I. *Draw one or more Paramœcia, showing all the details of structure you can make out. If opportunity offers, sketch individuals in the process of fission or of conjugation.*

HINTS ON COLLECTING.—As suggested in the paragraph on habitat, Paramœcia may be secured by making cultures of hay or dead leaves in jars of water. More typical specimens can usually be obtained, however, by the method of collecting and disposing water plants mentioned in the notes on the Amœba. Submerged sticks, leaves, and bits of bark from the edges of ponds or streams will also yield plenty of the animalcules when placed in jars in the laboratory. Remove snails, water beetles, or other large organisms from the jars, and keep the latter partially covered with panes of glass to prevent too rapid evaporation of the contained water.

VORTICELLA (Bell Animalcule).

Phylum I, PROTOZOA; class 5, INFUSORIA; order 1, CILIATA.

HABITAT.—Vorticella is found in pretty much the same situations as Amœba and Paramœcium—in ponds and pools of standing water. Colonies or groups of the organism, distinguishable with the naked eye, appear like tufts of whitish mold attached to sticks and leaves submerged in the water. Some genera are marine.

Technical Note. Mount on a glass slide a bit of vegetable substance from water containing Vorticellæ, and study first with a low power and later with a higher power of the microscope.

APPEARANCE.—Look for isolated organisms or groups of the same having a bell-shaped **body** and a long slender **stalk.** The stalks will be attached to some object and may be tangled up somewhat from your manipulation of the material in mounting it.

DETAILS.—Sudden contractions of the stalk, accompanied by changes in the shape of the body, occur frequently, especially if the slide be jarred by tapping it lightly. Study carefully the appearance of stalk and body in the normal and in the contracted position. Note the following:

a) A circlet of **cilia** around the distal end of the body. These hair-like threads of protoplasm are in constant motion except when the animal is contracted. The motion serves to maintain a food-bearing current of water; also if any individuals have been broken from their stalks they will be observed to swim about by means of the cilia. Look for some such stalkless specimens.

b) The **peristome,** a sort of flaring rim or flange just outside the circlet of cilia.

c) The **disc,** a convex, lid-like structure covering the mouth of the bell. Between the edge of the disc and the peristome on one side is the **mouth** or **vestibule** leading into a **gullet** running down into the inner protoplasm. Mouth and gullet are not easily made out.

d) A clear globule periodically increasing in size and then apparently collapsing. This is the **contractile vacuole,** an organ for the excretion of waste matter analogous to renal products in the higher animals. Time the pulsations of this vacuole.

e) The **nucleus,** a curved or crescent-shaped denser portion of the body, best distinguished by staining.

f) With a higher power of the microscope a differentiation of the body protoplasm into a firmer, more uniformly granular **ectosarc** and a more fluid **endosarc** is possible. A sort of **cuticula** invests the whole organism, giving it permanence of shape. The stalk is a continuation of the cuticula and ectosarc. Its central darker core—**axial fiber**—is the only part that is contractile.

g) Particles of food surrounded by **food vacuoles** in the endosarc. These food vacuoles contain water ingested with the food and perhaps also some ferment to assist in digestion.

REPRODUCTION.—Look for free-swimming stalkless specimens with a circle of cilia near the proximal end. The larger ones of these are the results of **fission,** the smaller of **budding,** two similar processes in reproduction. You may be able to find Vorticellæ undergoing one or the other of the processes.

Exercise 1. *Draw a group of Vorticellæ on a small scale. Make other drawings on a larger scale showing a single specimen in the extended position and also in the contracted position. Draw any specimens in the process of fission or of budding.*

HINTS ON COLLECTING.—Vorticella will usually appear in great numbers in jars or dishes prepared as for Paramœcium and Amœba. The organism is non-colonial, a characteristic which will serve to distinguish it from the branching, tree-like forms of related genera.

GRANTIA (A Marine Sponge).

Phylum II, PORIFERA; class 1, PORIFERA; order 2, HETEROCŒLA.

HABITAT.—Sponges are found in all seas, and at all depths from low tide mark to the deepest abysses yet dredged. The group is also represented in fresh-water streams and lakes by one family (Spongillidæ). Grantia is a non-colonial sponge common along the New England coast. It is attached to rocks, submerged piles, or other objects.

Technical Note. Specimens of Grantia for laboratory use can be preserved in alcohol or formaldehyde. Place one of the sponges in a watch glass partly filled with water and examine under a low power of the dissecting microscope.

EXTERNAL FEATURES.—It will be observed that this type of sponge is nearly cylindrical, though usually tapering somewhat toward the base—the end which was attached. The free end is crowned by a circlet of glistening **spicules** surrounding the **excurrent opening** or **osculum.** The entire surface of the sponge seems to be covered with a fuzzy growth, which is in reality a bristling mass of finer and shorter spicules arranged in tufts forming polygonal patterns, as will be seen under higher magnification. These spicules and others which are imbedded in the walls of the sponge form its skeleton or supporting frame-work, the real living substance being of a gelatinous nature.

Growing out from the side of some of the larger specimens, especially near the base, you may notice one or more **buds**—outpushings of the three layers of the body wall which will in time become separate individuals.

Exercise 1. *Draw a sponge natural size and one enlarged two or three times.*

Technical Note. With a sharp scalpel or a section razor split a sponge lengthwise into two halves. A dried specimen will be best for this purpose. Study the cut surface and note:

a) A central longitudinal passage, the **paragastric cavity,** extending from the osculum to near the base, but closed at the lower end.

b) A great many small round openings in the lining of the paragastric cavity. These are the **gastric ostia**—mouths of the **radial canals** which are outpocketings of the gastric cavity, like the fingers to a glove. Their outer ends are closed and are surmounted by the tufts of spicules referred to above. Similar canals show in longitudinal section on the cut surface of the thick walls of the sponge.

c) Running radially through the walls is also another set of passages, the **incurrent canals.** They are narrower than the radial canals and alternate with them, or rather lie in the spaces between them. They end blindly at their inner extremities—not reaching the paragastric cavity—but open by three or four **inhalant pores** at the outer end. The two sets of passages—incurrent canals and radial canals—running side by side, communicate at certain points by apertures, the **prosopyles.** It will not be practicable to demonstrate inhalant pores or prosopyles in this exercise. By means of **flagella** projecting from the cells lining the paragastric cavity and radial canals, a current of water is drawn in through the inhalant pores into the incurrent canals. From there the water passes through the prosopyles into the radial canals, through the gastric ostia into the paragastric cavity and out at the osculum. Food and oxygen are thus supplied to the cells. Of course, it will not be possible to distinguish the flagella in a dried specimen.

Exercise 2. Draw the inner surface of a longitudinal section on a scale of five.

Technical Note. Shave off very thin cross and tangential sections of a dried sponge by placing it between two pieces of elder pith. Also isolate some of the spicules by boiling portions of the sponge in a solution of caustic potash. Study the tangential sections and spicules with the compound microscope. Use the higher power of the dissecting 'scope for the cross-sections.

It will not be necessary to call attention again to the various parts that will show in the sections. The student should be able to recognize them from each point of view. In the tangential section the incurrent canals are the smaller four-sided or irregular passages that fill in the spaces between the larger and somewhat octagonal radial canals.

Three kinds of spicules should be distinguished—the long straight ones surrounding the osculum, the short straight ones, **oxeote spicules,** covering the outer surface, and the **triradiate spicules** imbedded in the walls. How does the peculiar form of the latter kind adapt them to the purpose they serve? Test the composition of the spicules by running a little dilute hydrochloric acid under the cover-glass.

Exercise 3. *Draw a complete cross-section, a small area of the tangential section and one or more spicules of each kind, all properly enlarged.*

Exercise 4. *If living specimens of Grantia are available for study in a dish of sea water, determine the direction of water currents by introducing a little ink.*

THE HYDRA.

Phylum III, Cœlenterata; class 1, Hydrozoa; order 1, Leptolinæ.

Habitat.—The fresh-water Hydra is very generally distributed throughout the country, but is likely to be absent in some particular locality or spot while abundant in others near by. It is found in ponds and sluggish streams, attached to weeds, sticks, or leaves. There are two common species, one brownish in color, the other green.

Appearance.—This little animal is not at all conspicuous. On the contrary, one must look carefully to distinguish it in a glass jar containing sticks or plant life from a pond. It is tubular in shape, about as thick as a pin, and from one-eighth to one-half an inch in length. One end will usually be attached to the sides of the aquarium or to the water plants, the other swings free and is surrounded by what appears to be a fringe of thread-like organs.

Technical Note. Specimens of Hydra may be obtained for class use by collecting, from three or four localities, water containing sticks, leaves, or plants. Place this in glass jars and stand the latter in a light place. The polyps will usually do well in such situations and may be kept indefinitely in the aquaria. Transfer specimens to a watch glass and study with a low power of the microscope or with a hand lens. If the polyp is attached to some small object it should be transferred without detaching from the latter.

Movements.—Were all the Hydras in the jar attached? Look for some swimming slowly about or crawling with a looping motion over the surface of the glass or plants. Evidently the attachment is only temporary, the animals being able to release their hold and seek new feeding grounds at will. Note the movements of contraction and extension in the attached specimens. At one moment the polyp may be long and thread-like, the next it may be all bunched up into a compact little mass. Do the filaments surrounding the free end partake of these movements of extension and contraction?

STRUCTURAL DETAILS.—Study the Hydras in the watch glass, taking note of the following details:

a) The **body,** long and cylindrical when extended, short and almost globular when contracted. The attached end is usually called the **foot.** Certain cells at this end secrete a sticky substance which enables the polyp to cling to objects.
b) Encircling the free end is a group of **tentacles.** Count them. Is the number the same in all your specimens?
c) Within the circlet of tentacles the body ends in a conical elevation, the **hypostome,** at the rounded apex of which is the **mouth.** You may not be able to make out this opening unless you have an opportunity to see the polyp feeding.
d) The mouth opens into an interior cavity called the **gastro-vascular space,** extending the length of the body but having no opening at the lower end. All food is taken in at the mouth and all indigestible matter thrust out at the same opening.
e) Look for **buds** growing out from the body at almost any point. If you find several on different specimens they will probably show various stages of development. After a time they are constricted off from the parent Hydra and form separate individuals. This is one method of reproduction, the asexual or vegetative.
f) Hydra has also a sexual method of reproduction. Search for ployps showing one or more enlargements on the body wall not far below the tentacles. These are the **testes** in which are developed a great many **sperm cells.** Nearer the foot may appear another enlargement, the **ovary.** In this is developed a single **egg cell.** The Hydra is, therefore, hermaphroditic, both male and female reproductive organs being present in the same individual.
g) Note the knotted appearance of the tentacles. This is due to the presence of numerous organs of attack and defense, the **cnidoblasts.**

Exercise 1. *Make at least two drawings of the Hydra on an enlarged scale showing the animal in an extended and in a contracted position respectively.*

Technical Note. Mount one of the polyps on a slide, supporting the cover glass in two places with small clippings of thick paper. Study with a higher power of the microscope.

By focusing sharply on the margin of the body or the tentacles you will be able to make out two layers in the wall, an outer **ectoderm** and an inner **endoderm.** Between these is a thin supporting layer, the **mesoglœa,** without cellular structure. In which layer is the coloring matter?

Examine now the knots on the tentacles—cnidoblasts—more carefully. Each contains a highly refractive stinging organ or **nematocyst,** the essential parts of which are a coiled hollow thread and a short spine-like trigger, the **cnidocil.** You may see some of the latter projecting beyond the general surface. If a small crustacean, as Daphnia or Cyclops, blunders against one of these triggers the coiled thread shoots out and paralyzes the intruder by the injection of a small quantity of poisonous fluid. The prey is then conveyed to the mouth by means of the tentacles.

Distended regions of the body or the tentacles probably contain particles of food which the endoderm cells lining the gastro-vascular space have not yet had time to deal with. Some of these cells secrete a digestive fluid, while others by means of flagella or pseudopods manipulate the food and cause it to circulate from one cell to another. Bear in mind that the hollow space in the tentacles is merely an outpocketing of the central body cavity. The same is true of the buds, which are thus supplied with food until separated from the parent polyp.

By removing the supports of the cover glass the weight of the latter will so compress the Hydra that certain details may be more clearly noted. Run a little weak acetic acid under the cover glass and then look for discharged threads of the nematocysts.

Exercise 2. *Draw polyps showing any details not included in exercise* 1, *particularly buds or sexual reproductive organs. If prepared slides of cross and horizontal sections of the Hydra are furnished you make drawings of these also.*

If time will permit, the student may undertake interesting experiments in mutilating some of the polyps and noting the gradual reproduction of the lost parts.

PENNARIA TIARELLA (A Hydroid).

Phylum III, Cœlenterata; class 1, Hydrozoa; order 1, Leptolinæ.

Habitat.—Pennaria is a marine zoöphyte (plant-like animal) occurring in shallow water along our coast. Colonies of it, looking like masses of delicate pink seaweed or moss, often cover the rocks over small areas.

Technical Note. Place a small portion of a colony, consisting of five or six polyps, in a watch glass full of water and examine with the simple microscope.

The Colony.—A colony of these organisms consists of a number of horizontal axes or stems, much like the creeping stolons of some plants, and vertical axes which give off lateral branches in alternate arrangement. At the ends of these short lateral branches the separate **polyps** or **hydranths** are borne. The vertical axes with all their branches constitute the **hydrocaulis,** the horizontal axes the **hydrorhiza.** Each part of the whole colony, except the hydranths, is covered by a tough horny sheath, the **perisarc.**

Note that the polyps are not all of the same size. How can you account for this? Some hydranths may be found which are mere buds, having not yet expanded. The specimen may also have short branches from which the hydranths have been accidentally broken off. Look for ringed constrictions on the stem in certain places. What purpose do they serve? In most places the perisarc is so transparent that the fleshy continuation of the hydranth down into the stem can easily be seen. This fleshy core of the stem is called the **cœnosarc.** It puts the various polyps of a colony into organic connection.

Exercise 1. *Make a drawing of the portion of a colony you have just examined, giving particular attention to the method of branching, position of the hydranths, and arrangement of the tentacles.*

Technical Note. With a pair of fine scissors snip off one of the hydranths, leaving a short piece of the stem attached, and mount it in water on a glass slide. Examine with a low power of the compound microscope.

THE HYDRANTH.—Note the flower-like form of an expanded hydranth. In the center is the **body,** shaped somewhat like a tenpin or Indian club. Encircling its base is a whorl of long slender **tentacles** and nearer the distal end are others of a different shape. Can you make out the number of each kind of tentacles? Is the number constant? Are the short tentacles in a single whorl?

In addition to the tentacles, certain large ovoid bodies may be seen to spring from just above the whorl of long tentacles in some of the hydranths. These are the **medusa-buds.** In some species of Pennaria they become detached and swim about; in other species they remain attached to the hydranth. In the latter case they are called **sporosacs.**

The knob-like distal end of the body is termed the **manubrium.** At its extremity is the **mouth,** an aperture capable of some dilation and contraction. It will probably not be seen in the preserved specimen. The mouth opens into the cavity of the manubrium and body, both of which are hollow. This hollow space is the common digestive and circulatory cavity of the animal, and is known as the **enteron** or **gastro-vascular space.** The cœnosarc being also hollow, its tubular cavity is continuous with the cavity of the hydranth and forms a part of the gastro-vascular space. Circulation from one hydranth to another is thus established.

It will be noted that the cœnosarc is in most places separated by an interval from the perisarc, but that processes of the former extend out toward the latter at irregular intervals.

Exercise 2. Draw a hydranth, giving attention to detail not shown clearly in the first exercise.

THE TENTACLES.—Under a higher power of the microscope it will be seen that a tentacle is made up of an axis of large **endoderm cells** surrounded by a layer of small **ectoderm cells.** Between these is the delicate non-cellular **mesoglœa,** corresponding to the **mesoderm in** sponges. The presence of this layer can not be demonstrated in this exercise.

The long tentacles are only slightly enlarged at the distal end, but the short ones are very distinctly capitate. Note the numerous clear, refractive bodies at the ends of both kinds of tentacles, and also down one side of the long tentacles. These are the **stinging capsules** or **nematocysts,** organs which serve for defense or for the capture of prey. Each consists of a cell containing a poisonous fluid and a coiled hollow thread which can be thrown out with some violence, numbing the animals upon which Pennaria preys.

Exercise 3. *Draw a long tentacle, a short tentacle, and a portion of a stem in the region where it branches.*

Exercise 4. *Draw a hydranth having an attached medusa-bud; some of the tentacles may be omitted.*

GONIONEMUS VERTENS (A hydroid medusa).

Phylum III, CŒLENTERATA; class I, HYDROZOA; order I, LEPTOLINÆ.

HABITAT.—This small jelly-fish may be found, along the New England coast, swimming about in tide pools or stretches of water in which eel-grass is growing. Its life history is not well understood, but it is probably a hydroid medusa budding off from plant-like masses of fixed hydroid polyps. Gonionemus is not, however, a medusa-bud from Pennaria. In turn it gives rise to egg- or sperm-cells which, after fusion, develop into a sort of larva called a **planula.** After swimming about for a time, the planula settles down, becomes attached, and by growth and subsequent branching forms a new colony of polyps.

Technical Note. Put a specimen of Gonionemus in a small glass dish full of water—a deep watch glass will do—and study with a hand lens or a dissecting microscope.

GENERAL APPEARANCE.—Note the transparent jelly-like substance of which the animal is composed. Not more than one per cent is solid matter, the rest being highly organized water. The body is flattened dome- or umbrella-shaped. The convex outer surface is generally referred to as the **ex-umbrella,** while the concave portion is termed the **sub-umbrella.**

STRUCTURAL DETAILS:

a) Depending from the center of the sub-umbrella, like the clapper to a bell, is the **manubrium.**
b) At the free end of this organ is the **mouth,** opening into a cavity which occupies the whole interior of the manubrium and from a dilation at its base sends off four tubes, the **radial canals,** to the margin of the umbrella.
c) Parallel with and close to the margin of the umbrella runs the **circular canal.** Into this the four radial canals open, the whole

forming the **gastro-vascular space,** a common digestive and circulatory cavity.

d) From the edge of the umbrella hangs a fringe of **tentacles.** Count the number in one of the quadrants intercepted by two of the radial canals. They are much longer and more thread-like in the living medusa and have the power to contract and stiffen when the animal is irritated.

e) Note the arrangement of the **nematocysts** on the tentacles. How does the grouping compare with that of the stinging thread cells in Pennaria?

f) The concave sub-umbrella is partly closed in by a perforated diaphragm, the **velum.** This muscular membrane is the principal organ of locomotion.

g) At the base of the tentacles are strongly pigmented round bodies, the **sense organs.** Their function is probably the perception of light.

h) The lobulated **reproductive elements** hang from the radial canals into the sub-umbrellar space. They are more or less prominent according to the conditions for breeding when the specimen was taken. The two sexes are separate, but there is no noticeable difference in the appearance of the elements. The egg- or sperm-cells are shed out into the water.

Locomotion.—The medusæ are free-swimming animals, moving with the convex surface directed forward by partly opening and closing the umbrella. This expansion and contraction of the umbrella is in turn secured by the action of the muscular velum. Sometimes, as the medusa swims, the umbrella becomes turned inside out.

Exercise 1. *Make one drawing of the medusa from the oral aspect and one from the side, each on a scale of two. Also draw on a larger scale a portion of the edge of the umbrella, including the bases of three or four tentacles.*

Exercise 2. *Mount the distal half of one of the more slender tentacles on a slide and study with the compound microscope. Draw.*

A PLANARIAN (Flat Worm).

Phylum IV, PLATYHELMINTHES; class 1, TURBELLARIA; order 2, TRICLADIDA.

HABITAT.—These small flat worms occur very generally in fresh-water ponds. They may be found on the mud of the bottom, on water plants, or on the under side of stones. Some genera are marine, certain species living as external parasites on the book gills of the King-crab.

APPEARANCE.—Fresh-water Planarians are very thin, flat little animals one-half an inch or less in length. They are comparatively broad, especially at one end. In color, shades of brown, reddish, or gray predominate. They move about sometimes with a steady gliding motion, at other times with more of an apparent muscular contraction.

Technical Note. Place specimens of Planaria in a watch glass, containing a little water, for study with a hand lens or the dissecting microscope. A good view of the ventral surface can be obtained by placing one of the animals in a drop or so of water on a slide and then turning the latter over. When smaller detail is to be studied mount a specimen and examine with higher power of the microscope. Clearer definition can sometimes be secured by using reflected instead of transmitted light from the mirror.

GENERAL STRUCTURE.—Is the symmetry of the animal bilateral or radial? Could you cut it by a plane into two similar halves? Note the movements before deciding which is the anterior and which the posterior end. Usually the former is the broader and more rounded. The surface on which the worm is creeping is, of course, the ventral; the other is the dorsal surface.

Near the anterior end, on the dorsal surface, are two dark-colored **eye-spots.** Search for the **mouth** in the middle of the ventral surface. It opens into a **pharynx** which is protrusible, forming, when thrust out, the **proboscis.** When drawn back it is enclosed in the **pharyngeal sheath.** If you place bits of the meat of a crushed snail on the slide or in the watch glass you may have a chance to see the proboscis extended to grasp the food.

The pharynx opens interiorly into a curious, much branched **intestine** divided into three main trunks. One of these runs forward in the median line, the other two extend backward nearer the right and left margins of the body. Trace them out in their coarser ramifications. The light colored Planarians will be best for this study. Those from the book gills of the King-crab are almost white. In their finer ramifications the three main branches of the intestine reach all parts of the body.

By focusing sharply on certain parts of a specimen under heavy cover-glass pressure other details can be at least faintly discerned. **Cilia** may be brought out along the margins. Of what use are the cilia? A light colored area beneath the eye-spots indicates the location of the main nerve ganglion or **brain.** From the brain light lines radiating forward represent **sensory nerves** and a faint streak down each side of the body to the posterior end locates the **longitudinal nerve cords.** The longitudinal nerves have many branches, **transverse nerves,** some of which anastomose, forming commissures.

The reproductive and excretory systems, though interesting, are too difficult of demonstration for this exercise. Planarians do not have a circulatory system or a fluid analogous to blood. Why are these not necessary? Respiration is carried on by the outer surface of the body.

Exercise 1. *Draw one or more Planarians on a scale of six to ten, showing all the detail you have been able to make out. The digestive and nervous systems should be shown on separate drawings.*

Interesting experiments in regeneration may be conducted by the student. Cut the animals into two or more pieces and keep them in watch glasses of clean pond water. Keep records, in drawing, of the original shape of the pieces and of the changes from day to day in the form of each piece.

A TAPEWORM (Tænia sp.).

Phylum IV, PLATYHELMINTHES; class 3, CESTODA; order 2, POLYZOA.

HABITAT.—This class of flat worms is entirely parasitic, living as an adult in the intestinal tract of various vertebrate animals. The cestodes have also an intermediate host in which they pass the larval state encysted in various tissues, as muscles, liver, brain, and peritoneum.

Technical Note. Tapeworms of the genus Tænia can be obtained for class study from the intestines of the dog or cat. Slit open the intestine, rinse with tepid water and remove the slender, ribbon-like worms a few inches in length which will be found attached by one end to the walls of the tract. If they are to be studied at once they may be kept alive for some time in a dish of blood-warm normal salt solution. If they are to be preserved use two per cent formalin or seventy per cent alcohol. For examination and study place in a shallow dish of water—the salt solution if the animal is alive.

STRUCTURAL FEATURES.—Note the following details, verifying all statements herein made:

a) The **body,** made up of a great many **proglottids** or false segments. As we shall see later, these are entirely different from the somites or real segments of the earthworm and the arthropods.

b) At the smaller end of the string of proglottids is a terminal knob, the **scolex.** This is the head of the animal. It is attached to the inner wall of the host's intestine by several **suckers** and also usually by two rows of chitinous **hooks.** Determine the number of these suckers and note presence or absence of the hooks. Where are the largest and where the smallest proglottids? The youngest? The oldest? Understand where and how the proglottids originate in development.

Exercise 1. *Count the number of proglottids and draw the animal on a scale enlarged sufficiently to show detail.*

Technical Note. Snip off the scolex, including a few of the indistinct proglottids that immediately follow it. Mount on a slide and examine first with a low power of the compound microscope. For the finer detail it will be necessary to use a higher power and to withdraw some of the water from under the cover-slip so as to compress the mount somewhat.

c) After examining again the hooks and suckers, look for some fine transparent tubes coiled about in the scolex. These are **excretory canals.** Other ramifications of the excretory tubes will be noted in the individual proglottids. The finer branches of the system end in the so-called **flame cells.** Some of these, each with its flickering, vibratile cilium, may be made out, in the living specimen, by focusing sharply on the more transparent portions of the scolex.

d) Observe the large number of minute, round **calcareous granules.**

Exercise 2. Draw the scolex, very much enlarged, showing any detail that can be clearly made out.

Technical Note. Mount stained specimens of proglottids in balsam or dilute glycerine and cover with a slip heavy enough to compress without crushing. If not convenient to stain, good results may often be obtained by first soaking the specimens a while in a solution of caustic potash and then in one of equal parts glycerine and water. The proglottids for this study should be selected from the body about one third way back from the scolex, as those nearer the posterior end are too much distended with eggs.

e) There is no digestive system, no body cavity, and no circulatory system in a tapeworm. The reproductive organs constitute the bulk of the organism. Along with certain **muscle fibers** they are imbedded in a spongy tissue, the **parenchyma.**

f) Running the entire length of the body, near each lateral margin, and continuous from proglottid to proglottid, is a **longitudinal nerve** and one or two main tubes of the excretory system referred to in the study of the scolex. These nerve cords and excretory tubes sometimes have **transverse commissures** or **transverse**

canals, respectively. Transverse connections of this sort, as well as longitudinal cords and canals themselves, are usually to difficult of demonstration for an exercise of this kind.

g) At one side of the proglottid note the **genital pore.** Extruding from this pore, or perhaps withdrawn into it, is the **cirrus.**

h) Leading back from the genital pore into the mass of the proglottid is a convoluted tube, the **vas deferens,** and a less tortuous canal, the **vagina.**

i) The vas deferens connects outwardly with the cirrus and by numerous interior branches with the scattered **testes.** The latter are small round bodies or groups of bodies occupying, at this stage, the bulk of the proglottid.

j) The vagina joins the genital pore and a point just below the **uterus.** The latter, when not distended with eggs, appears as a straight tube in the middle of the proglottid.

k) Posterior to the uterus are the two **ovaries,** large round or oval-shaped masses.

l) Close to the posterior border of the proglottid is an irregular mass of lobules forming the **yolk gland,** and between this and the end of the uterus another, smaller mass, the **shell gland.** The secretions or products of these glands, together with the **ova** from the ovaries, are discharged into the inner end of the vagina and from there pass by a duct into the uterus.

Development.—Each proglottid of a tapeworm possesses a full set of reproductive organs, both male and female, and is in reality, therfore, a hermaphroditic individual. Cross fertilization between two proglottids of the same or different tapeworms may, however, occur. When ripe, so to speak, the proglottids break off from the posterior end of the string and pass from the host. In time the eggs from these proglottids may, by the vicissitudes of chance, find their way into the food or drinking water of other animals and be taken into the alimentary tract of the latter. In the intestine of this **intermediate host** the eggs hatch. The larvæ now migrate to certain tissues, mentioned before, where they become encysted. No further development is ever attained unless the tissues of this animal are eaten by another, the **final host.** The larva, called the **cystocercus,** is a small bladder-shaped organism with a scolex very similar to that of the adult tapeworm, but inverted into the sack-like portion of the body. When the larva reaches the intestine of the final host this scolex is turned right side out and attaches itself to the wall where it begins to develop the proglottids of the adult individual.

Exercise 3. Draw the proglottid you have just studied with all the detail you have distinguished.

A ROTIFER (Wheel Animalcule).

Phylum VI, TROCHELMINTHES; class 1, ROTIFERA; order 2, BDELLOIDA, or order 3, PLOIMA.

HABITAT.—Rotifers are found in large or small bodies of water, both salt and fresh, in almost any quarter of the globe. They are common in ponds and stagnant pools and about the accumulated sediment and other inert material in aquaria.

Technical Note. On account of their minute size rotifers must be studied with the aid of the compound microscope, the lower powers being usually sufficient for the purpose. Mount bits of vegetation and scum from aquaria or stagnant pools and look for small organisms having a sort of forked tail and a broad anterior region. The latter ends in a disc furnished with what is apparently a rapidly rotating circlet of cilia. If possible, select for study specimens that are attached by the tip of the tail, rather than those that are swimming about.

APPEARANCE.—The wheel animalcules are minute, active creatures almost microscopic in size. They are somewhat larger than the Protozoa, however, partially transparent, and when swimming about do not exhibit the jerky movements of the cyclops. They are probably often mistaken for Protozoa, but the resemblance is only superficial. In spite of their minute size, they are many-celled animals having well developed systems of internal organs.

MOVEMENTS.—Watch the animal's movements from place to place. Does it creep with a sort of looping motion or swim freely? Species of the order Ploima move in the latter manner only; rotifers of the order Bdelloida adopt both methods of locomotion. Can you make out the organs of locomotion used in swimming? Which end is directed forward in progression? Is this always the case? Determine whether there is a distinction of dorsal and ventral surfaces. Can any portion of the body be shortened up—telescoped—or retracted?

STRUCTURE.—Identify and examine the following parts:

a) The broad anterior region called the **trunk,** terminating posteriorly in a slender, two-forked **tail.**

b) In some genera the trunk is enclosed in a transparent outer sheath of cuticle, the **lorica.** Does the specimen you are studying have such a glassy shield?

c) The anterior end of the trunk forms the **trochal disc,** with its **cilia** usually arranged in one or two circular rows. It is the vibratory movement of these cilia that presents the appearance of a rotating wheel, thus giving the animal its name. Determine whether or not the trochal disc is in any degree retractile.

d) Are there any elevations—**ciliary lobes**—on the trochal disc? If so, how many and where located? How do the cilia on these compare with those on the other parts of the disc?

e) By introducing a little coloring matter under the slide and watching the currents about the circlets of cilia one may locate the **mouth** in the ventral region of the trochal disc. The **anus** is dorsally placed at the junction of trunk and tail.

f) Look for **eggs** attached to the animal exteriorly near the base of the tail.

g) Rotifers are usually transparent enough that some details of the interior structure may readily be made out. Conspicuous, near the front of the trunk, is the **mastax,** a complicated grinding apparatus for reducing the food to fine particles. Watch carefully its movements and describe the process of grinding in your notes.

h) Anteriorly the mastax is connected with the mouth by a short **gullet,** and posteriorly it is followed by an enlargement, the **stomach,** and a short **intestine** ending in the anus. Make out as much of this digestive tract as possible.

i) A convoluted tube may be more or less discernible along either side of the trunk. These tubes are the **nephridia,** the main organs of excretion.

j) Look for a single nerve ganglion, the **brain,** just ahead of the mastax. On the top of this ganglion is a small red **eye-spot.**

k) When the animal stretches itself out you may be able to see some of the **muscle bands** which produce the movements of extension and retraction.

Reproduction.—No part of the reproductive system will be demonstrated in our study, except, perhaps, masses of eggs forming interiorly. The specimen you are studying is probably a female, for the male is quite small and inconspicuous and is found only in the autumn. The generations are produced parthenogenetically during the spring and summer; the winter eggs require fertilization. These eggs remain dormant during the winter and will stand drying up in the mud. In this condition they may be transported from place to place by the feet of birds and other higher animals.

Exercise 1. *Draw one or more rotifers on a much enlarged scale, showing all the details of structure you have been able to make out.*

BUGULA TURRITA (A Sea-mat).

Phylum VII, MOLLUSCOIDA; class 1, POLYZOA; sub-class 1, ECTOPROCTA; order 1, GYMNOLÆMATA.

HABITAT.—The Polyzoa or sea-mats are common in shallow coast-waters the world over. They grow in short, bushy tufts or branching colonies attached to rocks, piles, and other objects in the water. In a superficial way the colonial masses resemble those of the Hydroid polyps.

Technical Note. If living specimens are available one may study them to advantage in a dish of sea water. In most cases, however, the student will have to depend upon preserved material. Place a small branching portion of a colony in a watch glass full of water and study by the aid of a hand lens or dissecting microscope.

STRUCTURE.—The following outline will serve as a guide in locating, identifying, and observing the various parts:

a) Each stem or branch is made up of a number of individual **zooids** arranged one above the other in a certain definite way. How many vertical rows of zooids constitute the branch? How are they arranged in the row? As growth in the colony is by budding, the younger zooids are those near the upper end of the branch.

b) Note that these zooids are each enclosed in an elongated, transparent cup from which a portion of the animal protrudes if the individuals were killed while they were in an expanded condition. These cups or sheaths—called **zoœcia**—are composed of chitinized cuticle. Do you find any empty zoœcia from which the zooids have perished. In what portion of the branch would you expect to find them. Look for short, blunt spines on the zoœcia.

Exercise 1. Draw the portion of a colony you have been studying. Give attention only to details of branching and arrangement of zoœcia on the stem.

Technical Note. Mount a small piece of a branch under a cover-glass and study with the compound microscope. If details can not be readily made out stain another branch with iodine, wash in water, and mount in glycerine.

c) The portion of the zooid which can be protruded from the mouth of the cup constitutes the **introvert.**

d) A circular ridge flaring out slightly from the introvert is called the **lophophore.** This bears a number of ciliated **tentacles.** Count the latter.

e) Locate the **mouth** within the circle of tentacles. It opens into a **pharynx** which, in turn, narrows below to a short **œsophagus.**

f) Follow the œsophagus to an enlargement in the central region of the body. This is the **stomach.** Below it ends in a blind sack, or **cœcum.**

g) From the upper end of the stomach trace the **intestine** to its terminus in the **anus,** located on the introvert just outside of the lophophore. The distal portion of the intestine forms the thick-walled **rectum.**

h) The cœcum is attached to the bottom of the cuticular cup by a band of threads called the **funiculus.** If male reproductive elements are present they will be found clustered about this band. **Ova** develop in the same individual on the wall of the body cavity near the cœcum.

i) Retractor **muscle fibers** pass from the walls of the zoœcium to the pharynx. These serve to retract the introvert and tentacles when the animal is disturbed.

j) Attached to the wall of the zoœcium in most of the individuals is a queer appendage resembling the head of a bird. This **avicularium,** in the living condition, has a movement of its own, drawing back the head, opening the beak, and snapping it together again at regular intervals. The function of this appendage is not well understood. It may serve to keep off encrusting organisms of a lower type of life and it may assist the zooid in securing food.

Some scientists regard it, not as an appendage, but as equivalent to a specialized zooid attached to the larger individual.

k) In some parts of the colony a rounded structure, the **oœcium,** may be found just in front of the zoœcium. It contains a single developing ovum.

Exercise 2. Draw one or more individuals, showing on a large scale the various structures indicated in this study.

ASTERIAS VULGARIS (A Starfish).

Phylum VIII, ECHINODERMATA; class 1, ASTEROIDEA; order 2, CRYPTOZONIA.

HABITAT.—The common starfish which forms the subject of this study is found along the Atlantic coast. Many other species occur in temperate and tropical seas the world over. They are sluggish creatures, clinging to rocks and timbers or crawling slowly about on the sea bottom, often in large numbers, feeding on the various mollusks they encounter. In color *A. vulgaris* varies considerably, shades of brown and reddish-yellow predominating. Occasionally a specimen is bright purple.

Technical Note. The student will find a dried specimen best for studying the external features. A hand lens will be useful in making out some of the structural details.

ABORAL SURFACE.—This is the more convex of the two surfaces. In studying it, note the following:

a) The **body** or **disc,** pentagonal in shape, with its five radiating **arms.**

b) The **madreporite,** a circular mushroom-like plate, light in color, near the junction of two of the arms. Examine it with the lens. The presence of this plate interferes with the radial symmetry of the animal. By drawing a line through its center and through the middle of the opposite arm we may demonstrate a bilateral symmetry.

c) The **skeleton** of the animal, made up of **calcareous plates** with projecting **spines.** These plates are not joined one to the other except by muscle and connective tissue, an arrangement which gives some flexibility to the arms. In the dried specimen, of course, the whole structure is rigid. The separate plates will be demonstrated later.

d) In the spaces between the calcareous plates are **dermal pores** through which project very small, soft, tubular processes, the **dermal branchiæ,** which function as organs of respiration and, perhaps also, of excretion and sensation. They are capable of being retracted, and will probably be seen with difficulty if at all. In the dried specimen the pores will be closed and the branchiæ shriveled up.

e) The **pedicillariæ,** very small pincher-like organs situated at the bases of some of the spines and in the intervals between them. Their function is supposed to be that of keeping the surface of the body free from particles of dirt or minute organisms that might prove harmful.

Exercise 1. *Draw the aboral surface on a scale of two-thirds. The drawing may be natural size if the specimen is small enough to be conveniently figured.*

Exercise 2. *Draw the madreporite, enlarged three or four times, using the lens to determine the structure.*

ORAL SURFACE.—Study the oral surface for:

a) The **mouth,** situated in the center of the disc. It is surrounded by a tightly stretched membrane, the **peristome,** capable of considerable dilation and contraction. The mouth is protected by a number of specialized spines.

b) The arms on this surface are channeled by the **ambulacral grooves** into which project, from the interior of the body, the **tube feet.** In the dried specimen these are much shrunken. How many rows of tube feet in each ambulacral groove? What is the arrangement of the rows and of the tube feet in the row?

c) In the center of each ambulacral groove is a faint line marking the position of the **radial nerve.** These five nerves proceed from a **nerve ring** in the central disc, and each ends in a pigment fleck, the **eye-spot,** at the tip of the arm. The nerve ring can not be demonstrated in this exercise. If the eye-spot has faded out, look for it later in a specimen preserved in liquid.

d) Scrape a few of the tube feet from a small space in one of the grooves and observe the arrangement of the **ambulacral plates** which form its walls, and of the **ambulacral pores** through which the tube feet had projected. Are the pores in the plates or between the plates?

Exercise 3. Draw the oral surface on the scale suggested in Exercise 1.

Technical Note. Study, with a lens, the cross-section of the skeleton of an arm cut with a fine-toothed saw; also a small area of one side of the ambulacral groove from which the tube feet have been removed.

Note, in the cross-section, the varying thickness of different portions of the firm dermal wall. While the dorsal region is strongly arched, the ventral part is in the form of an inverted V. The arms of the V, ambulacral plates, meet above like the rafters on a roof and form the **ambulacral ridge,** the apex of which is truncate or slightly channeled.

The shriveled up inner end of each tube foot can now be seen. This inner end, called the **ampulla,** was bulb-like in the living animal. Where the tube foot passes through the dermal wall it is connected by a short horizontal branch with the **radial water tube** which runs the full length of the arm. This water tube can be seen in cross-section as a tiny hole in the ambulacral ridge just above the radial nerve, which, as has been said, appears as a faint line in the bottom of the ambulacral furrow.

Exercise 4. Draw the cross-section, on a scale of one and one-half, and a group of the ambulacral pores and plates on a still larger scale.

Technical Note. With a pair of fine-pointed scissors remove the aboral wall, with the exception of the madreporite, from a preserved specimen, taking care not to injure any of the internal organs. In this dissection make an incision from the end of the arm down each side to where it joins the disc, clip out the angle at the junction of the two arms, cut around the madreporite, and then carefully remove the "roof," *using a scalpel to free it, in the region of the disc, from any adhering organs. Place the specimen in a large pan or dish and cover with water.*

INTERNAL ANATOMY.—Study the internal organs, observing the following relations and parts:

a) A large, much-wrinkled, five-lobed pouch, the **stomach,** centrally located. This was attached to the aboral wall by a short conical **intestine** ending in the **anus** near the center of the disc. The intestine and anus are probably not functional. Locate the latter if possible.

b) Connected with the intestine is a small, irregularly branched appendage, the **intestinal cœcum.** It may have been torn away with the aboral wall.

c) Opening into the upper, pyloric, part of the stomach are five **ducts** leading from the two-lobed **hepatic cœca** occupying the arms. The function of the cœca is to secrete a digestive fluid. They were attached to the aboral wall by light threads and films of connective tissue, the **mesenteries.**

d) Beneath the cœca (which, unless they remained attached to the roof, may be removed in one or two arms), in the furrow on either side of the ambulacral ridge, are the five pairs of **reproductive organs.** These are more or less well-developed according to conditions for breeding and the age of the animal. In general appearance they differ but little in the male and female, although the **ovaries** sometimes have a light yellow color and are more voluminous than the white **testes** of the male. The right lobe or glandular mass in each arm unites with the left in the adjacent arm to open externally by a common duct in the space between two rays. This duct is at the point where the gland is attached to the dermal wall.

e) The **retractor muscles,** a pair attached to each lobe of the stomach and to the corresponding ambulacral ridge. These serve to pull the stomach back into the body after it has been rolled out of the mouth to envelop food.

Exercise 5. *Copy the outline of the starfish in Exercise* 1 *and fill in the details of structure indicated above, where necessary showing some in one arm, some in another. Omit the madreporite.*

Technical Note. In a specimen that has had the water vascular system injected remove all the organs already figured. Study under water, as before.

AMBULACRAL SYSTEM:

a) Along each side of the ambulacral ridge will be seen a double row of the bulb-like ampullæ already mentioned. These communicate with the radial water tubes to which reference has also been made.

b) In the bony frame-work about the mouth runs a **circular water ring** from which the radial water tubes branch off. This ring also sends up, at points between the origins of the water tubes, two sets of ampullæ-like bodies—the **Polian vesicles,** of which there are ten, and, just below them, the **Tiedemann bodies,** nine in number.

c) The circular water ring is connected with the madreporite by an S-shaped tube, the **stone canal.** Thus the ambulacral system—madreporite, stone canal, circular water ring, radial water tubes, ampullæ, and tube feet—is supplied with water for the hydraulic operations incident to locomotion.

Exercise 6. *Using the outline in Exercise* 1, *as before, make a semi-diagrammatic drawing of the ambulacral or water vascular system.*

Exercise 7. *Make a study of the physiological processes correlated with the various sets of organs you have just represented by drawings, and enter results in your notes.*

HINTS ON COLLECTING.—It is a simple matter to prepare the dry specimens wanted for a study of the external anatomy. The starfish are collected in shallow water along the shore and placed in a pail of fresh water for about a half hour. This will kill them, without allowing the body to collapse. After this treatment they may be placed in alcohol for about the same length of time and then spread in the hot sun to dry. It may be well to fasten them down in some way so that they will not warp too much in the process of drying. Specimens that are wanted for a study of the internal anatomy should be preserved in two to four per cent formaldehyde. The fluid may be brought into immediate contact with the internal organs by injecting it through a slit in one of the arms.

LUMBRICUS TERRESTRIS (An Earthworm).

Phylum IX, Annulata; class 1, Chætopoda; sub-class 2, Oligochæta; order 2, Lumbricomorpha.

Habitat.—The Earthworm, or Angleworm, is found in all habitable parts of the globe, any particular community having perhaps several distinct species. It lives in burrows in the ground, coming out at night or in damp weather to feed on leaves or other vegetable substances. Its food also consists largely of organic matter in the soil which passes through its alimentary tract as it extends its burrow.

Movements.—Watch the movements of a live specimen placed on a sheet of paper. Note the scratching sound as the worm crawls about. What causes this sound? Observe the changes in length and in the diameter of the cylindrical body. Is the progression forward or backward? Look for pulsations in the blood-vessel which shows through the dorsal wall.

Technical Note. Place a preserved specimen on a sheet of white paper pinned to the cork or wax in the bottom of a dissecting pan. Cover with water and study with a hand lens.

External Features.—Note the following relations and parts:

a) An anterior and a posterior end, the former distinguished from the latter by its more rotund and tapering appearance.

b) A dorsal surface darker in color and more convex than the paler and flatter ventral surface.

c) The body **segments** or **metameres.** Count them. They are somewhat longer near the anterior end than they are farther back.

d) A rounded knob-like, lobe, the **prostomium,** projecting from the dorsal portion of the first segment or **peristomium.**

e) The opening of the **mouth** just behind and below the prostomium.

f) The **anal segment**—the most posterior—with its small median opening, the **anal aperture.**

g) The **clitellum,** a saddle-like swelling occupying the dorsal and lateral portions of segments thirty to thirty-six approximately. The location varies considerably in different species. The degree of development, also, depends on the conditions for breeding.

h) The short **locomotor setæ** arranged in rows along the ventral and lateral surfaces. How many rows are there? How many setæ on each segment? Are there setæ in the region of the clitellum?

i) The slit-like openings with tumid lips on the ventral surface of the fifteenth segment. These are the **male reproductive apertures.** On the segment immediately in front are two minute openings, the **female reproductive apertures.** These are seen with difficulty.

j) The **capsulogenous glands** lodged in the sacks at the bases of some of the setæ in the region of the reproductive apertures. Their presence is indicated by local swellings.

Exercise 1. *Draw the first forty and last twenty segments—ventral view—on a scale of two.*

Technical Note. With a pair of fine scissors carefully slit the body wall, along the mid-dorsal line from the prostomium to a point an inch or so behind the clitellum. Sever the internal partitions attached to the wall and spread the specimen open, pinning it to the cork in the bottom of the pan.

INTERNAL ANATOMY.—Note, further, the following:

a) The transverse partitions or **septa** partially dividing the body cavity—**cœlome**—into a series of chambers.

b) The **pharynx,** a muscular enlargement of the alimentary canal at the anterior end.

c) The **œsophagus** extending from the pharynx to "d)." It will probably be hidden by other organs.

d) The **crop,** a soft-walled sack occupying segments twelve to fifteen.

e) The **gizzard** just back of the crop. It has firm walls and is light in color.

f) The **intestine** leading from the gizzard to the posterior end of the body. It is constricted in the intervals between the segments.

g) The **dorsal blood-vessel** lying upon the intestine. Some of the larger transverse branches of this blood-vessel may show in the region of the œsophagus. These are called the **aortic arches.**

h) The **reproductive organs,** three pairs of large white bodies and two pairs of smaller white sacks, all surrounding the œsophagus.

i) The **œsophageal pouches**—first pair—and **œsophageal glands**—second and third pairs—attached to the œsophagus back of the pharynx. These are dark in color.

j) The **nephridia,** slender, much convoluted tubes occurring in pairs in all the segments except the first three and the last. They are organs of excretion.

k) The **cerebral ganglion,** a minute, two-lobed, white speck near the anterior end of the pharynx.

Exercise 2. *Make a life-size drawing locating the parts just indicated.*

Technical Note. Sever the intestine at the posterior limit of the slit in the body wall and carefully remove the alimentary tract, picking out with a needle the portion in the region of the cerebral ganglion.

l) The **ventral blood-vessel** will be exposed by the above dissection. How does it compare with the dorsal blood-vessel in size? There are in addition, three smaller blood-vessels in this region, but they are too difficult of demonstration for this exercise.

m) Beneath the ventral blood-vessel is the **ventral nerve cord.** Note its branches and the swellings or **ganglia.**

n) At the anterior end of the nerve cord a loop, **circumœsophageal collar,** encircles the œsophagus and connects the cord with the cerebral ganglion.

Exercise 3. *Make a diagram of the nervous tract, showing also the ventral blood-vessel if possible.*

Exercise 4. *Cut out a piece of the nerve cord, about a half inch in length, place it in water in a watch glass and study with a dissecting microscope or hand lens. Note the method of branching. Draw.*

Exercise 5. *Draw one of the cocoons or egg-sacs* of the Earthworm. *These may be secured by digging among their burrows in the early summer.*

HINTS ON COLLECTING.—Earthworms are most abundant in the rich soil of old gardens and lawns and along the banks of ditches or drains. They can be secured by digging at almost any time in the spring or summer. Some collectors prefer to search for them with a lantern on warm, rainy nights, when they may be found with a part of the body, at least, protruding from the burrow. When searching in this way the collector should go about quietly and not allow the light to shine too long on one spot. The worms having been secured by either method, take them to the laboratory and place them between moist sheets of blotting paper or filter paper in covered dishes of some sort. Keep them there a day or two, changing the paper every half day. Do not put more than a dozen in the same dish. They will soon have eaten enough of the moist paper to clean the alimentary tract of earth. If they are to be preserved place them now in 4 per cent alcohol and gradually increase the strength to 8 per cent by adding a little alcohol at a time for the next few hours. After washing them in water to free them from mucus place them in fresh 8 per cent alcohol until they are dead. Now put them in 50 per cent alcohol for four hours and then in 70 per cent for twice that length of time. Harden them in full strength alcohol for a day and then return to the 70 per cent for final preservation. Keep them as straight as possible during these processes.

In the American Naturalist, November, 1905, is given an excellent method of preserving Earthworms by means of chromic acid. Specimens preserved in this way are in better shape for dissecting than those preserved by the alcohol method.

A CYCLOPS (Water-flea).

Phylum X, ARTHROPODA; class 1, CRUSTACEA; sub-class 1, ENTOMOSTRACA; order 3, COPEPODA.

HABITAT.—The various species of Cyclops are abundant in fresh-water streams, ponds, and pools. One is pretty sure to find them also in aquaria and frequently in the ordinary drinking water from our city hydrants. Nearly related forms swarm in the surface waters of the sea. All feed upon Paramœcia and other Protozoans, Rotifers, and the like. In turn the Cyclops forms the main food of most of the fresh-water fishes while young. They breed so rapidly that it is estimated that the progeny of a single female would number more than four billions in a year if all the eggs hatched and all the young survived to reproduce in turn. The males are smaller and much less abundant than the females.

APPEARANCE.—Individual Cyclops are plainly visible to the naked eye as little white specks swimming about with a peculiar jerky motion. They are about a millimeter in length. By tapping the sides of the aquarium with a pencil one can start them from cover, when their movements may be readily observed.

Technical Note. If the aquarium is shallow specimens may be captured with a pipette. If the water is too deep for that, use a glass tube open at both ends. Close one end of the tube with the thumb and lower it until the open end is close to the specimen, then release the thumb and the Cyclops will be drawn into the tube with the water. Close the tube again and transfer your Cyclops to a watch glass. Study movements for a short time with a lens, then place the Cyclops in a few drops of water on a slide. Cover, and study with a low power of the microscope. If the little animal moves about too rapidly add a drop of ether to the water, or use glycerine instead. A few fibers of cotton placed between the slide and cover glass may sufficiently restrict the movements.

STRUCTURAL DETAILS.—The body of a Cyclops is somewhat pear-shaped, broad and rounded in front and tapering behind. Note the division into segments, characteristic of the Arthropods. The upper surface can be distinguished from the lower by its more convex form and by the absence of the jointed limbs, which are attached to the under side. Distinguish the following:

a) The **cephalothorax**—fused head and one segment of the thorax—comprising the anterior third of the body, and covered dorsally by the **carapace.** If material is at hand compare this carapace with a similar structure in the crayfish and in Daphnia, or in one of the small so-called bivalve crustaceans often seen swimming about in aquaria or ponds.

b) The four **free thoracic segments** following the cephalothorax. How do they compare in width and in length?

c) The **abdomen,** comprising the rest of the body. How many segments has the abdomen, if we regard the foremost one as made up of two fused together?

d) As your specimen is probably a female, there may be a pair of **egg-sacs** attached near the front of the abdomen. The eggs were extruded into these through a small opening on each side at the point of attachment of the sacs. The openings mark the line of fusion of the first two abdominal segments.

e) Projecting from the front of the cephalothorax is a pair of long, tapering jointed appendages, the **antennules.** Do you notice the animal making any use of these? If you happen to find a male specimen you will observe that the antennules are curiously modified, so that one portion closes up on the other like the blade of a jack-knife.

f) Behind the antennules is a smaller pair of appendages, the **antennæ.** These will be partly, or perhaps entirely hidden beneath the body. By proper manipulation you can make the ends at least to show.

g) The single median **eye** near the front of the carapace. Examine this carefully with a lens to see if there is any evidence of the fusion of two eyes. In what way is this eye-spot associated with the name of the animal?

h) The last segment of the abdomen ends in a pair of diverging **caudal styles** bearing plumose **setæ.**

i) The **intestine** may be seen through the body wall of the abdomen. It ends in the **anus** on the dorsal surface of the last segment. Note its rhythmic contractions which are supposed to facilitate the circulation of a body fluid corresponding to blood.

j) Dark, branched masses seen through the carapace represent **reproductive organs—ovaries** and **oviducts,** in case the specimen is a female.

Exercise 1. *Draw a view of the Cyclops, representing the animal as about three inches in length.*

Examine a specimen from beneath or from the side and determine the number of pairs of **swimming feet.** The last thoracic segment bears a pair of vestigial limbs, and the abdominal segments have no appendages at all. By careful inspection you may be able to make out a pair of **mandibles** and two pairs of **maxillæ** in the head region. Taking the number of cephalic appendages as an index of the number of fused segments in the head, determine that number. How many segments, then, in each of the three regions of the body?

Exercise 2. *Draw, on a large scale, one of the antennules and a thoracic leg.*

A LOBSTER OR A CRAYFISH.

Phylum X, ARTHROPODA; class 1, CRUSTACEA; sub-class 2, MALACOSTRACA; order 3, DECAPODA.

HABITAT.—Crayfishes of the genera *Cambarus* or *Astacus* are common in the fresh-water streams and ponds of this country, and allied species or genera inhabit the streams of other continents. The ordinary lobster (*Homarus americanus*) is at home in the shallow seas washing the rugged, irregular outlines of our New England coast. Crayfish and lobster are so similar in external form and internal anatomy, as well as in habit and general method of living, that the same directions for study may be made to apply to either. Both move about at or near the bottom of the water, preferring localities which are rocky or stony; both are carnivorous, feeding on smaller animals and on carrion.

Technical Note. When the season will permit, live crayfishes should be kept in aquaria or in a cool, moist chamber of some sort. Methods of locomotion and respiration, and perhaps also habits connected with the care of the eggs and young, can then be studied. For dissection fresh material is the better, but specimens preserved in alcohol or four per cent formalin will do very well. A dissecting pan must be supplied to the student, as much of the work will have to be done under water.

EXTERNAL STRUCTURE.—Note the following details:

a) The hard **exoskeleton,** composed, as in the insects, of **chitin,** but with the addition here of calcareous salts. In the adult this outer covering is moulted periodically, perhaps once a year; in the young moulting occurs more frequently.

b) The division of the body into **segments** or **metameres,** the exact number of which will be determined later in a study of the appendages.

c) Two distinct regions of the body, **cephalothorax** and **abdomen,** the former consisting of an immovably fused **head** and **thorax.**

d) The large shield-shaped **carapace** covering the first-named region of the body and showing no traces of segmentation, except, perhaps in a depressed line, the **cervical groove,** which marks the boundary between head and thorax. Anteriorly this shield is prolonged into a more or less pointed structure, the **rostrum.** The lateral portion of the carapace, gill **cover,** is not attached at its ventral border, as can be demonstrated by inserting a flat object. Between it and the body wall proper is the **gill chamber** enclosing eight groups of **gills.** These will be studied later.

e) The abdomen is composed of a number of movable segments, the last of which is termed the **telson.** How many are there altogether? Each segment consists of a dorsal piece, the **tergum,** two lateral continuations of the same, the **pleura,** and a ventral piece, the **sternum.**

f) The posterior opening of the alimentary canal, **anus,** on the ventral surface of the telson.

Execrise 1. *Pin out a specimen in a natural position and make a dorsal sketch of the animal, enlarging or reducing the scale to a total length of three or four inches. Label all the parts.*

g) The abdominal appendages. Not counting the stalked **eyes,** there are nineteen pairs of appendages. Six of these, the **swimmerets** or **pleopods,** belonging to the abdomen. In the male the first two pairs are modified to form secondary sexual organs. In the female the first pair may be rudimentary or wanting, while some of the others are modified for carrying the eggs and young. The last pair in both sexes, **uropods,** is much broader than any of the others, and with the telson forms the **swimming fin.** The telson has no appendages. Study the fifth pleopod and note that it consists of a basal piece, the **protopod,** a lateral branch, the **exopod,** and a median branch, the **endopod.** This biramous type can be traced in most of the other appendages.

h) The thoracic appendages. The posterior half of the cephalothorax bears five pairs of **walking legs,** the first pair, called **chelipeds,** terminating in large pincher claws, the **chelæ.** These are formidable organs of offense and defense and are also useful in securing food. Are the two chelæ alike in size and shape? The last four pairs of legs are called **periopods.** How many pairs terminate in chelæ? On the ventral surface of the basal segment in the last pair look for the **genital pores,** if the specimen is a male. If a female these will be found similarly located on the second pair from the last. In front of the chelipeds are three pairs of **maxillipeds,** which are classed with the mouth parts. Remove these carefully from the right side, beginning with the third pair.

i) Appendages of the head. Preceding the maxillipeds are two more pairs of mouth parts, the **maxillæ.** To the second of these is attached the **gill scoop,** an organ whose function is to scoop the water out of the front part of the gill chamber, thus allowing a fresh current to be constantly drawn in at the free ventral margin of the gill cover. Remove the right maxillæ. This will expose the **mandibles,** the real jaws of the animal. To each is attached a jointed **palpus,** and the two are bordered posteriorly by a pair of small flaps, the **paragnatha,** which are not considered true appendages. Between the mandibles is the **mouth,** bounded in front by the **labrum.** Finally we come to the **antennæ** and the branched **antennules,** the latter the smaller and more anterior. On the ventral side of the basal joint of the former notice the opening of the **green gland,** an organ to be observed later. On the dorsal surface of the corresponding joint of the antennules is a slit or depression with a minute opening into a sack filled with a liquid containing fine sand grains. This structure has been termed the **otocyst** and to it was assigned the function of hearing. Many zoologists, however, believe it to be a balancing organ. In the fine, hair-like projections of the antennæ is believed to be located the sense of smell. The otocyst will not be studied in this exercise.

Exercise 2. Draw, in their order, the right antennule, antenna, mandible, first maxilla, second maxilla, first maxilliped, second maxilliped, third maxilliped, and the fourth and sixth swimmerets, removing each, in the reverse order, if this has not already been done.

Technical Note. Cut away the gill cover from the left gill chamber and place the specimen under water.

j) The gills. Extending up into the gill cavity are seven **epipods,** large blade-like flaps which separate the gills into groups. They are attached one each to the three maxillipeds and the four anterior walking legs. The gills themselves show three methods of attachment—to the bases of the appendages just named (**podobranchs**), to the articular membrane between appendage and body wall (**arthrobranchs**) and to the body wall itself (**pleurobranchs**). There are two arthrobranchs in some segments. What purpose is served by having some of the gills attached to the basal joints of the appendages?

Exercise 3. Sketch the gill groups in position, side view, showing also outline of the cephalothorax and bases of the appendages.

Exercise 4. Make a diagram in your note book showing the presence or absence of the three sorts of gills and the epipod in each of the eight segments of the thorax. The following will serve for a plan; write the name of the appendage in the first column and indicate by figures, in the appropriate space, the number of each kind of gill:

Segment.	Appendage.	Podobranchs.	Arthrobranchs.	Pleurobranchs.	Epipod.
1.	....	....	....	....	....
2.......	....	....	....	....	....
3.......	....	....	.. ..	....	....
4.......	....	....	....	....	....
5.......	....	....	....	....	....
6.......	....	....	....	....	....
7.......	....	....	....	....	....
8.......	....	....	....	....	....

Technical Note. As the blood vascular system is to be studied in this dissection it is best to have injected specimens. Injection is accomplished, in the living specimen, by thrusting the needle of the hypodermic syringe beneath the posterior border of the carapace and pushing it well forward. A yellow starch injection mass will set well and show up clearly. When ready to dissect, very carefully remove the dorsal wall of the carapace and the abdomen piece by piece, separating the hard exoskeleton from the more delicate skin beneath. Clear away the latter and study the organs thus exposed.

INTERNAL ANATOMY.—Note the following organs and their relations to one another:

a) At the anterior end of the cephalothorax a large membranous sack, the **stomach.** It has an anterior **cardiac chamber** and a small posterior portion, the **pyloric chamber.**

b) A short **œsophagus,** almost vertical in position, connects the mouth and stomach.

c) On each side of the stomach the torn ends of a mass of muscle fibers. These are the **mandibular muscles.**

d) Back of the stomach is the shield-shaped **heart,** from the anterior end of which five arteries proceed. Three of these, the **ophthalmic** (central) and the two lateral **antennary arteries,** will be easily seen. The other two, **hepatic,** are beneath some of the other organs.

e) The large **dorsal abdominal artery** with its numerous branches arise from the posterior angle of the heart and extends to the telson. To expose this artery it will be necessary to remove the superimposed layer of firm white **extensor muscle.** This can be accomplished by simply making a shallow cut down the mid-dorsal line and folding the muscle back on either side.

f) From a point near the origin of the dorsal abdominal artery another artery, the **sternal,** takes a downward course. When it reaches the ventral wall of the body it divides and is continued anteriorly and posteriorly as the **ventral longitudinal artery.** These blood-vessels can be seen later.

g) Immediately beneath the dorsal abdominal artery lies the **intestine,** leading from the stomach to the anus.

h) The large **flexor muscle fills** most of the space within the abdomen. Why is it more strongly developed than the extensor muscle?

i) On both sides of the stomach and partly beneath and behind it is a pair of **digestive glands** whose secretions are poured into the alimentary canal by a common duct at a point near the junction of intestine and stomach.

j) Situated beneath the heart and in front of and behind it are the **reproductive organs.** In the female crayfish the **ovaries** are brownish yellow, in the male the **testes** are white. From the latter organs the coiled **sperm ducts** lead to the external openings previously mentioned. The external openings of the **oviducts** have also been previously noted.

Exercise 5. *Make an outline drawing, on the same scale as in exercise* 1, *showing the above-named organs in position.*

Technical Note. Clip off the œsophagus close to the stomach, and the sternal artery close to the heart. Remove carefully all the organs figured in Exercise 5, *noting in the process any details that could not be observed before. Place the stomach and the heart in water. Pick away all muscles and other tissues covering the ventral nervous system.*

k) Note six openings in the heart, two on the dorsal surface, two on the ventral and one on each side. These are the **ostia**; by means of their valves blood is admitted to the heart from the surrounding **pericardium,** a membranous sack which was probably torn away in removing the carapace.

l) Sit open the stomach and note the chitinous lining, with its toothed lprojections forming what is called the **gastric mill.** This lining is shed with the outer exoskeleton in moulting.

m) Situated in the head, below the bases of the antennæ is a pair of excretory organs, the **green glands.** The external openings of these glands have already been pointed out.

n) The nervous system. This consists of a **supra-œsophageal ganglion** or **brain** located just back of the eyes. It sends off several cerebral nerves which may be noted. It also gives rise to a pair of **commissures** which pass around the œsophagus and connect it with another ganglion, the **sub-œsophageal.** From the latter a double **ventral nerve cord,** with paired ganglia at intervals and with numerous branch nerves, runs the length of the body. In its passage through the cephalothoracic region it follows the **sternal channel,** formed of transverse ridges of the hard ventral wall. Break away this structure so that the cord may be exposed for its entire length. The double nature of the cord is apparent at the point where the sternal artery passes through it.

Exercise 6. *Make a diagram of the nervous system on the same scale as in Exercise* 1.

Exercise 7. *Make separate sketches of the heart and the gastric mill of the stomach.*

Exercise 8. *Separate a ring of the abdomen with its attached swimmerets, remove the muscle from the inside of the ring, and draw on a slightly enlarged scale.*

A CENTIPED (*Scolopendra heros*).

Phylum X, ARTHROPODA; class 3, MYRIAPODA; order 2, CHILOPODA.

HABITAT.—Centipeds are of world-wide distribution, some species being adapted to the higher latitudes or elevated cold regions, while others, particularly the larger species, abound in the tropics. They are all terrestrial. We may look for them under stones, logs, and leaves or the bark of decaying trees and stumps. One genus—*Scutigera*—frequents cellars and the darker corners of houses. The food of Centipeds is mainly insects, spiders, and snails.

APPEARANCE.—Centipeds are worm-like animals with a great many legs. In color they range from straw-yellow to various shades of brown or reddish. They can be distinguished from the Millipeds, their near relatives, by their flattened bodies, by their swifter movements, and by their smaller number of legs. The Millipeds are more nearly cylindrical, have two pairs of legs to most of the segments, and usually curl up or move slowly away when disturbed. Scolopendra heros is one of the larger species, measuring from three to five inches in length.

Technical Note. Centipeds may be collected in the situations mentioned above and placed in alcohol or formalin for class use. Fresh specimens can be killed in a cyanide bottle. As the bite of these creatures is poisonous, they should be picked up, when alive, with long forceps. Fasten the specimen to a piece of board or sheet cork, by inserting a pin near each end, and study with a hand lens. Other species than the one treated in this exercise will answer the purpose very well.

EXTERNAL FEATURES.—The following notes will serve as a guide in determining relations and parts:

a) The comparatively simple or generalized type of structure is apparent in the similarity of the numerous **segments** into which the body is divided. Two body regions may be recognized, a **head** and a **trunk.** Is there any indication of a division of the latter into thorax and abdomen? Count the segments. The number is sometimes of importance in classification.

b) Examine the **legs.** Do they differ in any respect except that of size? How many joints in a leg? The number of pairs should correspond exactly to the number of trunk segments. What is the function of the single **claw** on the end of each leg and of the **spines** on some of the joints?

c) The legs of the hindermost segment are modified into a pair of **anal feelers,** probably to enable the animal to perceive what is back of it.

d) Examine now the modified front pair of legs, sometimes called **maxillipeds.** These curve forward so as to act with the mouth parts and terminate each in a strong claw traversed by a duct leading to a **poison gland.** The opening of the poison duct is near the tip of the claw, but you may not be able to find it. Contrary to popular opinion, the claws of the other legs are not poisonous.

e) Determine the number of joints in the **antennæ** projecting from the front of the head. This point is also sometimes useful in classifying the species.

f) Just back of the antennæ are the **eyes.** Study these carefully. They seem to be simply groups of **ocelli.** Determine the number of ocelli for the species you have in hand. Is the number constant for all the specimens used in the class? In one genus, at least, the eyes are rudimentary—not sufficiently developed for vision. How is this fact correlated with the habits of Centipeds? The House Centiped—*Scutigera*—has compound eyes.

Exercise 1. *Draw the entire animal, dorsal view, if necessary enlarging enough to make the sketch four or five inches in length.*

g) Study the under side of the head. There is a more or less movable upper lip, **labrum,** and three pairs of mouth parts proper, not including the poison jaws. The last pair of these, most posterior, is the **second maxillæ.** They lie just in front of the poison jaws, their palps projecting far enough to be easily distinguished.

Ahead of these come the **first maxillæ,** less conspicuous on account of the absence of a projecting palp. Between the first maxillæ and the labrum are the real jaws or **mandibles.**

h) Note the slit-like openings in the soft integument of the sides of the body just above some of the legs. These are the **spiracles** opening into the tracheal respiratory system. On which segments do they occur?

Exercise 2. *Draw a ventral view of the head on a scale of six, showing the mouth parts in position.*

Exercise 3. *Remove the poison jaws and the mouth parts carefully and draw them separately on an enlarged scale.*

The internal anatomy of the Centiped will not be considered here as it is similar to that of the grasshopper, which can be more conveniently dissected. On the whole, however, the internal organs are less complex than the corresponding organs of an insect. This we would expect of an animal which showed less external specialization than an insect.

A GRASSHOPPER (*Melanoplus differentialis*).

Phylum X, ARTHROPODA; class 4, INSECTA; order 2, ORTHOPTERA.

HABITAT.—Grasshoppers are probably common wherever grass or herbaceous vegetation grows, for genera and species are usually numerous in any locality inhabited by man. To the groups having short antennæ the term Locust is also frequently applied. Grasshoppers feed on green vegetation of almost any sort, especially such as grows low on the ground. Most of the adults die in the fall, in temperate climates, the females leaving a packet of eggs to perpetuate the species. They are very destructive to growing crops, especially when rapid increase of numbers and consequent scarcity of food forces them to migrate in swarms from their native haunts.

Technical Note. Live grasshoppers can be kept under bell jars or in cages consisting of a lamp or lantern chimney tied over at the top with gauze and standing upright on the earth in a common flower pot. They should be supplied with fresh grass at least once a day. Preserved material, kept in two per cent formalin or seventy per cent alcohol, may be used when fresh specimens can not be obtained from the field.

EXTERNAL STRUCTURE.—With grasshopper and lens in hand note the following relations and parts:

a) The **head,** at the anterior end of the body. Is it placed in line with the longer axis, or at right angles to it?

b) The **thorax,** movably articulated with the head, but immovably fused with the first segment of the posterior body region. There are three divisions of the thorax, each bearing a pair of **legs.** They are termed, respectively, the **pro-, meso-,** and **metathorax,** beginning with the most anterior division. Which of these is free to move at either end? Trace out the line of division between the other two.

c) A long, sub-cylindrical, segmented **abdomen** completes the body divisions. Determine the number of rings or **somites** that compose it. Trace out the line that separates it from the metathorax. In counting the somites you are likely to be puzzled as you approach the tip of the abdomen, the ventral pieces of one or two of the rings being absent. Other parts are also there, which will be considered later.

d) Let us examine carefully the more prominent appendages. On the front and near the top of the head are the jointed **antennæ,** certainly organs of touch and probably of smell also in some insects. Compare with the antennæ of a green meadow grasshopper, or a cricket. The legs have already been noted. Why is the hind pair larger and longer than either of the other two pairs? What prevents the animal from slipping when walking or leaping?

e) Contrast the two pairs of **wings** in shape and structure. Pull the outer pair forward so as to expose the other pair folded like a fan beneath the first. The outer wings, sometimes called **tegmina** or wing covers, are not of much use in flight. What purpose do they serve, then, in the economy of the animal? To what divisions of the thorax are the wings attached?

f) At the sides of the head are the two prominent **compound eyes.** Under the lens the **cornea** of each will be seen to be made up of a great many hexagonal **facets,** corresponding to separate eye elements in the structure beneath. Search the front of the head for three small simple eyes or **occelli.**

Exercise 1. *Fasten the grasshopper to a piece of sheet cork or soft wood by two pins, spread out and pin down the wings of the left side and draw a dorsal view on a scale of three. Label all the parts observed and number the segments of the abdomen.*

Technical Note. Release the specimen from the pins and clip off the left wings close to the body. Also remove the legs from the left side, using the forceps in the process so as to secure the basal joint intact. Sever the head from the prothorax and disconnect the abdomen at the *suture between the second and third somites. Save all the parts for study with the dissecting microscope. The wings and legs may as well be cut from the other side also, as they are only in the way.*

g) Under the lens the head is seen to be made up of a number of plates or **sclerites** joined at fixed **sutures.** The largest of these plates is the **epicranium.** It forms the top and front of the head and extends on the sides to the cheeks or **genæ.** Below it is bordered by the **clypeus.**

Exercise 2. *Draw the front of the head on a scale of five or six. Label all the parts, some of which are named in "h)."*

h) In working out the mouth parts begin with the upper lip—**labrum**—attached to the lower border of the clypeus. Raise it with the dissecting needle and disclose a pair of strong, dark-colored jaws, the **mandibles.** Move these back and forward. Do they work horizontally or vertically? Note the toothed edge. With scissors and forceps carefully remove labrum and mandibles and place them in a watch glass. Disregarding a brown, tongue-like organ, the **hypopharynx,** remove next the **maxillæ,** a second pair of jaws, and finally the lower lip or **labium.** Save these also.

i) Mount the labium and the maxillæ on separate slides and study with a low power of the compound microscope. Note, in the labium, a basal piece, the **submentum.** Beyond this is the **mentum,** from the distal end of which projects the ligula. From each side of the mentum arises also a **palpus.**

j) The basal segment of the maxillæ is called the **cardo.** Next comes a broad piece, the **stipes,** which terminates in a toothed, cutting **lacinia.** A spoon-shaped piece—**galea**—serves as a covering for the lacinia, and to one side of this is a **palpus.** Compare the labial with the maxillary palpi.

How many pairs of appendages have we found in the head? Which of the mouth parts are not paired appendages? Is there any evidence that the labium is made up of a pair of appendages?

Exercise 3. *Draw the labium, one of the maxillæ and one of the mandibles on an enlarged scale.*

Exercise 4. *Clip off a piece of the cornea of a compound eye, clean it on the inside, mount on a slide, study, and draw.*

k) Note the massive, box-like build of the thorax, particularly the second and third segments. Account for these generous structural proportions. Why is the prothorax less heavily built than the meso- and metathorax? Typically the walls of each segment of thorax and abdomen are made up of four parts—a dorsal piece, the **tergite,** a ventral piece, the **sternite,** and two lateral pieces, the **pleurites.** These pieces are not necessarily separated by sutures, or, in fact, by any lines of demarcation.

l) Look for three impressed lines subdividing the shield of the prothorax into an anterior **præscutum,** followed by a **scutum,** a **scutellum,** and a **postscutellum** in their order. The pleurites of the meso- and the metathoracic segments are also subdivided each into an anterior piece, the **episternum,** and a posterior piece, the **epimeron.** Note the blunt spine on the sternite of the prothorax.

m) Just above the second legs on each side is a little slit-like opening guarded by a pair of lips. This is a **spiracle** opening into the tracheal respiratory system. Look for other spiracles, one pair on the prothorax and a pair each on certain of the abdominal segments. How many do you find in all?

n) Under the bases of the wings on the first abdominal segment is a pair of parchment-like, oval membranes called the ear drums or **tympana.** Look for similar structures, differently located, in a cricket or a meadow grasshopper. On the anterior rim of each tympanum is the spiracle of that segment.

Exercise 5. *Draw a lateral and a ventral view of the thorax and first two segments of the abdomen on a scale of four. Label all the parts.*

o) Examine now the tip of the abdomen in several grasshoppers. If it ends in two pairs—a dorsal and a ventral—of hard pointed projections, the specimen is a female and the projections taken together constitute the **ovipositor.** By alternately bringing together and spreading the four pieces the female is able to work her body down into the hard ground the full length of the abdomen when depositing her egg capsule. The abdomen of the male is rounded or even enlarged at the tip, which is covered by a sort of hood formed of the tenth sternite.

p) In either sex there is a pair of pointed projections from the posterior border of the last tergite but one. These projections are the **cerci,** whose function, perhaps, is sensory. Between the cerci is the last abdominal tergite and partly beneath the cerci the **podical plates.**

Exercise 6. Draw a side view of the posterior end of both a male and a female grasshopper, enlarged four times.

q) Make a study of the legs, comparing the first and third. The basal joint is the **coxa.** What is its shape? It is followed by a smaller joint, the **trochanter,** which is the more clearly defined in the first leg. In the grasshopper the coxa and trochanter seem to be immovably fused together. After the trochanter come, in their order, the elongated **femur,** the more slender **tibia,** and a **tarsus** of several short joints. How many? Between the **claws** is a cushion-like pad, the **pulvillus.**

Exercise 7. Draw one of the first and one of the third legs on a scale of three.

Technical Note. Fresh specimens are best for a study of the internal organs, but preserved material will do if not too soft. Cut the wings and legs from a large female and then, with fine pointed scissors, make a slit along each side of the body from near the tip of the abdomen to the base of the head. Carefully remove the dorsal surface of abdomen and thorax and pin the specimen down to the wax in a dissecting pan, spreading the lateral walls slightly. Cover with water and study on the stage of the dissecting microscope.

Internal Anatomy.—If you have been careful not to tear or cut any of the internal organs you will have little trouble in making out the following:

a) A mass of yellow bodies occupying the dorsal region of the abdomen. These are the **ovarian tubules** and taken together constitute the right and left **ovaries,** easily separable by a dissecting needle along the median line. Each tubule is connected at one end with the **oviduct** from that side, and is filled with eggs in various stages of development. Mount some of the tubules and examine with the compound microscope. Follow up the light-colored oviducts and observe that they unite to form a single duct which leads to the exterior opening at the base of the ventral pair of ovipositors. Do the tubules stand vertically or do they slant in any way?

Exercise 8. Make a diagram of the reproductive system in an outline of the abdomen.

b) Note, in the thorax, the **muscles** which move the legs and wings.

c) If your specimen is a fresh one you will have noticed a great many branching silvery tubes, the **tracheæ,** and white, glistening **air sacs** connected with them. By following up one of the larger trunks its exterior opening can be identified with one of the spiracles already noticed. That the branching tracheæ penetrate to every part of the body can be proven by examining the merest bit of tissue under the microscope. What is the object of the spirally wound thread that follows the inner wall of even the finer branches of the tracheal system?

Exercise 9. Mount a piece of a tracheal tube on a slide, examine and draw.

d) After removing the reproductive organs free the underlying digestive tract from any tracheæ or fatty tissue that conceals it. Note its dark color due to contained food. The several parts of the tract are, in their order, **mouth, œsophagus, crop, ventriculus** and **intestine.** The crop is merely an enlargement of the œsophagus. Its posterior border is not marked by any constriction, but is just in front of the line of attachment of the curious double cone-shaped pouches called **gastric cœca.** How many of these pouches are there? It is from the crop that the live grasshopper ejects "tobacco juice" when picked up. Why this habit? After you have made the next drawing split open the crop, rinse it and examine the grinding structures in the lining. The ventriculus extends posteriorly to just in front of the line of attachment of a great many tangled brown threads, the **Malpighian tubules,** having an excretory function similar to that of the kidneys in higher animals. The intestine ends in the **anus** at the base of the dorsal pair of ovipositors. How does the length of the digestive tract compare with the length of the body?

Exercise 10. *Draw the alimentary tract in its natural position, using the outline of the entire body.*

Technical Note. Snip off the alimentary canal at the base of the head and near the anus, remove, and rinse the specimen with clean water. Cut away the hard covering from the top of the head.

e) Between the eyes observe a light-colored mass, the **brain** or **supra-œsophageal ganglion.** Trace out its connection, by means of **commissures,** with the **subœsophageal ganglion** lying beneath the œsophagus. From this ganglion a **nerve cord** extends to the posterior end of the abdomen along the ventral body wall. Follow it out and determine the number of thoracic and abdominal ganglia. Look for fine nerves branching off from the ganglia. Does the ventral nerve cord appear to be double?

Exercise 11. *Make a diagram of the nervous tract.*

f) The circulatory system is relatively simple in an insect. A delicate pulsating tube called the **heart** extends along the dorsal side of the abdomen. It was probably torn in dissecting the specimen, but even under the most favoring circumstances it is quite hard to make out. In its walls are some valvular openings through which a body fluid corresponding to blood is drawn in and pumped forward, returning again through the body spaces or cavities. Explain the interdependence of a simple blood circulatory system and a complex tracheal respiratory system.

A SPIDER.

Phylum X, ARTHROPODA; class 5, ARACHNIDA; order 6, ARANEIDA.

HABITAT.—Spiders are common in all lands except the very coldest, where little life of any kind exists. The species are much less numerous than in the insect class, but individuals are often very abundant. Certain tribes or families live habitually in webs, which serve also as snares for their prey. Some species live under bark and stones or lurk in the concealment of foliage and flowers, while others prefer to roam about obtaining their food by the chase. All live upon insects or upon one another.

Technical Note. Spiders have such soft bodies that they cannot be dried and preserved like insects. If the season will permit, specimens for class use may be obtained fresh from the field and killed in a cyanide bottle. Otherwise use material preserved in alcohol or formalin. Study with a hand lens or place on the stage of the dissecting microscope, using a light or dark background as the case may require. If the preserved material is used it is best to keep the spider under water, as detail comes out clearer in this way than when the body has become dry and the hairy covering matted together.

A DORSAL VIEW.—Members of the several family groups of spiders differ markedly from one another in detail, so much so that it will be necessary to keep within the bounds of the general in this outline. Any one of the larger species of the Lycosidæ, or Running Spiders, may be easily obtained and will serve very well as a type. Note the following relations and parts:

a) A division of the body into two regions—**cephalothorax** and **abdomen.** Can you make out any traces of segmentation in either region? Is the cephalic part of the cephalothorax in any way distinguishable from the thoracic part? If the specimen you are studying has not been hardened in a preservative fluid you will note that the abdomen is very soft and easily ruptured or crushed.

b) The **eyes** arranged in rows on the front part of the cephalothorax. Determine the number of these rows, the number of eyes in each row, and compare the eyes in size. With the exception of members of two small groups, which you are not likely to encounter, all spiders have the same number of eyes as your specimen. If material is at hand compare the arrangement of the eyes with that of other groups of spiders.

c) The four pairs of **legs** attached to the cephalothorax. Compare in length. How many joints in a leg? Note the **hairs** and **spines** on the legs, as well as on other parts of the body. The colors of the spider are partly due to these hairs, spines, and scales and partly to pigment in the skin.

d) Projecting downward and forward from the front of the cephalothorax are the **cheliceræ,** strong jaw-like organs. Each consists of a basal piece and a terminal **claw** in which is a small opening communicating by a duct with a **poison gland.** Find this opening if possible. Move the claw back and forth, noting that it fits into a groove like the blade of the jack-knife in its handle.

e) At the sides of and extending beyond the chelicerae are the **pedipalps** resembling a fifth pair of legs, though they really function as accessory mouth parts. If your specimen is a mature male the terminal joint will end in a complicated knob, the **palpal organ.**

f) Connecting the cephalothorax and the abdomen is a more or less slender stalk, the **pedicle.** It is not likely to be visible unless the two body regions be pushed apart slightly. It will not appear in the drawing.

Exercise 1. Draw a dorsal view of the spider enlarged three to five times.

A Ventral View.—In addition to the parts appearing on the dorsal aspect note also, on the under side:

a) The **sternum,** a piece fitting in between the basal joints of the legs.

b) The proximal joint of each pedipalp is seen to have a lateral projection, the **endite.** These projections sometimes meet just back of the **mouth,** in other cases they are not contiguous. Between them is the **labium,** a sort of lower lip. Look for tufts or brushes of hairs about these organs. Count the number of joints in one of the pedipalps and compare with the number in a leg.

c) Near the front of the abdomen is a shallow transverse groove at the ends of which are the two **lung slits,** openings leading to the **book-lungs.** Just in front of the groove at the middle point is the **genital opening,** called the **epigynum** in the female.

d) At the posterior end of the abdomen are the **spinnerets** occurring in pairs. How many pairs? Determine the number of segments in each spinneret.

e) Just back of the spinnerets is the **anal opening** and just ahead of the aforesaid organs the **tracheal spiracle** opening into the respiratory **tracheæ.**

Exercise 2. Draw the under side of the spider on the same scale as before, omitting all but the proximal joint of legs and pedipalps.

Technical Note. Detach a leg, a pedipalp, one of the cheliceræ, and a spinneret. Study these organs with a low power of the microscope. They may be mounted on a slide or viewed in a watch glass.

The Appendages.—The legs will be found to consist of the following joints, beginning with the proximal one: **coxa, trochanter, femur, patella, tibia, metatarsus,** and **tarsus.** Which one of these is lacking in the pedipalp? Compare with the leg of an insect, such as a grasshopper or a beetle. Examine the claws at the tip of the tarsus.

The palpal organ, mentioned above, appears after the last moult of the male and is, therefore, an evidence of maturity. The distal joint of the female pedipalp has no such enlargement. Maturity in this sex is indicated by the appearing of the epigynum after the last moult.

With a higher power of the microscope one can make out a great many **spinning-tubes** on the blunt ends of the spinnerets. Some may occur also on the sides of these organs. Through these fine tubes a viscid liquid is exuded, the scores of tiny threads coalescing into one and hardening from contact with the air.

The cheliceræ are in most cases furnished with a furrow for the reception of the folded claw. Frequently the margins of this furrow are set with teeth. Does your specimen have a smooth rounded prominence near the base of the chelicera? This is the **lateral condyle.** It does not occur in all species.

Exercise 3. *Draw a chelicera, a pedipalp, a leg, and some of the spinning tubes on an enlarged scale.*

Exercise 4. *Draw an enlarged front view of the spider including the cheliceræ and the eye group.*

A FRESH-WATER MUSSEL (*Anodonta* sp. or *Unio* sp.).

Phylum XI, MOLLUSCA; class 1, PELECYPODA; order 4, EULAMELLIBRANCHIA.

HABITAT.—Fresh-water mussels are found in rivers, ponds and lakes in most parts of this and other continents. Some species frequent sandy bottoms, while others are more at home in the mud and ooze.

Technical Note. If live mussels are obtainable they should be used to demonstrate water currents, movements, and protrusion beyond the shell of certain organs. They can be kept alive for weeks in jars or tubs of water with a layer of three or four inches of sand at the bottom. The water should be changed every few days. A four per cent solution of formaldehyde makes an excellent preserving agent for specimens to be used in dissection. If the live animals are placed for a few minutes in water about as hot as the hand can bear, the shell will soon gape enough to allow a small wooden wedge to be inserted. This will prevent the shell from closing again and will give free entrance to the preservative fluid. Before preserving, the clams should be killed by smothering them in a closed vessel containing only just enough water to cover them, for if the live clams are thrown directly into the preserving fluid, some of the internal organs will contract and become distorted.

EXTERNAL APPEARANCE.—The mussel is bilaterally symmetrical, compressed from side to side, and enclosed in a **shell** consisting of two **valves** hinged together on one of the margins. Observe the following:

a) The concentric **lines of growth** paralleling the margin of the shell. Each of these represents what was at one time actually the margin.
b) The convergence of these lines about the **umbo,** an elevation on each valve near the hinge toward the forward end of the shell.

This is the oldest and thickest portion of the shell and is the initial point from which growth proceeded.

c) The anterior and the posterior ends of the animal, determined by the nearer proximity of the umbo to the former.

d) The dorsal and ventral margins of the valves, the former hinged, the latter gaping.

e) The **hinge ligament** connecting the right and left valves of the shell.

f) The **foot,** a tough, tongue-shaped, muscular body protruding from the anterior end of the gape between the valves, if the animal is alive. In the preserved specimen it will be withdrawn within the shell, but can still be seen.

g) The **mantle,** a delicate membrane one lobe of which lines internally each valve of the shell. Normally the mantle lobes extend to or project quite beyond the margin of the valves, but, being muscular and sensitive at the border, they contract when irritated.

h) Two oval openings, the **siphons,** formed by the close approximation of the edges of the right and left mantle lobes at the posterior portion of the gape between the valves. The lower is called the **inhalant siphon,** the upper the **exhalant siphon.** Note the delicate projections, **fimbriæ,** around the edges of the former.

If you have a living specimen, watch for the protrusion of the foot and the forward movements of the animal. How is this progression accomplished? Can the mussel stand alone? The currents of water at the posterior end of the gape in the shell can easily be detected by lowering a few drops of ink through a tube to a point opposite the siphonal openings. The water thus taken in at one opening and exhaled at the other serves the double purpose of conveying oxygen and food to the animal, the latter in the form of microscopical organisms. What is the probable function of the fimbriæ? Touch them.

Technical Note. In a preserved specimen carefully remove the left valve of the shell. This is accomplished by freeing it from the corresponding mantle lobe by means of a thin knife, and then severing, *near each end of the gape, the large muscle which holds the two valves together.*

Note that the shell now stands widely open. Push it shut. Will it stay in this position? Understand the mechanism of opening and closing the shell. Break the hinge ligament and place the half of the shell containing the body of the animal in water.

Exercise 1. *Draw the outside of the left valve, natural size.*

INNER SURFACE OF THE SHELL.—Examine now the inside of the left valve. Note the following:

a) Parallel with the edge and a short distance from it is the **pallial line.** Look on the right valve for the cause of this delicate streak.

b) Beneath and a short distance ahead of the umbo the pallial line ends in the **anterior adductor impression.** A similar **posterior adductor impression** lies near the opposite end of the shell. What caused these impressions?

c) Just above each of the large impressions is a smaller scar marking the insertion of the **anterior** and **posterior retractor muscles** of the foot, respectively. The large and small anterior impressions are slightly separated; the two corresponding posterior scars are contiguous.

d) Immediately behind the lower half of the anterior adductor impression is another small scar made by the **protractor muscle** of the foot.

e) If the specimen is a species of *Unio,* you will find several **hinge teeth** just beneath the hinge ligament. What purpose do they serve? *Anodonta* has no such teeth.

f) Observe an outer layer of the shell—**periostracum**— composed of **conchiolin,** a tough, horn-like substance analogous to chitin.

g) An inner, smooth layer, the **nacre,** with a pearly luster.

h) Between them is the **prismatic layer,** formed of minute prisms of calcium carbonate separated by thin leaves of conchiolin. Examine the edge of a piece of freshly broken shell.

The first and last layers mentioned are secreted by the thickened edge of the mantle, the nacre by the whole outer surface of that organ.

Exercise 2. Draw the inner surface of the left valve, natural size.

THE BODY PROPER.—You will now observe that the mantle which lines the shell is attached to the dorsal wall of the body and completely envelops it, hanging down on either side like a cloak.

a) When the edges of the two lobes are brought together a large chamber, the **branchial cavity,** is enclosed. Into this the inhalant siphon opens.

b) Turn back the mantle lobe, without tearing it loose at any point, and note, within the chamber, the wrinkled hatchet-shaped foot projecting from the larger and thicker **visceral mass.**

c) On either side of the visceral mass are two thin plate-like organs with parallel vertical striations. These are the **gills,** an outer pair and an inner pair. It will be noted that they extend from a point somewhat anterior to the middle of the visceral mass to the siphonal openings, where the united dorsal edges of all four constitute a horizontal partition between the branchial cavity and a much smaller chamber, the **suprabranchial cavity,** from which the exhalant siphon opens.

d) In front of the gills on either side are two triangular flaps, the **labial palps.**

e) Just back of the anterior adductor muscle is the wide **mouth,** bordered in front by a sort of lip formed of united folds projecting from the outer pair of palps. Similar folds from the inner pair of palps unite back of the mouth. The palps thus resemble, as it were, a pair of military mustaches attached to each lip. They are provided with cilia which aid in sweeping food particles to the mouth.

f) In front of the posterior adductor and above the attachment of the mantle lobe to the body is a triangular chamber with very thin walls. This is the **pericardium.**

Exercise 3. Remove the left mantle lobe, except a small portion immediately surrounding the siphonal openings, and make a sketch of the body of the animal lying thus in the right half of the shell.

INTERNAL ANATOMY.—Very carefully remove the thin wall of the pericardium and make out the following:

a) The **heart,** consisting of a single thick-walled **ventricle** and two **auricles** of thin filmy tissue. The latter are triangular pockets attached by the narrow end to the sides of the ventricle and by the broader end to the lateral part of the floor of the pericardium.

b) The pericardium is traversed by a portion of the alimentary tract, the **rectum,** which emerges from the visceral mass at a point beneath the umbo and passes posteriorly over the adductor muscle. It ends in the **anus** just within the upper siphonal opening. Trace it out. The ventricle of the heart is strung on the rectum like a bead on a string, but has no communication with it.

c) From the ventricle an **anterior aorta** passes forward above, and a **posterior aorta** passes back beneath the rectum. These blood-vessels have such thin walls that the student will probably not be able to make them out unless the specimen has been injected.

Exercise 4. Begin another sketch, filling within the outline of the right valve of the shell only the organs contained in the pericardial chamber.

d) Probe the outer part of the suprabranchial cavity and note that farther back it divides into four **suprabranchial passages,** one just above the dorsal border of each gill. Understand precisely the attachment of the gills to each other and to the other organs.

e) Remove the heart and rectum. Immediately beneath the floor of the pericardium are two dark-colored **excretory organs.** Each extends from the anterior part of the pericardium to the posterior adductor muscle, where it turns and runs forward again. It is thus narrowly U-shaped, one arm, the **ureter,** lying upon the other—**kidney.** Make an opening into the bend of the organ and probe both ureter and kidney. The external openings of the excretory organs are too difficult of demonstration for this exercise.

Technical Note. With a sharp scalpel shave off portions of the wall of the visceral mass.

f) Note anteriorly a dark glandular mass, the **liver,** surrounding a cavity just back of the mouth. This cavity is the **stomach;** it is connected with the mouth by a short **œsophagus.** The **intestine** has several coils in its course from stomach to rectum. To trace these out will probably require more time than the student has at his disposal.

g) A cream-colored granular substance appears to fill the bulk of the visceral mass. This forms the **reproductive organs,** indistinguishable in the two sexes except by microscopic examination. Note, imbedded in the mass, sections of the intestinal coils.

Exercise 5. *Complete Exercise* 4, *showing the location of the excretory organs, stomach, liver, œsophagus, and reproductive organs, with reference to the other structures.*

THE GILLS.—Examine the structure of a gill. Each is composed of two plates or **lamellæ** united along their lateral and ventral margins, but separate above. A gill is thus a deep trough with a V-shaped cross-section. Vertical partitions in the trough (**inter-lamellar junctions**) divide it off into distinct compartments called **water tubes.** These partitions can easily be seen on the dorsal border of the gill. The lamellæ themselves are wicker-like, being made up of a great many vertical **gill filaments** connected by horizontal **inter-filamentar junctions.** The spaces between the filaments and the junctions are called **ostia.** Through these openings pass the water currents induced by the action of cilia along their borders. Up through the vertical water tubes, back along the suprabranchial passages and out at the exhalant siphon the water continues to flow, aërating in its passage the blood in the walls of the gills. The cilia also aid in sweeping forward the food particles to where they can be helped along by the cilia of the labial palps.

Exercise 6. *Study, under the microscope, bits of tissue scraped from the gills and from the inner surface of the palps of a live mussel. Watch the action of the cilia. Make a diagram of the structure of a gill.*

THE NERVOUS SYSTEM.—The nervous system consists principally of the three groups of ganglia and their commissures. On each side of the œsophagus is a **cerebro-pleural ganglion,** the two connected by the **cerebral commissure.** From these two ganglia a pair of commissures runs back to the **visceral ganglion,** placed on the ventral side of the posterior adductor muscle; another pair also runs down to the **pedal ganglion,** situated at the junction of the visceral mass with the foot. The pedal ganglion and the visceral ganglion are likewise connected by a pair of commissures. None of these ganglia or commissures will be demonstrated in this exercise.

DEVELOPMENT.—The impregnated eggs of the mussel pass into the cavity of the outer gill, which thus forms a brood pouch and becomes very much distended. In these brood pouches the young hatch and undergo considerable development. After a time they pass out at the exhalant siphon and attach themselves to fishes by means of hooks on their tiny shells. Becoming encysted, they lead a parasitic life for eight or ten weeks before beginning their proper free existence.

A SNAIL.

Phylum XI, MOLLUSCA; class 3, GASTROPODA; sub-class 2, EUTHYNEURA; order 2, PULMONATA.

HABITAT.—The most common of our snails in the middle West are the fresh-water forms found in ponds, stock tanks, and running streams. The species are all comparatively small, and, in fact, the same may be said of our terrestrial species. We should look for the latter in damp situations under boards and stones or the bark of decaying logs. In the eastern part of our country and in Europe larger species occur some of which are used for food.

Technical Note. By scraping the sides of watering troughs with a large dipper having a perforated bottom, or by dredging in ponds with an insect net one may easily obtain a supply of snails. If placed in aquaria containing algæ or other growing plant life they may be kept indefinitely. They can then be transferred to a tumbler or to a shallow glass dish when wanted for study. With the aid of a hand lens you should be able to make out all the details of structure indicated in this exercise. Specimens may be killed in an expanded condition by placing them for a few hours in a tightly corked flask of water that has been allowed to cool after boiling for some time to exclude the air.

MOVEMENTS.—Note the snail's method and rate of progress. Though proverbially slow, it moves faster than its relative the clam. Does the direction in which it moves indicate a head end? Would you characterize the movement as creeping, crawling, gliding, or swimming? Touch the animal with a pencil or stick and note results. Some of the specimens in the aquarium will probably be found floating on the surface of the water or clinging to the glass at its edge. Disturb one of these and observe how it sinks to the bottom. How was it able to remain afloat? Did you notice a bubble of air escaping as it descended? Can it rise to the surface again?

EXTERNAL FEATURES.—The details of structure may be studied in the following order:

a) Observe first the univalve **shell** which always conceals a part of the body, and into which the entire animal may withdraw when seeking safety. In what respects does it differ from the shell of a clam? The pointed end is called the **apex,** the opening at the other end the **aperture.** Between apex and aperture are a number of spiral turns or whorls, the larger—lower—one termed the **body whorl,** the other constituting the **spire.** How many whorls in the spire of your specimen? The spiral grooves separating the whorls are the **sutures.** More or less at right angles to these are very many fine striæ, the **lines of growth,** each indicating a former position of the **lip** or outer rim of the aperture. What part of the shell corresponds to the umbo of the clam?

b) Determine the direction of the spiral turns in your specimen. To do this hold the shell with apex up and the aperture turned toward you. If the lip is to the right the spire is a right-handed or **dextral** one; if to the left, it is left-handed or **sinistral.** The interior axis around which the spiral coils is called the **columella.** This axis can be demonstrated by sawing the shell of a large sea snail from apex to aperture.

c) The fractured edge of a snail shell will show the same three layers appearing in the shell of the clam. The outer of these, the **periostracum,** is tough and horn-like; the inner is the **pearly layer,** smooth and of beautiful luster. Between the periostracum and the pearly layer is the thick **prismatic layer.**

Exercise 1. *Draw the empty shell of a snail in the position referred to in b), if necessary enlarging considerably to show detail.*

Exercise 2. *Draw the longitudinal section of a sea snail shell furnished you by the instructor.*

d) Turn now to the occupant of the shell and note the **foot** or broad disc on which the animal creeps. In some sea snails there is attached to this an oval piece of calcified material, the **operculum,** which closes up the aperture of the shell like a lid when the animal has withdrawn into the interior.

e) The snail has a distinct **head** bearing a pair of **eyes** and one or two pairs of **tentacles.** Are the eyes, in the species you are studying, at the base of a pair of tentacles or at the tips? Which position of the eyes is associated with two pairs of tentacles?

f) Look for the **mouth** on the under side of the head and closely applied to the surface of the glass. Is it longitudinal or transverse with respect to the longer axis of the body? The animal feeds by rasping the surface of a leaf, or that of the algæ-covered glass, with a curious tongue-like **radula.** Watch the process if possible. In some European localities the land snails are abundant enough to be very destructive in gardens.

g) The **mantle** enwraps that portion of the body within the shell. It can be seen only at the edges of the aperture.

Exercise 3. Draw an enlarged side view of the snail extended as in creeping. If the subject moves about too much, use a specimen killed as suggested in the technical note.

Look for the eggs of the snail on vegetation in the aquarium or on the glass. They appear as dark specks enclosed in globules of gelatinous substance. In molluscs of the sub-class to which land and fresh-water snails belong the sexes are united, the animal being hermaphroditic.

Whether living in fresh water or on land, snails are air-breathing, the so-called **lung** being a sort of sack richly supplied with blood-vessels. Watch the fresh-water snails getting the air.

Interesting points of comparison with snails are furnished by the closely related slugs, common enough in most localities. These possess no shell, or at least but the rudiments of a shell.

LOLIGO PEALII (A Squid).

Phylum XI, MOLLUSCA; class 4, CEPHALOPODA; sub-class 1, DIBRANCHIATA; order 1, DECAPODA.

HABITAT.—The species of Cephalopod which forms the subject of this study is common along our Atlantic coast, sometimes occurring in schools. Its rapid movements, its changing play of colors, and its large staring eyes make it an object of more than ordinary interest, even to the causual observer of shore life. Other species and other genera are distributed in seas the world over. They live on small fishes, crustaceans, and the like, and in turn form the food of larger animals of the same groups they themselves feed upon. They are very generally used for bait by the fishermen of some coasts. In a few localities they are used also for food by human beings.

Technical Note. As squids are readily taken in trawl nets or fish pounds, a supply for laboratory purposes can be secured from some marine distributing station. When preserved material is to be used male specimens having the vascular system injected are much to be preferred because of the facility with which details can be made out. For complete dissection, however, it is best to have on hand specimens that have not been injected so that the more expensive material need not be torn to pieces, but may be kept for succeeding classes. As a preservative solution formaldehyde should be used in all cases in preference to alcohol. Of course if the student lives near the sea shore fresh or living specimens should be secured.

EXTERNAL FEATURES.—Having thoroughly soaked or washed the formaldehyde from a preserved squid, place it in a pan of water and note the following:

a) The cylindrical **body** tapering somewhat toward one end. Scattered over its surface are a great many pigment spots, or **chromatophores.** During life the size and shape of these spots, by muscular action, can be changed at will, producing the play of color referred to in the notes on habitat. What useful purpose might this change of color serve in the economy of the animal?

b) At one end of the body, and on the plane of one part of the surface, is a broad **swimming-fin.** At the other end of the body is the large **head** bearing a circular group of **arms.** How many of the latter? Are they all alike in shape and appearance? Is there any symmetry in the arrangement of the arms or that of the external parts of the body in general?

c) On a portion of the surface of each arm are a great many **suckers** grouped in orderly arrangement. Study this arrangement. Is it the same on all the arms?

d) Clip one of the larger suckers from an arm and study its structure. You will observe a stalk-like part, the **peduncle,** and a cup-shaped portion having a thin outer rim. Within this rim is a horny ring and, in the central depression of the cup, a disc-like **piston** forming a continuation of the peduncle. It will be left to the student to suggest the function of each part of the sucker.

e) A pair of large **eyes,** resembling those of a vertebrate animal, are a conspicuous feature of the squid. They usually lack fullness in a preserved specimen, partly due to the fact that the sea water, which can enter the space between the **cornea,** and the **pupil,** has drained out through the opening by which it had entered. Locate this small opening in the space between the eye and the base of the arms. Can you suggest a use in the optical mechanism for this enclosed sea water?

f) A fold of tissue on the side of the head behind the eye is termed the **olfactory organ.**

g) Push aside the arms and note, in the center of their enclosing circle, the **mouth.** Partly protruding from the mouth, or at least not far down in its cavity, may be seen the tips of a dark colored horny **beak** somewhat resembling that of a parrot.

h) The student will observe that the neck of the squid projects from a cavity formed by an enclosing circular wall of firm, thick tissue. This cavity is the **mantle cavity,** into which the head and neck may be partly retracted by means of muscles to be shown later. The outer covering of the squid is, therefore, not the true body wall but the **mantle.** Refer here to your notes on the mussel and the snail, a study of which forms should have preceded this. The free edge of the mantle, surrounding the neck, is called the **collar.**

i) Protruding from the collar on one side of the body is a funnel-shaped organ, the **siphon.** Note its terminal opening. The siphon may also be partly retracted into the mantle cavity.

Exercise 1. *Make a drawing of the side of the animal on which the siphon is located, reducing the scale to one-half natural size.*

Exercise 2. *Draw a top view of one of the suckers, and a side view of the same after it has been split vertically through the cup and the peduncle. Enlarge enough to show detail.*

ORIENTATION OF THE SQUID.—In order to avoid confusion no reference has thus far been made to anterior and posterior end or to dorsal and ventral surface of the animal. To get a clear idea of these relations of parts stand the squid on its head, spreading out the arms so that it will maintain this erect position. The arms now correspond in position, and are really homologous in development, to the hatchet-shaped foot of the mussel and the broad, creeping belly-foot of the snail; hence the term Cephalopod (head-footed). The siphon is also a modification of a part of the foot—that part which, from the position of organs in the mantle cavity, is shown to be the posterior. The surface on which the siphon is located is thus in reality the posterior and that to which the fin is attached the anterior. The ventral surface is represented by the end of the head and the outspread arms on which the animal is resting, while the dorsal surface is reduced to the rounded opposite end of the body.

Since the squid never naturally maintains this position, however, but rests or swims about with the longer axis of the body in a horizontal position, we shall hereafter in these notes disregard the true morphological relation of parts and call the head the anterior end for convenience sake. From this it will follow that the rounded tapering end of the body will be the posterior. The surface having the fin is uppermost in swimming and will therefore be termed the dorsal. The position of the siphon will determine the apparent ventral surface.

Technical Note. If you have an injected specimen supplied by some marine laboratory the mantle cavity has probably already been opened. If not, make a longitudinal incision a little to one side of the mid-ventral line of the mantle, extending the cut from the collar nearly to the posterior end of the body. Turn back the flaps of the mantle and fasten them down in some way. Place in the dissecting pan, head from you, and cover with water.

THE MANTLE CAVITY.—Study the organs exposed by the above dissection and observe that they are attached to the mantle only in the mid-dorsal line and that the collar is entirely free from the head and neck. Note the following:

a) The **pen,** a hard structure whose thin edges show at the sides of the **visceral sac** occupying the posterior third of the mantle cavity. It protects the other organs from injury on the dorsal side. Its form and structure can best be studied in another dissection.
b) The siphon widens out posteriorly and has on each side a bulging **lateral pocket** opening toward the mantle cavity. When distended with sea water these serve to close the opening between the mantle collar and the neck. The approximation of the **mantle cartilages** to the **siphon cartilages** also contribute to this end. The former appear as a pair of longitudinal thickened ridges on the mantle collar, the latter as a pair of trough-like depressions on the sides of the siphon.
c) Slit open the siphon at the outer end and look for a **valve.** Which way does the latter open? By powerful rhythmic contractions of the mantle water is alternately drawn in around the neck and forced out at the siphon. Study out the principle by which locomotion is thus caused. Which way will the animal move? Why do the rhythmic contractions go on when the squid is not moving about? How is the generai shape of the body adapted to the method of locomotion?
d) Note the heavy cord-like structures attached to the sides of the

siphon. These are the **retractor muscles** of the siphon. Beneath them are the similar **retractor muscles** of the head. Explain the function in each case. How could the former pair operate to affect the direction of movement in swimming?

e) Running forward almost to the rear opening of the siphon, midway between the retractor muscles of the latter, is the posterior portion of the alimentary canal—**rectum**—ending in the **anus.** Note the two flap-like **rectal-valves** bordering the anus. What is their probable function? It is evident, then, that the alimentary canal, which begins with the mouth, has doubled back on itself and that this arrangement will permit the fœcal matter to be swept out with the current of sea water ejected from the siphon. Compare this arrangement with that of the mussel.

f) Beneath the rectum, and bulging out on each side of it, is the **ink bag.** It opens by a small duct into the rectum, as can be demonstrated in another specimen by slitting the rectum for a short distance back from the anus and gently pressing the ink bag to force out the contents. If you have a chance to study the living animal prod it with a pencil and note results. What purpose is served by thus clouding the surrounding sea water with ink?

g) Ink bag and rectum are attached to the other organs by strips or films of connective tissue called **mesenteries.** Look for similar attachments elsewhere.

h) Prominent on each side of the group of organs in the mantle cavity is a long plume-like structure, the **gill.** How does its position and its structure adapt it to its function?

i) Between the left gill (on your right) and the rectum will be seen the tubular **penis,** a male organ of reproduction. In the female a portion of the **oviduct** will be similarly located.

j) A thin transparent membrane, the true **body wall,** envelops the visceral mass. Account for its being so frail.

k) Push aside the head and note a pair of large nerve centers, the **stellate ganglia,** with their short nerves radiating to the mantle.

l) Running from the base of each gill to the mantle is a **branchial retractor muscle.**

m) Note, in the posterior region of the rectum, a pair of small protuberances or papillæ. On these are located the external openings of the **kidneys.** The latter are merely capsules or cavities with such delicate walls that their form and extent can be demonstrated only by reference to certain parts of the blood circulatory system.

Exercise 3. Begin a sketch of the mantle cavity on a convenient scale, labeling all of the organs thus far determined.

THE CIRCULATORY SYSTEM.—Locate and study the following parts of the circulatory system and get a clear idea of the course of the blood:

a) At the base of each gill is a rounded, light colored organ, the **branchial heart.** A **branchial artery,** running thence along the dorsal side of the gill, carries the blood to the latter organ to be oxygenated.

b) Three sets of vessels bring the blood to the branchial hearts. These are the **anterior venæ cavæ,** the **posterior venæ cavæ,** and the **mantle veins.** The single trunk of the anterior vena cava may be seen emerging from beneath the posterior opening of the siphon and passing back under the rectum. Just anterior to the external openings of the kidneys it divides, one branch passing around each side of the rectum and entering the cavity of the corresponding kidney. Here the branches widen into the **glandular portions** of the anterior venæ cavæ, which, being easily made out, help to determine for the student the position and extent of the kidneys.

c) The posterior venæ cavæ may be seen to spring from the mantle laterally to the anterior end of the visceral sac. Each widens rapidly and runs forward to the region of the branchial hearts. Between the latter each terminates in a small **glandular portion** connected with the corresponding division of the anterior vena and occupying the posterior part of the kidney capsule. The connections of these glandular portions with each other and with the branchial hearts can not be demonstrated in this dissection.

d) Lift up the gills and note on each side, the mantle vein arising from the anterior portion of the mantle surface and running back to the branchial heart.

e) Between the branchial hearts and a little forward is a median, somewhat irregular, firm structure, the **systemic heart.** As it is concealed by portions of the venæ cavæ its location need not be verified until the student takes up the next dissection.

f) The **branchial veins** running along the ventral surface of the gills return the blood from the latter organs to the systemic heart.

g) The **posterior aorta** arising from the systemic heart can readily be seen. It is quite short, dividing almost immediately into three branches. These are a **median mantle artery** and two **lateral mantle arteries.** Trace the course of each of these branches.

h) An **anterior aorta** and several smaller arteries spring also from the systemic heart. The course of the former will be traced in the next dissection.

Exercise 4. *Complete the sketch begun in exercise* 3.

Exercise 5. *Make a diagram of the circulatory system, including the gills. Label the parts and indicate by arrows the direction of the blood currents.*

Technical Note. Use a male specimen for this dissection if obtainable. Remove the entire siphon and its retractor muscles, taking care not to injure any other organs. Cut away the lower surface of the head until you come to portions of the alimentary canal. Carefully remove also the thin body wall in the region of the visceral sac, the anterior and posterior venœ cavœ, the gills, and the branchial hearts. The systemic heart may be freed from its attachments, but the anterior aorta should not be served.

THE DIGESTIVE SYSTEM.—Note the following relations and parts, making further dissections when necessary:

a) In the head is the large bulbular **pharynx** enclosing near its anterior rim the beak.

b) Running back from the pharynx is the slender **œsophagus.** Trace the latter to the base of the head, where it passes under a large elongated glandular organ.

c) This glandular organ is the **liver.** Its posterior limit may be found in a pointed projection beneath the kidneys.

d) Passing into the head in company with the œsophagus is the anterior aorta previously mentioned in this exercise. Locate it. Just under the anterior end of the liver is a small median **salivary gland** whose duct also follows the œsophagus into the head.

e) Snip the mesenteries that tie down the rectum and ink bag and turn these organs back. Just where the **intestine**—of which the rectum is a continuation—bends upward from the other organs beneath it passes between the two lobes of a gland sometimes called the **spleen,** sometimes the **pancreas.** Just in front of this organ, on the left side of the body, the anterior aorta and the œsophagus emerge from the liver, having passed through it from beneath.

f) A pair of very delicate transparent **hepatic ducts** arise from the liver near the same point and pass back through the lobes of the pancreas with which they are intimately connected.

g) A thick walled **stomach** follows next. Find the points where the œsophagus enters and the intestine leaves this organ. Trace also the anterior aorta back to the systemic heart.

h) Connected with the stomach is a large thin walled **blind sac** extending back and occupying most of the conical space enclosed by the walls of the mantle cavity. The hepatic ducts, previously noted, probably pour their secretions into this sac instead of directly into the stomach.

THE REPRODUCTIVE SYSTEM.—

Technical Note. Sever the mesenteries and carefully remove the penis and all organs attached to it. Place in water and straighten out the parts as much as possible.

You should be able to make out the following divisions:

a) The **spermatophoric sac** following the penis and forming much the largest division of the tract. In contains the **spermatophores.**

b) Bending forward from the posterior end of the spermatophoric sac and running along its left side for half its length is the **vas efferens,** a tube of smaller diameter than the penis.

c) The vas efferens ends in an enlarged convoluted portion of the tract, the **seminal vesicle.** This has two or three minor divisions.

d) From the seminal vesicle the convoluted **vas deferens** leads posteriorly.

e) Remaining in the mantle cavity beneath the blind sac of the stomach is the large, flat, elongated **testis.** The student will note that it was not connected with the rest of the reproductive tract, but is attached to the stomach. It lay in a thin membranous capsule of its own which was probably torn in the dissection. The vas deferens communicated with this capsule.

In the female the single **ovary** occupies a position corresponding to that of the testis in the male. It is likewise surrounded by a capsule, which in this case communicates with an oviduct running forward and opening into the mantle cavity to the left of the rectum. Along its course is the **oviducal gland.** A pair of large light colored **nidimental glands** overlie all the other organs in the central region of the body. These secrete the shells or capsules for the eggs.

Exercise 6. *Remove the alimentary tract, with the attached testis, place in water, arrange the parts in proper order, and make a diagram or sketch.*

Exercise 7. *Sketch the parts of the male reproductive system.*

Exercise 8. *Open the pharynx and examine the beak. Draw the latter.*

Exercise 9. *Open the spermatophoric sac and secure some of the slender spermatophores. Place in a watch glass and examine with lens or microscope. Draw one of the spermatophores on an enlarged scale, showing the enclosing sheath, the coiled discharging apparatus, and the opaque mass of spermatozoa.*

Exercise 10. *Remove the pen entire by making an incision carefully in the mid-dorsal line of the mantle and withdrawing the pen from its sheath or pocket. Draw the pen.*

A study of the nervous system will not be undertaken in these notes. The stellate ganglia have already been observed. All the other large nerve centers are in the head, protected by cartilaginous structures. They can be studied only by making serial sections of the head with a sharp scalpel or a razor.

THE CATFISH (*Ameiurus* sp. or *Ictalurus* sp.).

Phylum XII, CHORDATA; sub-phylum, 3, VERTEBRATA; class 2, PISCES; sub-class 3, TELEOSTOMI; order 4, TELEOSTEI.

HABITAT.—The catfish family contains about one thousand species, the majority of which are confined to the tropical waters of South America and Africa. Only a few species are marine, all the others inhabiting fresh-water streams, ponds, and lakes. In the United States we have thirty recognized species distributed through the streams that discharge their waters into the Atlantic or the Gulf of Mexico. There are no native catfishes in the fresh waters of our Pacific coast region. As a whole the family may be said to be adapted to the warmer and more turbid waters of prairie and plain countries.

Technical Note. Inasmuch as the taking of small catfish or bullheads for class study will certainly come within the provisions of the "Scientific Use" clause of most fish and game laws, specimens might be caught in ponds or creeks with an improvised seine of some sort. Enough material might also be secured with hook and line, as the common bullhead bites readily at any kind of bait. The catfishes are very tenacious of life and may be kept alive a long time in a tub or barrel if given proper care. They should be supplied with food and the water should be changed frequently, or aerated by dipping it up and pouring it back into the vessel. In watering troughs or stock tanks the fish will thrive for months without attention. Specimens preserved in three to four per cent formaldehyde will do very well for a study at least of the external anatomy. A short piece of stiff hollow reed or of straw should be inserted into a slit in the ventral wall of the body so that the preservative fluid may reach the viscera.

EXTERNAL DETAIL.—Note the following relations and parts in your study of the catfish:

a) The elongated body, only slightly compressed, terminating anteriorly in a large depressed **head** and posteriorly in a **tail.** Between the two extremes is the **trunk,** not sharply distinguished from either. Is there any region which could properly be called a neck? Arbitrary limits have been assigned to the three body divisions, however; these will be discussed later.

b) Observe the color of the catfish. Is there any good reason why the under parts should be much lighter than the sides and back? Recall the appearance of the fish as you saw it swimming lazily about near the bottom of a shallow pond. Place a live catfish in a pail or box having a glass bottom and view the animal from beneath, excluding from your eyes all light except that which comes down through the water.

c) Examine carefully the **skin** on different parts of the body. Is there any evidence of the scales you find in some fishes?

d) Running along each side of the fish is a row of small tube-like papillæ constituting what is called the **lateral line.** Examine it with a hand lens and determine its anterior and posterior limits. Its intimate association with a prominent nerve beneath the skin leads to the conclusion that its function is sensory.

e) Observe now the organs of locomotion and equilibrium—the **fins.** These may be divided into two classes—those situated in the sagittal plane of the body, and the paired fins corresponding to the limbs of the higher vertebrates. How many fins of each class are present in the catfish? The one on the mid-dorsal line, just back of the head, is the **dorsal fin.** Like all of the others, except one, it is supported by **fin rays.** Behind this fin, near the tail, is the **adipose fin,** a small projecting flap unsupported by rays. The tail ends in a **caudal fin,** forked in some fishes, truncated or rounded in others. What is the form in your specimen? Do you know any fish in which the upper fork is much longer than the lower? In front of the caudal fin, on the under side of the body, is the **anal fin.**

f) The paired fins are more lateral in position. The front pair—**pectoral fins**—is connected with a firm girdle of bones encircling the body in that region. Prove this by feeling these structures. Determine also the extent of the "girdle" to which the hindermost or **pelvic fins** are attached. Compare with some small scale fish in which the pelvic fins are so far forward as to be beneath the pectoral.

g) Spread the fins, one at a time, and count the fin rays in each. Examine with a lens and note that all the rays are jointed like the antennæ of a crayfish and that they bifurcate one or more times. The web of the fin is simply a sharp fold of skin enclosing the rays. Are the latter connected in any way with the endoskeleton? Satisfy yourself on this point by cutting down into the flesh on the right side of the dorsal fin. How many of the fins are provided with a stout **spine**? What purpose do these spines serve?

h) About the **snout** are a number of long, projecting filaments, the **barbels.** Count them. The largest pair, at the corners of the wide **mouth,** are the **maxillary barbels.** Move one of the latter about and note that it is attached to a short cylindrical bone, the **maxilla.** This bone is better developed in the common scale fishes. Is there any probable connection between the name "catfish" and the presence of these barbels? What is their function?

i) It will be noted that the **eyes** have no lids and that there are no external evidences of the **ears.** Determine the number and position of the **nostrils.** Probe them to see what connection they may have with one another. Do you find any opening from the nostrils into the mouth?

j) The mouth is terminal in the catfishes. Compare with a sucker in this respect. Look for the **teeth,** which are located on pads at several places. The two pads just inside the upper lip are borne on the **premaxillary bones.** Are the latter united in the median line? Similarly situated on the **dentary bones** of the lower jaw, or **mandible,** are the **mandibular teeth.** Rub the tip of your finger over them to see which way they project.

k) Elevate the **tongue** by pressing down with the thumb on the mandibular pads of teeth and upward with the fingers on the under side of the lower jaw. Has the tongue much freedom of movement?

l) Just above the **pharynx** are two pads of teeth, the **upper pharyngeals,** one on each side of the median line. Below are the **lower pharyngeals,** so situated as to meet the upper when the mouth is closed. Feel of these pads.

m) At each side of the head is a flap—the **operculum**—covering the **gills.** It is supported by several **opercular bones.** Lift the flap and examine the bony **gill arches** bearing the red **gill filaments.** How many such arches are there? On the borders of the gill arches note the rows of hard, tooth-like projections constituting the **gill rakers.** Do they occur on both margins of all the arches? Are the projections all of equal length? Watch a live fish in a glass jar until you understand the cause and the direction of the current of water that passes over the gill filaments to aërate the blood. What part would the gill rakers play in this respiratory process? The slits between the several arches are known as the **gill clefts.**

n) Just back of the barbels on the chin is a V-shaped fold of skin with the open part of the V directed backward. This is the **branchiostegal** membrane. It is supported by a number of bony **branchiostegal rays.** Determine the number and shape of these rays. The narrow region at the apex of the V is called the **isthmus.**

o) Look for the **anal opening** a short distance in front of the anal fin. Just back of the anus is the **urino-genital aperture** of the male, a common exterior opening for the renal excretions and the reproductive elements. In the female of the catfish the urinary duct and egg duct open externally on separate papillæ. We have thus a means of distinguishing the sexes without dissection, remembering that there are three separate openings in the case of the female and only two in the case of the male. Is this true of all common fishes?

MEASUREMENTS.—With ruler and dividers take the following measurements: Head, the distance from the tip of the snout to the posterior angle of the operculum; snout, distance from tip of nose to anterior border of eye; trunk, distance from the posterior angle of the operculum to a mid-lateral point directly above the anus; tail, the distance from the latter point to the base of the caudal fin; depth, the greatest vertical diameter; width, the greatest diameter from side to side. How many times is the width contained in the total length? The region between the anal and the caudal fins is the **caudal peduncle.**

Exercise 1. *Make an outline drawing of the left side of the fish, natural size if the specimen is not over five inches long. Represent the mouth open slightly and the fins extended in the normal position when swimming. Give attention to the actual number of rays in the fins. Label all the parts.*

Exercise 2. *Make an outline sketch of the ventral surface of the head and a small portion of the trunk.*

Exercise 3. *Remove the operculum on the left side and sketch the head and gills.*

Exercise 4. *Split the mouth from the corners to the upper angle of the operculum in order to get a better view of the interior. Make one diagram of the roof of the mouth and one of the floor.*

Exercise 5. *Remove and draw, on an enlarged scale, the spine of the dorsal fin and one of the longer jointed fin rays.*

INTERNAL ANATOMY.—With a fresh specimen, if obtainable, or a preserved one from which the formaldehyde has been thoroughly rinsed, we will proceed to a study of the internal organs.

Technical Note. With the scissors make an incision in the mid-ventral line of the body at a point just ahead of the anus. From here cut transversely right and left as far as the thin ventral wall extends, thence forward on each side to the shoulder girdle. Turn forward the flap thus partially cut free, or remove it entirely by cutting across back of the shoulder girdle.

Exercise 6. *Without displacing any of the organs exposed by the dissection, draw them in position, identifying later such as you are not familiar with.*

Note the following as the specimen lies on its back in a dissecting pan:

a) The **peritoneum,** a thin, silvery, pigmented lining to the **abdominal cavity.**

b) The **liver,** a dark-colored, lobulated organ in the front part of this cavity. Note its position in relation to the other organs, and the inequality of the lobes. On its dorsal surface is the **gall bladder** containing the greenish **bile.** By gentle compression force the bile into the **bile duct,** thus demonstrating the location of the latter and its communication with a region of the digestive tract. How is the liver supported in the abdominal cavity?

c) Look for the **œsophagus** entering the cavity through its anterior wall. It soon enlarges into a pouch-like **stomach** which, in turn, is followed by a short division of the **intestine** known as the **duodenum.** At the junction of duodenum and stomach there are, in some species of fish, a number of blind pockets called **cœca.** Are there any in your specimen?

d) Beneath the stomach is a small, dark red gland, the **spleen.**

e) Stomach, intestine, and spleen are suspended from the dorsal wall of the abdominal cavity by the **mesentery,** a fold of peritoneum. Intimately connected with the mesentery is usually more or less fatty tissue. Trace the intestine to the anus. Straighten out its folds, by tearing the mesentery, and compare its length with that of the trunk. At what point does the bile duct enter? Snip off the alimentary canal just ahead of anus and stomach, respectively, and remove it. Remove also the liver.

f) In the dorsal wall of the œsophagus, a short distance from its posterior end, is an opening into a tube leading to the **air bladder.** Demonstrate the connection by inflation or by a small, flexible, blunt probe.

g) Note the inflated condition of the air bladder and the proportionately large amount of room it takes up in the body cavity.

Understand its function and the reason for its connection with the œsophagus.

h) In the hinder part of the abdominal cavity are the **reproductive organs,** partly overlying the air bladder. The **testes** of the male are long, depressed, grayish white structures, lobed on one border and straight along the other. The reproductive elements are discharged through a pair of tubes—**vasa deferentia**—which unite before opening into the urino-genital sinus. The **ovaries** of the female are cylindrical in form and bluntly pointed at both ends. The two **oviducts** unite for a part of their length, like the vasa deferentia, but, instead of opening into a urino-genital sinus, the united ducts discharge the eggs through a separate orifice located between a **urinal aperture** and the anus.

i) A small **urinary bladder** may be located a short distance ahead of the urino-genital sinus (male) or urinary papilla (female). Note its connection with one or the other of these openings and also, by means of the **ureters,** with the **kidneys.** The latter are long, dark colored, irregular organs, partly fused together and adhering closely to the dorsal wall of the abdomen. By means of a beaded bristle trace the connections of the external openings with the organs considered in this and the preceding paragraph.

Exercise 7. Make a diagram of the arrangement of the urinary and reproductive organs of the female, together with their ducts and external apertures. Make a similar diagram for the male.

j) By removing the pectoral fins and the portion of the pectoral girdle included between them, the cavity occupied by the **heart pericardial cavity**—will be exposed. This cavity is bounded posteriorly by the **false diaphragm.** Taken together, the pericardial and the abdominal cavities constitute the **cœlome.** Note the way in which the heart is protected from injury. Its four parts can be readily made out: Posteriorly is the **sinus venosus,** a semi-transparent enlargement of the returning blood vessels. This is preceded by the lobed **auricle,** which, in turn, connects with the single **ventricle,** the firmest and largest division of the organ.

Arising from the front of the ventricle is the light colored, conical **bulbus arteriosus** from which spring the branches of the arterial system.

The dissection of the brain and other portions of the nervous system will not be taken up in this exercise.

Exercise 8. *Make a drawing of the heart on an enlarged scale, showing its several divisions.*

THE FROG, OR THE TOAD.

Phylum XII, CHORDATA; sub-phylum 3, VERTEBRATA; class 3, AMPHIBIA; order 2, ANURA.

HABITAT.—Frogs are common the world over. They abound in marshy places or along fresh-water streams and ponds, spending part of the time in water and part on land. Their eggs are laid on plants or sticks in the water, and the young, known as tadpoles, live a truly aquatic life for some weeks, breathing by gills and swimming by means of a broad, well developed tail. Later the tail is absorbed, the gills functionally give place gradually to lungs, limbs appear, and the young frog is ready to hop about on the shore. Certain species known as tree frogs lead an arboreal life after leaving the water.

The life history of the toad reads about the same as that of the frog, except that the former, after the period of his tadpole existence, wanders farther away from the waters that his infancy knew and takes up his abode in gardens or, in fact, almost anywhere that vegetation offers concealment and cooling shade. The so-called "horned toad" of the plains is in reality a lizzard.

Technical Note. This outline will serve equally well for a study of the frog and the toad. Most students prefer to handle the former on account of certain ungrounded prejudices against the toad, but the latter is usually more easily obtained and kept alive until wanted. Frogs may be easily taken with an insect net as the collector walks along the water courses they frequent. They may be kept alive for a long time in a box, having a few holes for ventilation, stored in a cool, damp place. Toads may be picked up almost anywhere after dark. They are especially numerous under the electric lights on our city streets. They can be kept in a cellar until wanted, perhaps all winter for that matter. The box they occupy should be partly filled with damp earth.

THE LIVE FROG.—Place a frog in a pail of water and note its position when floating and movements when swimming. Does it exert itself to keep afloat? How much of the body is submerged? Observe the relative position of the limbs and the toes.

Notice a frog or a toad sitting at rest. Describe the relative position of the parts of each limb. Do you see the hump? We will learn the cause of that later. Touch the eyeballs and note results.

Describe the movements of certain parts in the process of breathing. Near the posterior end of the backbone, on each side, slight pulsations of the **lymph hearts** may sometimes be seen.

Keep toads in a roomy observation box for some days and feed them all sorts of insects. Record their preferences for certain kinds, if any are shown. Gauge their capacity for food by feeding them all the insects they will eat. Keep records of individual gastronomic feats. Try them on certain noxious insects of the garden. Understand their method of snapping up the food.

Exercise 1. *Make a drawing of the live toad in a sitting position, natural size or nearly so.*

Technical Note. Select two or three frogs whose abdomens are but little distended, place them in a jar or pail fitted with a tight lid, and introduce a wad of cotton saturated with chloroform. In about five minutes remove the lifeless animals and rinse them off. The rinsing is especially necessary if you are using toads instead of frogs, as the former excrete from pores in the skin an acid substance having a disagreeable odor. In life this excretion was a source of protection to them.

External Features.—Look the animal over carefully, noting the following structural points:

a) Two regions of the body, **head** and **trunk.** Determine the line of division between the two by moving the head up and down. Neither neck nor tail are in evidence. How would you characterize the shape of the body as a whole?

b) Compare the **fore limbs** with the **hind limbs** in size. Why the great difference? You will note that the divisions of the limbs are the same—an **upper arm,** a **forearm,** and a **hand** in the former, and a **thigh,** a **shank,** and a **foot** in the latter case. Locate **knee, heel, elbow,** and **wrist.**

c) Count the **digits—fingers** and **toes.** Do any possess nails? What is the use of the **web** between the toes? Look for a hard pad on the palm of the toad's hand, and for a spur just inside the inner toe.

d) The **skin** is so loose that it can be gathered up in folds here and there. It is kept moist by a secretion of mucus, and plays an important part in respiration. This explains how a frog is able to remain under water so long and to hibernate in the mud for months. The fact that the toad's skin is rough and warty has given rise to the superstition that its excretions will, by contact, produce warts on the hands of human beings.

e) Study the color pattern of the skin with reference to its utility. Are there any evidences of protective coloration?

f) The gape of the mouth is unusually wide, extending considerably behind the **eyes.** The eyes are large and quite prominent, though capable of some retraction as can be seen by looking at the roof of the mouth while pushing on the eyeball with the finger. Observe a heavy **upper eyelid** and a thin fold of skin, the **nictitating membrane,** arising from the lower margin of the eye. Move both about with the forceps.

g) A short distance behind and below the eye is a circular area of tightly stretched skin, the **tympanum** or **ear-drum.**

h) The **nostrils** are located on the dorsal surface of the snout near the tip. Open the mouth and locate the **inner nostrils** by thrusting a blunt probe through the external openings.

i) Do you find any **teeth** in the mouth? If so, what is their nature and where are they located?

j) Push a probe through the ear-drum and look for its appearance in the mouth cavity. This internal opening is the entrance to a short **Eustachian tube** designed to equalize the pressure of the air on the tympanum.

k) Examine the **tongue.** What is its shape? How is it attached to the floor of the mouth? What advantage in this method of attachment?

l) In the back part of the mouth cavity, on the floor, is a short, centrally located slit, the **glottis.** Through this slit air is forced into the lungs from the mouth. Understand the several movements in respiration that would contribute to this result.

m) The **anus** is centrally located at the posterior end of the body.

n) The male of some species of frogs has, at the corners of the mouth, a loose fold of skin forming the **vocal sac.** This is inflated into a globular form when the animal is calling.

Exercise 2. Draw the hand and the foot of the frog, with the toes outspread.

Technical Note. With a pair of scissors slit the skin along the mid-ventral line from near the anus to the front angle of the lower jaw. Notice how loosely it is attached to the muscular body wall beneath. Cut transversely right and left from the extremities of the first incision, lay the specimen on its back in a dissecting pan and pin out the flaps of the skin.

The Muscles.—The above partial dissection lays bare some of the principal **muscles** of the body. If desired, the skin may be stripped part way down the hind limbs, where the number and arrangement of the muscles is very similar to that in human anatomy. Each muscle is enclosed in a thin, transparent **muscle sheath** and is made up of many bundles of fibers similarly enclosed.

The muscles in the region of the arms are mainly attached to the **pectoral girdle,** those connected with the legs to the **pelvic girdle,** of which the **pubic bone** forms the center. The **abdominal muscles** are broad and sheet-like. Mount a few muscle-fibers and study with the microscope.

Technical Note. Cut through the thin abdominal wall from the pubic bone to the shoulder girdle. Separate the bones of the latter, cut transversely right and left, as when removing the skin, and pin out the flaps of muscle. Rinse with clear water as often as necessary. Keep the specimen under water or weak alcohol if you prefer.

Exercise 3. *Sketch, in the natural position, the internal organs thus exposed, including the outlines of the entire body.*

Exercise 4. *Draw a small bundle of muscular tissue and a single fiber of the same as seen under the microscope.*

INTERNAL ANATOMY.—The following notes will serve as a guide in locating and identifying the various internal organs; as the animal is lying on its back the student will bear in mind the reversal of the cardinal directions, "right" and "left:"

a) In the front part of the body cavity is the **heart,** still pulsating if you are using a fresh specimen. Time the pulsations for several minutes and see if they are regular. Remove the thin **pericardium** that envelops the heart. The lower, pointed part of the latter is the thick walled **ventricle;** the pulsating pockets at the top are the right and left **auricles.** Raise the point of the heart and watch the order of contraction. Near the top of the organ, and to the right of the center, is the **conus arteriosus** from which arise two large **arteries.** Follow these until you find each dividing into three branches—an upper, **carotid artery** going to the region of the head, a lower, **pulmonary artery** carrying the blood to the lungs and skin, and, between the two, the large **systemic artery.** The impure blood from the returning **veins** is poured into the right auricle, the pure blood from the lungs and skin into the left auricle. Both auricles discharge into the single ventricle, from which the mixed blood is sent out as indicated above in the discussion of the conus arteriosus.

b) Flanking the heart on each side and extending below it is the **liver.** How many lobes has it? Note the **gall bladder** attached between the two main lobes on the under side. If possible trace its connection, by means of a **bile duct,** with the alimentary canal.

c) To the left of the liver is the **stomach,** communicating with the back part of the mouth cavity—**pharynx**—through the **œsophagus.**

d) Trace the **small intestine** from the stomach to the **rectum,** an enlarged division of the tract near the anal end. The portion of the small intestine immediately following the stomach is the **duodenum.** There is no external line of division to separate it from the rest of the intestine. Find the place where it is entered by the bile duct.

e) The coils of the intestine are held together and the whole tract suspended from the roof of the abdominal cavity by a fold of the **peritoneal lining** called the **mesentery.** In the web of mesentery between stomach and duodenum is a light colored gland, the **pancreas.** Farther back along the tract is the small, dark, roundish **spleen.**

Exercise 5. *Make a diagram of the digestive tract, including liver spleen, and pancreas.*

Exercise 6. *Make a diagram of the heart, including the two main arterial trunks and the stubs of their first three branches.*

f) Lift the lobes of the liver to expose the **lungs.** These are pinkish organs each looking somewhat like an elongated strawberry. Thrust a blowpipe into the glottis and inflate them. How they swell out! Correlate this expanded condition with the act of floating. Tie a string around the neck of one of the lungs when inflated, cut the latter off above this point and lay it aside to dry. You will then observe that it is not a mass of spongy tissue, but a simple, hollow sack. The lungs are so close to the glottis that there is no need of an air tube or trachea. There is, however, a short **laryngo-tracheal chamber** stiffened by cartilage and containing the **vocal chords.**

g) Lying ventrally to the rectum is the large, thin-walled **urinary bladder.** It is probably empty and may be difficult to distinguish. If so, try inflation with a blowpipe inserted in the anus. The urinary bladder is connected by a small opening with the **cloaca** or posterior division of the alimentary tract. Into this vestibule open also the tubes from the reproductive and renal organs.

h) Remove the organs so far studied, saving the stomach for an examination of its contents. The numerous finger-like masses of yellowish tissue in the back part of the abdominal cavity constitute the **corpus adiposum** or **fat body.**

i) The **reproductive organs** lie to the right and left of the median line, the **ovaries** of the female probably more or less distended with very many small, dark **eggs** or **ova.** The long, coiled **oviducts** open at one end into the cloaca. Find the other end of the ducts by careful searching. How might the ova get from the ovaries into the oviducts? The two whitish, oval **testes** of the male discharge their products into the kidneys. From there they pass into the cloaca through the **urino-genital ducts.**

j) The elongated, dark colored **kidneys** are located above the reproductive organs. Trace their connection by means of the **ureters** (female) or urino-genital ducts (male) with the cloaca. It will be observed that the urinary bladder is not, as in the catfish, an enlargement of the ureter, but a pocket from the cloaca filling by gravitation.

Technical Note. Remove the remaining internal organs and rinse the body cavity. Make out such portions of the bony skeleton as can be determined without further dissection.

k) Note the several **vertebræ** forming the backbone. Determine the number if possible. Are there any ribs? The last vertebra, **sacral,** is followed by a long, slender bone, the **urostyle.** On each side of the urostyle is a part of the pelvic girdle called the **ilium.** The two ilia unite posteriorly, thus forming an arch shaped very much like the wish-bone of a bird. The anterior extremities of the arch articulate with lateral projections of the sacral vertebra. At these articulations we have the two humps so noticeable on the frog's back when sitting at rest. All these structures and arrangements can be made out, without dissection, by the sense of touch. Relate them to the animal's movements in jumping.

The Nervous System.—In a specimen that has been preserved in alcohol, or one that has been macerated for a day or so in 20 per cent nitric acid, dissect away carefully the roof of the skull and the top of some of the anterior vertebræ. Make out the following divisions of the nervous system in their order: **Olfactory nerves, olfactory lobes,** hemispheres of the **cerebrum, optic lobes, medulla oblongata,** and **spinal cord.** Note also the **optic nerves** running from the optic lobes to the eyes, and the **spinal nerves** branching off from the spinal cord.

Exercise 7. Make a diagram of so much of the nervous system as you have dissected out.

A more careful study of the circulation may be made by injecting a colored mass of some sort into the ventricle of the heart in a specimen recently chloroformed. The details of this process and study will be left to the student's investigation. A study of the blood circulation in the web of the frog's foot will also prove profitable and interesting.

If the eggs of frogs and toads are secured in the early spring, or their larvæ taken a little later, a study of the development of the tadpole is practicable in a properly arranged school aquarium.

Exercise 8. Draw tadpoles in various stages of development.

THE ENGLISH SPARROW (*Passer domesticus*).

Phylum XII, CHORDATA; sub-phylum 3, VERTEBRATA; class 5, AVES; section B, CARINATÆ; order 21, PASSERES.

HABITAT.—The home of the English sparrow was originally central Europe, but owing to its pushing qualities, its hardiness, its universal diet, and its rapid rate of multiplication it has spread not only over all of Europe, but into almost all the regions of the earth inhabited by civilized man, including Siberia, South Africa, Australia, and America. It was first introduced into our country in 1850. The species frequents the habitations of man, nesting about the buildings and gleaning its food from alleys and barn yards. Its dirty, thieving, pugnacious habits have brought it into general disrepute.

Technical Note. Sparrows may be captured about buildings in various ways. The ingenuity of the average boy can be trusted to cope with his sparrowship's craftiness. If the birds are killed with a gun, very fine shot—known as taxidermist's or dust shot—should be used. The more specimens secured the better, especially for our own shy songsters that have been driven out by these obtrusive foreigners.

EXTERNAL FEATURES.—Study the specimen in hand with reference to the following details:

a) The body divisions—**head, neck,** and **trunk.** What is the shape of the head? On account of the heavy covering of **feathers** the neck seems relatively short, but when plucked it will be seen to be quite a distinct body region.

b) The hind limbs or **legs,** developed for walking and perching. You will note that they are composed of a thigh joint—**femur,** a "drum-stick"—**tibia,** and an elongated **tarsus.** Locate the heel and the knee. The femur is bound so close to the body by a fold of skin that the tibia seems to be the uppermost joint. Which joint, or joints, is elongated in wading birds? Note the covering of the tarsus. What group of animals has a similar covering over the whole body? By reason of its **scales** the front part of the tarsus is said to be **scutellate.** The hind part is netted or **reticulate.**

c) The **toes** are four in number. Compare with a cat in this respect. They are termed, respectively, the **hind toe,** the **inner toe,** the **middle toe,** and the **outer toe.** The first mentioned opposes the other three in grasping. Note the effect on the toes of placing the leg in a squatting or perching position. How is a bird able to cling to a perch when asleep? Each toe terminates in a **claw** and has a covering similar to the tarsus. What part of the leg is feathered? Do birds differ in this respect?

d) The fore limbs or **wings** will be found to have the same number of divisions as the legs, the corresponding parts being an **upper-arm,** a **fore-arm,** and a **hand.** Feel for the **thumb** at the base of the hand in front. Two **fingers** are distinguishable on the plucked bird, one forming the tip of the wing and the other projecting from the hind border of the hand about one third way back from the tip. Look for these fingers later, after you have stripped the feathers from your bird. Also notice then the **alar membrane** stretched between the upper-arm and fore-arm on the anterior border.

e) The **beak** consists of an upper and a lower **mandible,** each covered with a horny sheath. Are teeth present? Near the base of the upper mandible are the **nostrils.** Probe them with the head of a pin and discover where they open into the **mouth.** With the forceps seize the tip of the **tongue** and pull it about, noting its attachment and shape.

f) Note the position and color of the **eyes.** Raise the upper **eyelid** and look in the inner angle of the eye for the **nictitating membrane.** Draw the latter down over the eye with the forceps. What is the function of this membrane?

g) Push the feathers aside and look for the **ear-opening** back of the eye. Is there any external fold or structure for catching the sound?

h) Feel about the base of the tail feathers for a short conical projection of the trunk—the **uropygium.** This is the true tail of the bird, although the term is commonly applied to the feathers projecting from it. On its dorsal surface is a papilla bearing the opening of the **oil gland,** which furnishes a lubricant for preening the feathers.

i) At the ventral junction of the uropygium with the trunk is the transversely elongated **cloacal aperture,** a common external opening for the intestine, the reproductive organs, and the urinary excretions.

The Plumage.—An outer covering of feathers is peculiar to birds alone. It is entirely a dermal structure.

a) On examination it will be seen that the **contour plumage** is not uniformly distributed over the surface of the body, but springs from certain areas called **feather tracts,** separated by featherless spaces—**apteria.** Find some of the latter.

b) The **quill feathers** of the wing have been given special names. Those springing from the hand are the **primaries.** How many primaries has the sparrow? The **secondaries** arise from the fore-arm, and **tertiaries** are sometimes present on the upper-arm.

c) The feathers springing from the thumb constitute what is called the **false wing.**

d) The shorter feathers overlapping the quills of the wings are the **wing coverts.** Notice the way in which the quills themselves overlap and study the shape of the wing as a whole. Which surface is the more convex? What advantage is evident in this form and in the method of overlapping of the quills?

e) Study the tail also with a view to determining its adaption to its particular work. Count the quills and note their mode of overlapping. **Tail coverts** overlap the bases of the quills above and below. If opportunity offers compare the tail quills with those of a woodpecker or a chimney swift. Special names have been given by ornithologists to various tracts of the contour plumage, but these will not be considered here.

Exercise 1. *Draw a wing of the sparrow, dorsal view, partially extended as in flight.*

Exercise 2. Draw one of the legs on a scale of two.

A FEATHER.—Pluck one of the large primaries from a wing and note the following parts:

a) The central shaft composed of a hollow basal **quill** and the longer, angular **rachis** extending to the tip of the feather.
b) The expanded portion called the **vane.** Why is the rachis not in the center of the vane? Can you find any wing or tail quills that differ in this respect from the primary you are studying?
c) The vane, under the lens, is seen to be composed of side branches from the rachis—**barbs**—and these, in turn, to have lateral **barbules.** The barbs and barbules are locked together by tiny hooks, thus presenting one unbroken surface in resisting the air during flight.
d) At the tip of the quill note a tiny opening, the **inferior umbilicus,** into which a papilla of the skin once fitted. At the junction of the quill with the vane, on the under side, is another opening, the **superior umbilicus.**
e) Compare the primary just studied with a **down-feather,** a **pin-feather,** and one of the hair-like **filoplumes** about the mouth.

Exercise 3. Draw one of the large primaries on a scale of two, showing the under side.

Exercise 4. Pluck the bird and draw a lateral view of the entire specimen, naming all the parts.

Exercise 5. Draw an enlarged side view of the head.

INTERNAL ANATOMY.—On account of its larger size a pigeon would be better for a study of the internal organs than a sparrow, but by exercising a little more care the latter will serve the purpose very well.

Technical Note. After plucking the bird lay it on its back and fasten it to a small board by pins or tacks through the feet and outstretched wings. With a pair of fine pointed scissors slit the skin along the mid-ventral line from the cloacal opening to the base of the lower mandible. Work the skin back from the sides of the body and pin it out.

The following notes will serve to guide the student in a study of the internal anatomy:

a) Just beneath the skin of the neck is an enlargement of the **œsophagus** forming the **crop.** Insert a blow-pipe into the opening of the œsophagus in the mouth and inflate the food tube, noting its distensible quality.

b) Under the crop is the **trachea,** or air tube, with its rings of cartilage. Inflate this also, by inserting the blow-pipe in the **glottis,** and observe the swelling of the whole body. Now break the bone of the upper-arm—**humerus**—in one of the wings, push back the skin and flesh from the end next the body and slip a piece of rubber tubing over it. Blow into the latter and note results. Can you force air through the glottis? Can you force air from the glottis through the wing bone? If a sound is produced in either experiment, account for it.

c) Along the neck on either side of the trachea is a dark-colored **jugular vein** and closely associated with it a white nerve cord with several side branches. This is the **pneumogastric nerve.** Trace both vein and nerve as far as practicable. Note the **thyroid glands** in the same region.

d) It will be observed that the prominence of the breast region is due to the very large **pectoral muscle** which moves the wings in flight. It has a right and a left division, the two separated by the prominent central **keel** of the breastbone or **sternum.**

e) Feel for the right and left **coracoid bones** acting as braces between the front angles of the breastbone and the shoulders. Between these, its two forks meeting at a point just ahead of the sternum, is the V-shaped **furcula** or wish-bone. What is its representative in human anatomy? Where are the coracoid bones in the human skeleton.

f) After cutting carefully through the thin abdominal wall where it borders the posterior edge of the sternum, inflate the trachea again and note the swelling of the thin-walled **air sacs** in the abdominal region. Do you notice any air sacs also in front of the breastbone? There are several pairs of these sacs and all play an important part in respiration, acting together with the pneumatic cavities of the bones, as chambers for residual air. The entire lung space is, therefore, free to receive fresh or tidal air at each inspiration.

Technical Note. With a moderately stout pair of scissors finish the cut around the edges of the breastbone, severing the ribs, the coracoid bones, and the furcula. Carefully lift and remove the whole structure. Also cut away the remainder of the ventral abdominal covering.

Note the following:

a) The **heart** surrounded by a thin **pericardium** which was probably torn in dissection. Distinguish the main systemic veins entering the **right auricle** and the light colored **aorta,** with its large branches, given off from the **left ventricle.** From the **right ventricle** run two short **pulmonary arteries,** and the **left auricle** is entered by two **pulmonary veins.**

b) Behind the heart is the reddish-brown liver. How many lobes has it? Look for a **gall bladder** and for ducts leading from the liver.

c) On the left side of the body, beneath the liver, is the **gizzard,** a hard muscular structure for grinding the food.

d) A short, mottled portion of the food tube just preceding the gizzard and differing in structure from the remainder of the tube, is called the **proventriculus.**

e) Following the gizzard is a long loop of the alimentary canal termed the **duodenum.** Within this loop note a pinkish gland, the **pancreas.** Find, if possible, the ducts by which the pancreas opens into the duodenum.

f) Trace the **intestine** from the duodenum to its termination in the cloaca. Note, a short distance from the end, a pair of blind pouches, the **cœca.**

g) Look for the **spleen,** a small ovoid red body attached to the proventriculus.

h) Snip off the alimentary canal near each end and lay it aside for further study. Observe, in the region beneath the heart, the pinkish **lungs,** their dorsal surfaces fitting closely into the spaces between the ribs. How do they compare in spongy texture with the lungs of the domestic mammals we use for food? Are they relatively large or small? How do you account for the marked swelling of the whole body when you inflated the trachea?

i) Each lung is connected with the trachea by a short branch of the latter called a **bronchus.** At the junction of the bronchi with the trachea is the **syrinx** or voice-box containing the so-called **vocal cords.** Where is the voice-box of mammals located?

j) Back of the lungs, and fitting closely into the hollows of the pelvis, are the dark colored **kidneys.** How many lobes compose each kidney? Try to find a slender duct—**ureter**—connecting each kidney with the cloaca.

k) In front of and partly overlying the kidneys are the reproductive organs—two white oval **testes** in the male and a single **ovary** in the female. These organs will vary in size according to the season, though the ovary will usually show eggs, or **ova,** in different stages of development. The right ovary is commonly wanting entirely in birds, as is also the tube—**oviduct**—which would connect it with the cloaca. Can you find a vestige of this tube attached to the right side of the cloaca? Trace the left oviduct. Trace the tube—**vas deferens**—connecting each testicle of the male with the cloaca.

Exercise 6. *Make a sketch properly locating in the body outline all of the internal organs except the various divisions of the food tube.*

Exercise 7. *Make a diagram of the digestive tract exterior to the body outline.*

Split the gizzard and examine its interior, noting the contents, the thick, muscular walls, and the hard, rough lining. Separate the lining from the muscular walls. Account for the gravel mixed with the food.

Remove the heart and examine its chambers and the stubs of veins and arteries connected with it. Make two or three cross sections. Why are the walls of the left ventricle thicker than those of the right?

Carefully remove, with scissors, the roof of the **skull** and examine the **brain.** The large division in front is the **cerebrum.** Note the groove that separates it into two hemispheres. Behind the cerebrum is the **cerebellum,** with its large central and two very small lateral lobes. The **spinal cord** may be traced back to where it leaves the skull through a large opening, the **foramen magnum.** The **cranial nerves** will not be demonstrated in this exercise.

Exercise 8. *Draw a dorsal view of the brain, somewhat enlarged.*