TWENTIETH CENTURY TEXT-BOOKS

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TWENTIETH CENTURY TEXT-BOOKS

ANIMAL STRUCTURES

A LABORATORY GUIDE IN THE TEACHING OF ELEMENTARY ZOOLOGY

BY

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PREFACE

THE present book is intended to cover the laboratory work in a course in zoology for beginners. In addition a more general idea of animals should be gained from lectures, from the study of some text-book of zoology, and, above all, from the observation and collection of animals in the fields and streams.

Only a few forms have been chosen for study, experience having shown that in a beginning course better results are obtained by spending the time in the thorough dissection of a few forms than in the rapid study of many.

Few illustrations are needed in this work. While it is true that the student will make more rapid progress with the picture of the dissection before him, it is equally true that what is thus gained in time is lost in power, the student being naturally tempted to rely upon the picture rather than upon his own work.

The question as to the order in which the different forms should be taken up is largely one of convenience and individual preference. While in the present book we have followed the method of going from the simpler to the more complex forms, there is no reason why the order should not be varied, or even reversed at the desire of the teacher.

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ANIMAL STRUCTURES

ANIMAL CELLS

Mount a drop of the blood of a toad or frog—that is, place a small drop of blood on a glass slide, and on it place a cover-glass. Examine under the microscope, using first the low and then the high power.

Great numbers of small oval bodies, the *red corpuscles,* will be seen. What is the color of these when viewed singly? When many are together?

Each corpuscle has the shape of a flattened oval disk. Perhaps you may see some turned on edge; they will then have the appearance of short rods.

Scattered among the red corpuscles will be seen a few *white corpuscles.* They are not nearly so numerous as the red, are smaller, and are often of an irregular shape.

Watch a white corpuscle carefully for a few minutes and see if you can detect any change of shape due to the pushing out of short processes from the edge and the drawing in of others.

Both the red and white corpuscles are what are known as *cells.* The body of every animal and every plant is made up of cells, usually of great number of cells, of many different shapes and sizes, but some of the simplest animals and plants consist of a single cell.

The corpuscles consist of *protoplasm,* an extremely important substance, for it makes up the living part of every animal and every plant. The white corpuscles are almost pure protoplasm, but the red have in addition a coloring substance, called *hæmoglobin.*

The protoplasm of a cell consists of two parts: the outer part, called the *cytoplasm,* and an inner rounded body, the *nucleus.* Look for the nucleus in a red corpuscle. It may be seen, but will not likely be very distinct. Now place a drop of stain, methyl green or iodine, at the side of the cover-glass; some of this will run in and come in contact with the corpuscles. The nuclei will now be seen distinctly, owing to the fact that they become stained much more readily than the cytoplasm.

The vast majority of cells making up the body of an animal are not free as are the corpuscles, but are closely joined to one another, thus forming solid tissues.

With a scalpel scrape the surfaces of your own tongue, mount the substance thus obtained, together with a small drop of water, and examine under the microscope.

A few flattened cells will be seen, larger than the red corpuscles, and of a somewhat irregular, oval shape. Possibly you may find several joined together. Stain, and see if you can find nuclei in any of them.

In order to see that the solid tissues of an animal are composed of cells, place small pieces of the liver of a toad or frog, about the size of a grain of wheat, and also small pieces of the lining of the first part of the intestine, in a weak solution of chromic acid (1 part of acid to 5,000 parts of water), and allow them to remain in this for about twenty-four hours.

Tease out a piece of liver in a drop of water on a slide—that is, tear it into as small pieces as possible—add a drop of stain, and cover with a cover-glass. Tap on the cover-glass, or press on it with the finger, at the same time moving it about.

Under the high power of the microscope, look for more or less cube-shaped cells, each with a nucleus. Do you find any cases where a few cells are joined together?

Examine a piece of the lining of the intestine that has been similarly treated, looking for elongated cells with one end perhaps a little larger than the other.

THE AMŒBA

Amœbæ are very simple, microscopic animals found in the slime and mud at the bottom of fresh-water ditches or pools, or on the surface of submerged weeds and dead leaves.

Some of this material, together with water, should

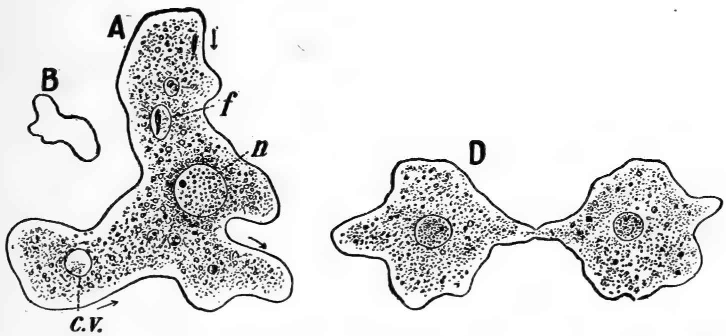

Fig. 1.—A, the *Amœba*, highly magnified, showing *c. v.*, contractile vacuole; *f*, food particle; *n*, nucleus. The arrows show the direction of movement. B, shape of same individual 30 seconds later. D, an *Amœba* in the process of division (after Schulze).

be brought into the laboratory and left standing for a day or two.

With a medicine-dropper place a drop of the slime and water on a slide and cover with a cover-glass. Amœbæ may be seen with the low power of the microscope, and after a certain amount of experience it will be best to search for them in this way, but at first it is better to use the high power, as they are much more easily detected with this than with the low power. First examine a strip around the edge of the cover-glass, not that the Amœbæ are more likely to be here than elsewhere, but in this way you will avoid going over and over the same area. If not found here, then search on other parts of the slide. Look for an irregular, more or less granular, jelly-like mass. When found, watch closely to see if there is any movement. If so, it is in all probability an Amœba.

There are a number of different kinds of Amœbæ which vary greatly in size, some being not much larger than a white blood-corpuscle, while others almost fill the entire field of the microscope, and could be seen as a minute speck with the naked eye. The large ones are the more desirable for study.

Having found an Amœba, observe the irregular processes, the *pseudopods*, or false feet, projecting from various parts of the body. These are constantly changing, old ones being drawn in and new ones sent out. In some Amœbæ the changes are quite rapid, in others so slow that they can be detected only by making a series of drawings at intervals of a minute or two.

Amœbæ have the power of locomotion—that is, of moving from place to place. This is done by sending out pseudopods from one side and drawing them in from the opposite side.

The Amœba is simply a mass of naked protoplasm, having no sort of a cell-wall nor cell-membrane surrounding it.

The protoplasm, or rather the cytoplasm, consists of two parts: a thin, clear, outer layer, the *ectoplasm*, and a granular, central mass, the *endoplasm*. Are you able to distinguish these? In some cases it is easy, in others difficult. When a pseudopod is formed, it is the ectoplasm which first pushes out, and into this the granular endoplasm streams later.

Observe the movement of the granules in the endoplasm.

Within the endoplasm you will likely see one or more relatively large bodies, simple plants, such as diatoms, which have been taken as food. To be sure of this, see if you can find similar bodies on the slide outside of the Amœba.

The Amœba has no mouth, but takes in its food at any part of the body by sending out pseudopods and surrounding it. After remaining in the endoplasm some time, and after the soft parts have been digested, the innutritious part of the food is ejected from any part of the surface. See if you can observe either of these processes.

Look for a small, clear, globular body, the *contractile vacuole,* which at regular intervals suddenly and entirely disappears, and then more slowly reappears. At first sight one might be inclined, on account of its pulsation, to compare this with the heart of a higher animal, but it is thought to have more the function of a kidney.

Within the endoplasm is a rather large oval *nucleus,* which may sometimes be distinguished quite readily in the living animal, but usually only with difficulty, or not at all. If you have trouble in finding it, stain as you did in the case of the blood-corpuscles. Even then you may not be sure of finding it.

From your study of the cells of the toad, you will readily understand that an Amœba is a single cell.

The process of reproduction is very simple; first the nucleus divides into two; then a constriction appears around the body, which becomes deeper and deeper, until the two parts thus formed are held together by only a slender strand. Soon this breaks, and instead of one amœba there are two, each with its own nucleus. Look for cases of dividing Amœba. They are not very common.

When the mud of the pond in which Amœbæ lives dries, the animal assumes a globular form, secretes a hard shell, or cyst, around itself, and remains dormant until the rains come. It then emerges from its cyst, and moves about as before.

THE PARAMŒCIUM

If a jar of water and water-weeds be brought in from a pond or stream it will in all probability contain a number of different kinds of minute, one-celled animals, among them one called Paramœcium. But these animals are so small and relatively so few in number that you might look for a long time without finding a single one. If, however, the water be allowed to stand for a few days and to undergo putrefaction, the conditions will be favorable for the rapid multiplication of the Paramœcia, so that every drop may contain a number of them.

Place a drop of this water together with a little of the scum or *débris* from the culture jar on a slide, and cover with a cover-glass. Examine with the naked eye. The Paramœcia will appear as little white specks moving about in the water. Now place under the low power of the compound microscope. Do they appear to move more rapidly or more slowly than when viewed with the naked eye? At first it will seem impossible to study the creatures on account of their constant motion, but after a little time they will become more quiet.

A Paramœcium is usually described as slipper-shaped, one end, corresponding to the toe, being more pointed, and the other, corresponding to the heel, more blunt. Which end is forward in locomotion? Does it ever move with the other end forward? Observe that it sometimes turns over—that is, rotates on its long axis. Is it possible for the body to change shape? To determine this point, watch the animals swinging around among the *débris*.

Locomotion is caused by the vibration of *cilia*—delicate, hair-like projections of protoplasm—which cover the entire surface of the body. In order to see these, turn on the high power and bring the margin of the body into sharp focus. The cilia may be seen best at the pointed end, where they are less active; elsewhere they may be moving so rapidly that they can not be seen. It may be necessary to cut off some of the light, as the cilia can not be seen with too strong an illumination.

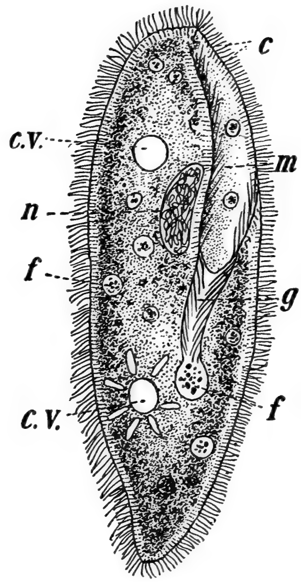

Fig. 2.—*Paramœcium aurelia*, a ciliate infusorian. *c*, cilia; *c. v.*, contractile vacuoles; *f*, food vacuoles; *g*, esophagus; *m*, buccal groove; *n*, macronucleus.

Now bring either the upper or the lower surface into focus, and observe a great number of little dots arranged in rows. These mark the position of the cilia, but the cilia themselves can not be seen.

The substance of a Paramœcium consists of protoplasm, which is differentiated into an outer, firmer layer, the *ectoplasm*, and an inner, more fluid portion, the *endoplasm*, the whole being surrounded by a thin membrane, the *cuticle*, which comes into immediate contact with the ectoplasm and has numerous perforations, through which the cilia, which are projections of the ectoplasm, protrude.

Again bring the margin into focus. The ectoplasm and endoplasm may now be distinguished, the endoplasm by the moving particles in it, and the ectoplasm by the striated appearance which it presents, an appearance due to the presence of *trichocysts*—structures to be studied later.

Look for two clear globular bodies, the *contractile vacuoles,* which at regular intervals appear and then entirely disappear. How often does this occur? Are they constant in their position or do they move about? Are they situated in the center of the body, or near the surface? To determine this point, observe an animal turning over.

An hour or so after the slide has been prepared enough of the water will have evaporated to allow the cover-glass to press lightly on the animals, and under these conditions the action of the vacuoles may best be studied. A number of clear rays will be seen around the vacuole, which, like the vacuole, appear and disappear. Make out the relation of these to the vacuole. The vacuole consists of a drop of water surrounded by highly contractile protoplasm, and when the latter contracts the drop of water is forced out of the body, but the fine canal, through which it passes, can not easily be seen.

Among the particles moving about in the endoplasm will be a number of granular globules; these are the *food-vacuoles,* each of which consists of a small drop of water containing a number of particles which have been taken into the body as food.

On the side of the body usually turned down, observe a wide groove, the *buccal groove,* which, beginning at the blunt end, extends obliquely backward and to the right, ending in a funnel-shaped opening which leads into the endoplasm. The part corresponding to the stem of the funnel is known as the *gullet* or esophagus. The entire apparatus is ciliated, the cilia movivng in such a way as to sweep particles of food down into the endoplasm.

In order to observe the process of feeding, rub up a little piece of carmine in water and place a drop at one side of the cover-glass; if it does not run under it may be drawn under by placing a piece of blotting-paper on the other side of the cover-glass. Small particles of the carmine will be swept into the gullet, at the inner end of which they will collect for a few seconds, and then, together with a small drop of water, will be suddenly swallowed, as it were, into the endoplasm. How often does this process take place? The food-vacuoles thus formed circulate in the same general direction through the endoplasm. Make out the course of this circulation. If food had been taken instead of carmine, it would ultimately have been converted into protoplasm; but the carmine after a time will be expelled from the body at a point called the *anal spot,* situated below the end of the gullet. It is much easier to observe the act of swallowing than of the expulsion of the carmine. The water that is taken in, together with waste matter that becomes dissolved in it, is ultimately expelled through the contractile vacuole. Thus this organ serves as an excretory organ or kidney.

Run a little stain, such as methyl green, under the cover-glass. The animal will be killed, and a relatively large oval body, the *macronucleus,* which could not be distinguished before, will now be plainly visible. Lying right by the side of the macronucleus is a much smaller nucleus, the *micronucleus,* which also becomes stained, but is not easily distinguished.

Around one of the dead individuals observe a great number of hairs, which might be mistaken for long cilia, but which are really *trichocyst hairs,* that have been sent out from the trichocysts in the ectoplasm.

Occasionally an individual may be seen with a constriction around the body about half-way between the two ends. It is then in the process of division, and should be watched under the low power. The constriction will become deeper and deeper, until finally the two parts will be entirely separated, and two Paramœcia will exist where there was but one before. Under favorable conditions of food and temperature division may take place as often as every twelve hours. Starting with a single individual, how many would there be at this rate at the end of a week?

Occasionally two individuals may be seen swimming about firmly attached together, with buccal groove toward buccal groove. They are then in the act of *conjugation*, and will remain thus attached for several hours. During this time important changes take place, which are not at all easy to follow, but which result in an exchange of nuclear matter.

THE HYDRA

Hydra are small, inconspicuous animals found attached to sticks, weeds, etc., in fresh-water ponds and pools, and in the sluggish parts of streams. They are of different kinds, some being of a green color, others brown, or almost colorless.

If sticks and weeds to which hydra are attached be placed in a jar of water, after a time some of the Hydra will detach themselves, move to the side of the jar, and there become reattached.

Examine such a jar which has been standing for at least a day or two. Do you find more Hydra on one side than on the other? If so, is it the side turned toward the light or away from it? Possibly you may find some specimens floating at the surface of the water.

With a lens examine one of the animals while it is still attached to the side of the jar. It will be seen to have an elongated cylindrical-shaped body, which is attached by one end, called the *foot*, while at the opposite, free end, a circle of long, slender arms, or *tentacles*, will be seen.

Now remove a specimen from the jar to a watch-glass containing a little water. This may be done with a lifter, or still better with a long glass tube. Place a finger over one end of the tube, and with the other loosen the specimen. As soon as it is free, remove the finger. The Hydra will be drawn into the tube, and may be transferred to the watch-glass.

Examine under the low power of the microscope. Possibly the animal may soon reattach itself. This it does

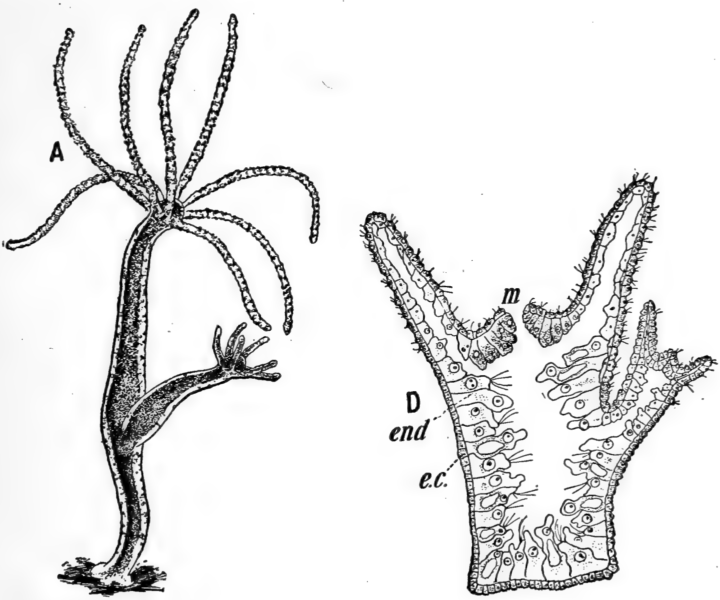

Fig. 3.—The fresh-water *Hydra*. A, entire animal, developing a new individual (enlarged 25 times) (after Schneider); D, section through the body; *e.c.*, ectoderm; *end*, endoderm; *m*, mouth.

by means of a sticky substance secreted by the cells of the foot. Observe that the body has great power of changing its shape, at one time becoming long and slender, and at another short and thick. How much longer is it when fully extended than when fully contracted? When extended, tap on the watch-glass and see if this has any effect on the animal.

Have the tentacles the power of movement or of being lengthened and shortened? How many tentacles are there? Is the number the same for all individuals?

The small, cone-shaped portion of the body beyond the base of the tentacles is the *hypostome.*

At the end of the hypostome, and therefore in the center of the free end of the body, is the *mouth.* This can not well be made out except when food is taken, at which time it may open wide enough to take in an object larger than the diameter of the Hydra itself.

Place a few small crustacea, such as Cyclops or Daphnia, in the watch-glass. In swimming about, one of them will come in contact with a tentacle, and will stop instantly, as if dead. After a time it will likely swim away, proving that it was not dead, but only paralyzed. The stinging apparatus by which this is done will be studied later. Is this Hydra able to paralyze another crustacean, or has it lost the power?

If the Hydra is hungry, the crustacean will not escape, but will be drawn to the mouth by tentacles and slowly swallowed into the digestive cavity, called the *enteron.* Here it may be distinctly seen by the swelling caused in the body of the Hydra. It may require considerable patience to see the process of taking food, but one should not rest satisfied until he has seen it.

After remaining in the enteron some time, perhaps several hours, and after all the soft parts have been digested, the shell of the crustacean will be thrown out at the mouth.

These observations show that the hydra has a digestive cavity with a single opening to the outside. The tentacles are all hollow, their cavities being continuous with the enteron.

Place a specimen in a drop of water on a slide. To prevent its being injured by the pressure of the cover-glass, place some small object, as a bit of broken cover-glass or a small piece of water-weed from the jar, near it. Now cover.

Examine with the high power of the microscope, taking great care not to break the cover-glass nor to crush the Hydra. When extended, bring the edge of the body into sharp focus, and observe the rather thin outer layer of the body wall, the *ectoderm*, and the thicker inner layer, the *endoderm*. In a green or brown hydra it is very easy to distinguish the layers, as the endoderm is colored, while the ectoderm is colorless. It is less easy to distinguish them in a colorless specimen, but even here it is not difficult. While the microscope is focused in this way, you may possibly be able to distinguish the enteron extending through the center of the body. Occasionally particles may be seen moving up and down in it.

Look for a clear, thin line separating the ectoderm from the endoderm. This is a supporting membrane, called the *mesoglœa*.

Examine one of the tentacles. Are you able to distinguish the ectoderm, endoderm, and mesoglœa, and also the central cavity of the tentacle?

The mesoglœa is a non-cellular layer, but the ectoderm and endoderm are each made up of many cells attached side by side. It is not easy to distinguish the individual cells of the ectoderm in a living specimen, but it is quite easy to distinguish those of the endoderm. For this purpose, raise the objective until the specimen is out of focus, and then gradually focus down on the center of the body. First the ectoderm will come into view; then by focusing just a little farther you will see the outlines of the rather large endoderm cells. Do these change shape as the body lengthens and shortens? Are you able to make out the endoderm cells in the tentacles?

When focusing on the ectoderm a number of clear, pear-shaped bodies will be seen, the *nematocysts,* or *nettle cells,* structures by means of which the Hydra paralyzes its prey. Extending into this nematocyst from the small end is a structure which will later be seen in a quite different position. If viewed from the end, instead of from the side, the nematocyst will appear round. Do you find nematocysts on the tentacles? Where are they most numerous? Are they in the ectoderm or endoderm?

Focus carefully along the edge of a tentacle and look for delicate, short hairs projecting out just a little from the ectoderm. These are the *cnidocils,* or trigger-hairs, structures which when irritated cause some of the cells of the ectoderm to contract and discharge the nematocysts. A cnidocil is not a part of a nematocyst.

Run under a drop of weak acetic acid, and in or near the tentacles look for rounded, flask-shaped bodies, with rather long, pointed necks, which are continued into a very long, slender hair. They are the discharged nematocysts. Do you find any barbs on the neck? The neck and thread are hollow and are the structures seen on the inside of the undischarged nematocyst. The threads penetrate the body of an animal, and a poisonous fluid passes through it from the nematocyst. When discharged a nematocyst can not be used again, but new ones are all the time developing.

Lift up the cover-glass, remove the supports, and place a drop of methyl green upon the specimen. Now replace the cover-glass and press on it until the specimen is crushed. Examine under the high power of the microscope. Some of the cells will be isolated. Among these look for some with nematocysts inside of them. These are called *cnidoblast cells,* and are from the ectoderm. Do you find any of the endoderm cells? If it is a green or brown hydra they may be distinguished by the little round colored bodies they contain.

Hydra reproduce both sexually and asexually. In the latter case a bud grows out from the side of the body, consisting of both ectoderm and endoderm, and contains a cavity continuous with the enteron. This grows larger and larger, a mouth and tentacles appear at the free end, the cavity of the new individual becomes separated from the enteron of the parent, and finally the new individual breaks away and leads an independent life.

Look for a budding individual, and when found keep in a small vessel of water under observation from day to day until the new individual becomes free.

Look for a specimen having two or three low, cone-shaped projections of the ectoderm on the body a little below the tentacles. These are the *testes,* or male reproductive organs. Examine a testis under the high power of the microscope. Possibly a great number of very small objects may be seen moving about inside. If so, they are the *spermatozoa,* or male reproductive cells.

In the same or in another individual a larger rounded projection of the ectoderm, the *ovary,* may be seen. This is the female reproductive organ, and contains a large cell, the *egg* or *ovum.*

It will be seen that one individual may have both male and female reproductive organs. Such an animal is said to be *hermaphrodite.*

Individuals with buds are more numerous than those with testes, and those with testes than those with ovaries.

If a hydra be cut into two or more pieces, each part will in time reproduce the lost parts and become a perfect individual. Try this experiment.

If our own bodies were cut into halves from front to back the resulting parts would be exactly alike, and there is only this one plan through which they could be cut into similar halves. Such an animal is said to be *bilaterally symmetrical.* A Hydra has neither right nor left side, front nor back, and it could be cut the long way through a number of planes so that the resulting halves would be exactly alike. Such an animal is said to be *radially symmetrical.*

THE STARFISH

As starfish live exclusively in salt water, the living animals can be studied only at the seashore.

In a preserved specimen note the central *disk,* from which radiate five *arms* or *rays.* Observe that one side is flat, the other convex. The former is known as the *oral side,* the latter as the *aboral side.* The animal moves with the oral surface down.

Note the numerous hard *spines* covering the body. Can you find more than one kind?

Between the spines observe many soft, short bodies, the *respiratory cœca.* On what part of the body do they occur? They are blind tubes, like glove-fingers, and are connected with the body-cavity as glove-fingers are connected with the palm. During life the cœlomic fluid may be seen, with a hand lens, circulating within them.

Scrape off a little piece of the skin, tease it out on a slide, add a drop of solution of caustic potash, and under the low power look for the *pedicillaria,* little cone-shaped pincers at the end of short stalks. The jaws of the pincers have a calcareous skeleton which looks dark under the microscope.

With a lens look for the pedicillaria on the surface of the body. If not visible, add a drop of caustic potash and look again. How widely are they distributed? During life the jaws may be observed constantly snapping together.

In the center of the oral surface of the disk is a small opening, the *mouth.* Possibly some of the spines may be bent over so as to conceal it; if so, break them away with the forceps. Occasionally a part of the stomach may be seen protruding from the mouth.

Immediately surrounding the mouth is a soft membrane, a part of the body-wall, the *peristome.*

In the center of the aboral surface of the disk is a very small opening from the alimentary canal, the *anus,* which you will perhaps not be able to find.

Along the oral side of each ray is a deep, wide groove, the *ambulacral groove.*

Each groove is completely filled by the *tube-feet,* cylindrical structures with sucking-disks at their end, which serve as organs of locomotion. With forceps pull out the tube-feet from a half inch of the groove a little distance from the end and examine them to see if they are tubes, as their name implies. Where the tube-feet have been removed, observe a number of holes, the *ambulacral pores,* through which the tube-feet communicated with certain internal structures. From these holes determine whether there is any regularity in the arrangement of the tube-feet.

On the aboral surface of the disk, some distance from the center, and between two of the rays, is a round body an eighth of an inch or more in diameter, the *madreporic body.* Examine the surface with a lens. Can you find more than one madreporic body?

Because the madreporic body is situated between two of the rays, it is said to be *interradial* in position. Structures such as the tube-feet that are situated along or within the ray are said to have a *radial* position.

Extending along the middle of the ambulacral groove is an inconspicuous ridge, the *radial nerve.* Here the nerve is a part of the skin, and not a distinct cord within the body, as is the case with most animals.

Follow the nerve toward its inner end. A short distance from the mouth it will be seen to join the *circum-oral nerve ring,* a low ridge or fold which surrounds the mouth and connects the five radial nerves with one another.

Now follow a radial nerve out to the tip of the ray. It will be found to end in a small red or orange-colored speck, the *eye.*

In the body-wall is a sort of skeleton, made up of numerous small calcareous bodies called *ossicles.* Some of these, known as *ambulacral ossicles,* may be seen in the ambulacral groove where the tube-feet have been removed. The ambulacral pores pass not through these, but between them.

Cut off an inch or more of the end of a ray and place it for several hours in 20-per-cent nitric acid and observe the result.

Cut off a quarter of an inch more of the same ray and boil it for a few minutes in a strong solution of caustic potash. The soft parts will be eaten away and the ossicles left free. Examine these.

Look at the cut end of the ray and observe a large cavity, the *body-cavity* or *cœlom.* During life this cavity contains a nutritive fluid, called *cœlomic fluid.*

The cœlom is almost filled by two brown bodies, the *pyloric cæca,* portions of the digestive system.

With stout scissors make a cut through the body-wall along both sides of the ray, and lift up the aboral portion. It will be seen that each pyloric cæcum is suspended by a thin, double membrane, the *mesentery.* The body-cavity is lined by a thin membrane, the *peritoneum.* Can you separate this from the body-wall?

Extending along the floor of the cavity of the ray, observe a prominent ridge, the *ambulacral ridge.*

Remove the dorsal body-wall from all the rays and the disk, leaving the madreporic body, however, intact, and taking great care not to injure the internal organs. As some of these are attached to the dorsal body-wall, they should be carefully separated from the latter before it is lifted up. The digestive system will now be exposed.

The pyloric cæca may have the appearance of solid bodies, but are really elongated sacks with much folded walls, the cells of which secrete a digestive fluid. Note that at their inner ends the two pyloric cæca of a ray unite and give off a single short *duct.*

The cavity of the disk is occupied by the *stomach,* which is usually much lighter in color than the pyloric cæca. It is divided into a smaller upper part, the *pyloric* portion, and a larger lower part, the *cardiac* portion. The former is pentagonal in shape, and may be easily distinguished by the fact that it receives the ducts of the pyloric cæca.

A very short *intestine* leads from the center of the pyloric portion of the stomach to the anus, but this has likely been cut away, so that it can not now be seen.

Lying upon the pyloric portion of the stomach, though not connected with it, is a branching body of doubtful function, the *intestinal cæcum* or *respiratory tree.* It is connected with the intestine. Is it arranged in five parts, as are most of the organs of the starfish?

The cardiac portion of the stomach is immediately below the pyloric portion. It has thin and much folded walls, and gives off pouches, one for each ray, the *cardiac cæca,* which extend a little way into the rays. Lift up a cardiac cæcum and note the two *cardiac muscles* attached along the side of the ambulacral ridge on the one hand and to the stomach on the other.

Cut these muscles, lift the stomach still higher, and look for the very short *esophagus* leading from the mouth to the stomach.

Usually the starfish does not take its food into the stomach, but instead protrudes the cardiac portion of the stomach through the mouth, wraps it around the food, which usually consists of mollusks, and thus digests and absorbs the soft parts, leaving the shell perfectly empty. At the end of the process the stomach is drawn into the body by the contraction of the cardiac muscles.

In each ray are two reproductive glands, *testes* in the male, *ovaries* in the female. They are attached to the sides of the body-wall near where the ray joins the disk. They vary greatly in size with the time of the year, being small at the close of the breeding-season, and gradually increasing as the next season approaches. They communicate with the exterior interradially through openings which are quite difficult to find.

When ripe the eggs from the female and the sperm from the male are discharged into the water. Here they come in contact and the former are fertilized by the latter.

Tease out a small piece of the reproductive organ in water on a slide and examine with the compound microscope. If ovary, large spherical cells will be seen—the eggs. If testis, a fine granular substance will be seen.

Cut the stomach off near the mouth and remove it, together with the pyloric cæca. Along either side of the ambulacral ridge observe numerous small, bladder-like structures, the *ampullæ.* They may be collapsed in the preserved specimen. Each ampulla is connected with a tube-foot by a fine tube, which passes through one of the ambulacral pores.

At the cut end of the ray, look for a small round hole a little above the radial nerve. This is the *radial water-tube,* which extends the full length of the ray. It gives off fine tubes at right angles to itself, which join the tube-feet. Thus each tube-foot is connected both with an ampulla and with the radial water-tube.

At their inner ends the radial water-tubes of the different rays are connected with a *ring-vessel,* which bears the same relation to the radial water-tubes that the circumoral nerve does to the radial nerves. This will be seen later.

In some kinds of starfish there are thin-walled, pear-shaped vesicles, the *polian vesicles,* which extend into the rays a little distance and are attached interradially by a slender stem to the ring-vessel.

Now look for an S-shaped tube, the *stone-canal,* leading from the madreporic body to the ring-canal. Scratch it with the point of a needle to feel the calcareous particles in its walls.

With a hypodermic syringe or a medicine-dropper which has been drawn out to a fine point inject some colored fluid into the end of the radial vessel. If successful, the fluid will fill the tube-feet and ampullæ of this ray, and passing through the ring-vessel, will also fill the radial vessels, ampullæ, and tube-feet of the other rays, and may pass into the polian vesicles and stone-canal.

During life the entire system, known as the *water vascular system,* is filled with a mixture of nutritive fluid and sea-water, the latter of which gains access through fine pores in the madreporic body. (However, it passes first into a little vesicle, and from this into the stone-canal.)

You may possibly find a specimen in which one or more of the rays are shorter than the others. This is because the rays have been broken off and new ones are growing out, for the starfish has the power of reproducing lost parts.

It will readily be seen that the starfish is for the most part a radially symmetrical animal. However, this radial symmetry is interfered with by the fact that there is but one madreporic body and one stone-canal, the plane passing through these structures being the only one along which the body could be divided into exactly similar halves.

THE EARTHWORM

Place a living earthworm upon the table and observe its mode of locomotion by alternately lengthening and shortening the body. Compare this with the crawling of a fly.

In locomotion one end is nearly always forward; this is known as the *anterior* end, while the opposite is the *posterior* end. One surface is always down and the other up; the former is known as the *ventral,* the latter as the *dorsal* surface. Can you notice any difference in shape between the anterior and posterior ends, or difference in color between the ventral and dorsal surfaces?

Place several worms in a jar of loose moist earth, and observe their mode of burrowing. Take them out and pack the earth as hard as possible. Are they able to burrow in this? Cover the jar so the worms can not crawl out, and in a day or two observe the pellets of earth that have been cast out of the alimentary canal. In this way you may gain some idea of the amount of earth taken as food by worms.

Now take a preserved specimen and observe that the entire body is divided into a large number of divisions, called *segments,* which are separated from one another by well-marked transverse grooves. The first division, called the *prostomium,* forms a sort of upper lip and is not a true segment. How many segments are there? Is the number the same for every worm?

About a third or a fourth of the distance from the anterior end there is a thickening of the skin forming a sort of girdle, called the *clitellum.* Counting from the anterior end, what segments does this occupy? The clitellum is an accessory reproductive organ, it is not found on young worms, nor on the adults of certain kinds of worms except during the breeding seasons.

Is the body of the earthworm divided into regions such as head, neck, trunk, and tail?

Draw a worm back and forth through the fingers and feel the bristles or *setæ.* Look for these with the lens. Observe that they are arranged in rows. How many rows are there, and along what part of the body do they extend? How many setæ are there on each segment? By means of special muscles the setæ may be pointed either forward or backward, and thus assist in locomotion by helping to anchor one part of the body while another is being moved.

Note the two openings of the alimentary canal, the *mouth* at the anterior end just below the prostomium, and the *anus* at the extreme posterior end. Do you find any jaws or teeth connected with the mouth?

On the ventral surface of the fifteenth segment look for a pair of openings, the *apertures of the sperm-ducts.* They are easily found, as each is guarded by a pair of prominent lips. On the ventral surface of the fourteenth segment look for the *apertures of the oviducts.* They are not conspicuous, and if difficulty is experienced in finding them, stretch the worm around the finger and look with a lens.

Situated along the sides of the body and in the grooves between the ninth and tenth and tenth and eleventh segments are two pairs of *apertures of the spermathecæ.* They are quite difficult to make out. The four pairs of apertures just described will be found later to be connected with the reproductive system.

There are two rows of *excretory apertures* extending almost the full length of the body about in line with the apertures of the sperm-ducts, but these are very difficult to make out.

Stretch the worm around the finger and with a lens look for the *dorsal pores* situated along the mid-dorsal line and in the grooves between the segments. How many do you find?

There is a thin transparent covering, the *cuticle,* over the entire body. Perhaps you may be able to strip this off.

Pin a specimen, dorsal side up, to the wax in the dissecting pan by passing two pins through the sides of the body at either end. Cover with water. With a pair of fine-pointed scissors cut through the body-wall from the posterior to the anterior end along the mid-dorsal line, taking care not to injure any of the internal organs.

At any point back of the twentieth segment gently pull the cut edges of the body-wall apart, the brown-colored *intestine* will be seen, and between this and the body-wall a series of spaces, separated from one another by delicate partitions called *septa.* Each septum is attached on the one hand to the alimentary canal and on the other to the body-wall. How do the septa correspond in number with the segments?

The spaces above mentioned are portions of an important cavity, the *body-cavity* or *cœlom,* which extends the full length of the body, and within which all of the internal organs are situated. It communicates directly with the exterior through the dorsal pores.

The cœlom contains a clear nutritive fluid, the *cœlomic fluid,* which consists of a plasma in which float numerous corpuscles. It does not circulate in the true sense of the word, but may pass from one division of the cœlom to another through openings in the septa on the ventral side. Hold a living worm in the vapor of chloroform. The cœlomic fluid will exude through the dorsal pores and a drop may be collected on a slide and examined under the microscope. Do you find amœboid movement in any of the corpuscles?

There is a well-developed circulatory system filled with red blood, the color of which is due to the presence of hæmoglobin, but here the hæmoglobin is dissolved in the plasma and is not located in the corpuscles as is the case with the blood of the vertebrates.

Select a small, light-colored, living specimen, and observe along the mid-dorsal line the pulsating *dorsal vessel.* Is the blood sent toward the anterior or toward the posterior end?

Allow the worm to crawl along the inside of a bottle, and observe along the ventral side the non-pulsating *ventral vessel.* Examine with a lens. You will likely also see the much smaller *subneural* vessel. There are two other small longitudinal vessels on the ventral side, but these you will hardly be able to make out.

Return to the dissection. With a sharp scalpel cut all the septa along either side, noting their absence in a few of the anterior segments, and pin out the flaps of the body-wall to the wax of the dissecting pan. The dorsal vessel will be seen imbedded in the walls of the intestine and presenting a beaded appearance. Follow it forward and in the sixth, seventh, eighth, ninth, and tenth segments find five pairs of branches, the so-called *hearts,* which pass around the alimentary canal and unite with the ventral vessel. Make out as much of this as you can without injuring any of the other organs. In addition to the hearts there is quite a complicated system of small vessels all along the body connecting the dorsal vessel with the longitudinal vessels on the ventral side, in some of which the blood passes dorsally and in others ventrally.

The earthworm has no specialized respiratory organs, the entire surface of the body serving for that function.

The alimentary canal extends the full length of the body and consists of various parts.

Beginning anteriorly, note the white, thick-walled *pharynx* from which numerous thread-like muscles proceed obliquely backward and outward to be inserted into the body-wall. By the contraction of these muscles the pharynx is drawn backward and its cavity enlarged. This produces a suction which draws in any particles to which the mouth may be applied.

Following the pharynx is the much smaller *esophagus.* It is partly concealed by the dorsal vessel and hearts, and by some large white bodies, the seminal vesicles, portions of the reproductive system. Gently press the seminal vesicles to either side, and carefully dissect away the blood-vessels and the parts of the septa attached to the esophagus. This may now be seen as a slender tube somewhat enlarged posteriorly due to the presence of three pairs of pouches which open into the esophagus.

Posterior to the esophagus the alimentary canal suddenly enlarges to form the short *crop.* This is of a whitish color, but may appear dark, owing to the food contained within.

Following the crop is the *gizzard*, which is about the same size as the crop. Make a longitudinal incision through the dorsal walls of the crop and gizzard, and note the relative thickness of their walls. In which segments are the different parts of the alimentary canal just described located?

The intestine has already been mentioned. It will be seen to extend from the gizzard to the anus. Cut out about an inch of the intestine, open it along the ventral side, and wash out the contents. A longitudinal fold, the *typhlosole,* will be seen to project into the cavity from the dorsal side.

The earthworm is hermaphrodite—that is, every individual produces both eggs and sperm, but the eggs of one individual are always fertilized by the sperm of another. All this brings about a rather complicated reproductive system.

The following is a list of the various organs: Female organs: One pair of *ovaries,* one pair of *oviducts,* one pair of *egg-sacs,* and two pairs of *spermathecæ.* Male organs: Two pairs of *testes,* three pairs of *seminal vesicles,* and in some worms two *median seminal vesicles,* two pairs of *seminal funnels,* and one pair of *sperm-ducts.* All these are located in segments nine to fifteen.

To serve as landmarks in determining the location of the various organs, pass pins through the flaps of the body-wall in the tenth and thirteenth segments.

Place the specimen under a dissecting microscope or under a tripod lens. In the thirteenth segment gently pull the esophagus far enough to one side so that the white nerve-cord may be seen beneath, and observe the *ovary,* a small white body attached to the anterior septum near its union with the body-wall and a short distance from the nerve-cord.

Facing the ovary on the posterior septum of this segment is a whitish patch, the *funnel of the oviduct.*

The *oviduct* is a very short tube, situated in the fourteenth segment, and extending downward, outward, and slightly backward from the funnel to open to the exterior about the middle of the segment.

The *egg-sac* is a vesicle attached to the oviduct just at its beginning, and having somewhat the same relative position in the fourteenth segment that the ovary has in the thirteenth. After breaking away from the ovaries the eggs may be stored for a time in the egg-sacs.

Press the seminal vesicles and esophagus slightly to one side in the ninth and tenth segments. In each a *spermatheca* will be seen as a rather conspicuous white body attached to the body-wall near the posterior boundary of the segment. The external opening has already been mentioned. The spermathecæ are vesicles in which the sperm from another worm is stored.

Observe the three pairs of *lateral seminal vesicles* either partly or completely overlapping the esophagus. In which segments are they?

Remove the esophagus without injuring the seminal vesicles. Two median seminal vesicles will be exposed, one in the tenth segment, with which both the anterior and middle lateral seminal vesicles are connected, and one in the eleventh segment, with which the posterior lateral vesicles are connected. (The median seminal vesicles are not present in young worms.)

Remove the dorsal walls of the median seminal vesicles. In each a pair of conspicuous white rosette-shaped bodies, the *seminal funnels*, will be seen.

A little to the side of the point where the oviduct pierces the body-wall the *sperm-duct* may be seen. It is slightly imbedded in the body-wall, and is not always easy to see. Trace it backward to its external opening on the fifteenth segment, and forward to the twelfth segment, where it branches, then follow each branch to its union with a seminal funnel.

In the same segments as the seminal funnels, and corresponding in position with the ovaries, are two pairs of *testes*. These may be made out best in an immature worm.

The testes produce cells which ultimately give rise to the sperm, but long before the sperm are formed they break away and become free in the seminal vesicles. Here they undergo repeated division, giving rise to a spherical structure consisting of a central portion surrounded by a layer of small cells, and presenting somewhat the appearance of a raspberry. Each of these little cells becomes changed into a motile spermatozoon. Tease out a portion of a seminal vesicle in water and examine under the microscope. If the vesicle of a fresh worm be examined, the spermatozoa may be seen moving about.

Remove a spermatheca, tease in water, and examine under the microscope. Sperm may possibly be found.

Remove an ovary and examine under the microscope. At the free pointed end large spherical cells will be seen—the *eggs* or *ova*.

With a lens observe along the body-wall on either side a series of white organs, the *nephridia*, each one of which extends from near the nerve-cord out toward the cut edge of the body-wall. These are the excretory organs or kidneys, and occur in all the segments except the first three and the last.

With the forceps pull away a nephridium, and under the microscope observe that it consists of a long tube bent back and forth several times and varying in diameter in different regions. One end opens to the exterior, the other pierces the septum and projects slightly into the segment in front, terminating in a funnel-shaped opening, the *nepheostome*. Look on the anterior face of a septum a little distance from the nerve-cord for the inner end of the nephridium. It is not always easy to find.

Slightly chloroform a worm, cut into the body, and with the forceps pull out some of the nephridia, mount in water, and examine under the microscope. You will see what appears to be rapidly moving streams or currents, but what is really the movement of the cilia within the lumen of the nephridium.

Where the intestine has been removed a conspicuous white cord, the *ventral nerve-cord*, will be seen extending along the mid-ventral line. (It may be that the ventral blood-vessel will also be seen.)

Remove the intestine and determine how far the nerve-cord extends posteriorly. In the same way trace it anteriorly as far as the posterior end of the pharynx. Cut the muscles which extend from the pharynx to the body-wall, and follow the nerve-cord to where it divides into two cords, the *circumpharyngeal commissures.* These bend up on either side of the pharynx and unite with the lower ends of the *cerebral ganglia,* two pear-shaped bodies lying on the dorsal side of the pharynx and united with one another in the mid-dorsal line. Thus it will be seen that there is a complete nerve-collar surrounding the pharynx.

The cerebral ganglia, the circumpharyngeal commissures, and the ventral nerve-cord together form the *central nervous system.*

Examine the cord with a lens. Slight swellings, known as *ganglia,* will be observed in each segment.

Fine white threads may be seen given off from the cerebral ganglia and from the nerve-cord. These are the *nerves,* which place the central nervous system in communication with all parts of the body. How many pairs of nerves are given off in each segment? Possibly this may be determined better by removing a half-inch of the cord and examining it under the low power of the compound microscope.

The body-wall is made up of three principal layers—an outer *epidermal layer,* a *middle muscular layer,* and an *inner muscular layer.*

With forceps pull away a piece of the inner layer, observing the fine threads, the *muscle fibers,* of which it is composed. In what direction do these fibers run? What effect would be produced by their contraction?

Pull away all the inner layer from a few segments, and under the microscope examine the part of the body-wall that remains. Muscle fibers will be found which belong to the middle layer. In what direction do they run? What effect would be produced by their contraction?

Tear the preparation into small pieces and look for the rather small cylindrical cells of the epidermal layer. Some of these are glandular and secrete a mucus, which moistens the surface of the body; others are sensory, being connected with the sense of touch. In this preparation you will likely see a number of pointed rod-like structures, the setæ.

In a preserved specimen cut the body in two through the region of the intestine, using either a sharp scalpel or a pair of sharp scissors; from one of the pieces cut off several sections not more than one segment thick. Wash out the contents of the alimentary canal, and with a lens look for the following parts: The intestine with its typhlosole, the septum, the blood-vessels, the nerve-cord, the nephridia, the setæ, and the layers of the body-wall. Study a series of similar sections through the region of the reproductive organs.

If a longitudinal section should be made through the middle of the body from the dorsal to the ventral side the resulting halves would be alike, and this is the only plane in which it could be cut into similar halves. Such an animal is said to be bilaterally symmetrical.

The eggs of the earthworm are laid in capsules which somewhat resemble a grain of wheat, except that there is no crease on the side. These may be found with little trouble by looking through a shovelful of earth in a place where worms abound. Cut into a capsule and observe that it is filled with albumen, like white of egg. It may also contain young worms large enough to be seen with the naked eye. If no worms are seen, mount the albumen on a slide, and under the microscope look for eggs or small worms.

THE CRAYFISH

In either a living or preserved specimen note the *body,* to which are attached, along the ventral side, a number of pairs of *appendages.*

The body is obviously divided into two parts—a posterior *abdomen,* consisting of a number of rings or *segments,* movably articulated with one another, and an anterior *cephalothorax,* which at first sight shows no signs of segmentation.

The cephalothorax is further divided into an anterior *head* and posterior *thorax,* a transverse groove, the *cervical groove* extending obliquely downward and forward from the dorsal side marking the boundary between the two.

The back and sides of the cephalothorax have a continuous covering, called the *carapace.*

Anteriorly the carapace is produced into a pointed structure, the *rostrum,* which varies in shape in the different kinds of crayfish. The part of the carapace posterior to the cervical groove is divided into a small central *cardiac area,* beneath which the heart is situated, and two large lateral flaps, the *branchiostegites,* which form the lateral boundaries of the *branchial* or *gill chambers.* The branchiostegites are marked off from the cardiac area by slight lines or grooves, the *branchiocardiac grooves,* which extend from the cervical groove to the posterior edge of the carapace.

See if you can pass a dissecting needle into the gill chamber between the ventral edge of the branchiostegite and the base of the legs.

How many segments are there in the abdomen? In what particulars do the first and last segments differ from the others? The last or posterior segment is called the *telson.* On its ventral side is the *anus,* the posterior opening of the alimentary canal.

Observe that the abdomen may be bent well forward under the cephalothorax. How far can it be bent in the opposite direction? Can it be bent from side to side? Try to make out the mechanical arrangement which permits motion in certain directions and prevents it in others.

The crayfish is completely enclosed in a case or covering called an *exoskeleton,* which is very firm and hard, except at the joints, both of the body and appendages, where it is thin and flexible. What is the advantage of this? The exoskeleton is not composed of cells, and is therefore not a living tissue, but is a cuticular structure secreted by the cells of the thin skin beneath. It is composed of a substance called *chitin,* which is rendered firm and hard by the deposition in it of lime in every place except at the joints.

Place a specimen in a jar of 20-per-cent nitric acid. This will remove the lime, but will not act upon the chitin. What change is produced? One specimen will do for an entire class.

In another specimen carefully separate the abdomen from the cephalothorax, and boil for half an hour or so in a strong solution of caustic potash. The soft parts will be eaten away, leaving only the exoskeleton and the lining of the esophagus and stomach. There should be at least one such specimen for every four or five students.

Make a further study of the way in which the rings of the abdomen are joined together, for this purpose separating them from one another. The dorsal part of one of these rings is called the *tergum* (plural *terga*), the parts extending freely down on the sides the *pleura* (singular *pleuron*), and the part between the appendages the *sternum* (plural *sterna*).

Though the carapace is continuous with the rest of the exoskeleton, it may with a little care be broken away without injuring either it or the part below. This should now be done. In the head, observe the *stomach,* or rather the lining of the stomach, which is attached by the *esophagus* to the mouth below. The lining of these organs is of the same nature as the exoskeleton and at the mouth is continuous with it.

Again examine the cephalothorax for indications of segmentation, paying especial attention to the ventral side, both inside and out, and to the side walls, which have been exposed by the removal of the cephalothorax.

At intervals of a year or more in old individuals, but more frequently in young, the exoskeleton becomes free from the skin, a break occurs on the dorsal side between cephalothorax and abdomen, and through this the animal backs out, leaving the exoskeleton in so perfect a condition that at first sight it has the appearance of a real crayfish. This process is called *ecdysis* or molting. Before the old exoskeleton is thrown off a new one is started. At first this is very soft, and while in this condition the animal increases so in size that it seems impossible it could have come out of the old exoskeleton. In a few days the new exoskeleton becomes hardened by the deposition of lime, and no further increase in size can take place until the next molt.

If possible, examine a living animal, observing which appendages are used in walking, the way in which objects are seized by the pincers, the movement of the many jointed feelers and of the eyes, and the force with which the abdomen may be bent downward and forward. This is a swimming motion, and causes the animal to dart backward swiftly when in the water.

Observe bubbles coming off from two points on the ventral side of the head; they are given out from the *cervical canals,* which lie just below the ends of the cervical groove and lead from the gill chambers. Hold the animal firmly by the back, and from the anterior end look into the cervical canal; a long thin plate, the *scaphognathite*, will be seen moving up and down in it. This moves in such a way as to bail the water or air out of the gill chamber.

Now hold the animal under water, ventral side up, and with a pipette drop some water containing powdered carmine along the base of the legs; soon this will be seen streaming out from the cervical canal. It will thus be seen how fresh water is passing constantly through the gill chamber for the purpose of respiration. Can a crayfish live out of water?

Break away the entire branchiostegiti from one side of a preserved specimen, and expose the *gills*. Each gill consists of a central stem, to which numerous filaments are attached. Move some of the appendages back and forth and observe that certain of the gills are caused to move. This is because they are attached to the basal joints of the appendages. Gills so attached are called *podobranchia*. Now move each of the appendages in the region of the gills in succession, and determine the ones to which gills are attached, and how many are attached to each appendage.

Carefully turn down the podobranchia. (This may best be done under water.) A new set of gills will be exposed. These are attached to the membrane connecting the basal joint of the appendages with the body. best be done under water..) A new set of gills will be hence called *arthrobranchia*. How do they compare in number with the podobranchia? What is the total number of gills?

If a specimen of the genus *astacus* from the Pacific slope be examined, look for a gill attached to the body-wall above the last thoracic appendage. This is known as a *pleurobranchia*. In a corresponding position in front of this, look for rudimentary gills, each one of which resembles a single filament of one of the functional gills.

Reexamine the caustic potash preparation. Were the gills eaten away by the caustic potash? What does this show?

With sharp scissors cut off one of the gills near its base, and with a lens examine the cut end of the stem. Two blood-vessels will be seen, one of which conveys the impure blood to the gill, the other conveys the pure blood away from it. From the first small side branches are given off to the filaments, and these connect with other fine branches which empty into the second. While passing through the gills, the blood is separated from the water by only a thin membrane, and through this the carbon-dioxid of the blood passes to the water and the oxygen of the water passes to the blood.

Now turn back the gills. A number of vessels, the *branchiocardiac canals,* will be seen in the body-wall passing from the base of the gills and converging toward the dorsal side. They convey the pure blood from the gills to the pericardial sinus.

The crayfish has nineteen pairs of appendages. These differ greatly in size and structure on different parts of the body, and going along with this difference of structure will be found a remarkable difference of use of function. An important fact which may readily be observed is that the appendages are jointed.

If an appendage is lost, as is often the case, a new one grows out, but it is some time before it becomes as large as its fellow of the opposite side. Look for examples of this.

Begin the study of the appendages with those of the fifth abdominal segment. Note the basal part, the *protopodite,* to which are attached two branches or rami, the inner one being called the *endopodite,* the outer the *exopodite.* Such an appendage is known as a *biramous* appendage. How many joints are there in the protopodite?

Are there any in the endopodite or exopodite? Note the numerous hairs or *setæ* on the endopodite and exopodite. In the female, the egg and later the young are attached to these.

Compare the last pair of appendages with the ones just studied. Are they biramous? Are they attached to the telson, or to the sixth abdominal segment? Observe that they can be spread out, so that together with the telson they resemble a fan. This fan, or *tail fin*, is a very efficient swimming organ when the abdomen is flapped forward.

Remove the appendages just examined from the same side as that on which the gills have been studied, and continue to do this with the others, as fast as they are studied placing them in order on a card.

In the female all the abdominal appendages with the exception of the last are like those of the fifth segment; but those of the first somite may be very small or entirely wanting.

In the male the appendages of the first and second segments are modified to serve as accessory reproductive organs, being used to transfer the sperm to the female. Observe that they are bent forward under the cephalothorax.

Next come five pairs of large appendages, the *ambulatory appendages*, the four posterior of which are used for walking, while the anterior, which are much larger than the others, serves by means of their powerful pincers or *chelæ* as a weapon of offense and defense, and are also used in seizing food and conveying it to the mouth.

Examine one of the posterior ambulatory appendages. Is it biramous? How many joints has it? Note that while all the joints are hinge-joints, like our elbow, a wide range of movement is obtained by their being in different planes. If a male, look for the opening of the sperm-duct on the first or basal joint.

Examine in succession the next four appendages, comparing them with the one just studied and carefully noting resemblances and differences. In the female, look for the opening of the oviduct on the basal joint of the third appendage. In removing the appendages be careful that the podobranchia, but not the arthrobranchia, are also removed.

Next come six pairs of appendages, which are crowded close together and serve as mouth parts, being used in the process of mastication. Of these, the posterior three are known as *maxillipedes,* and belong to the thorax. How many pairs of thoracic appendages are there?

Examine the third or last maxillipede. Observe that it is biramous. The protopodite is made up of two joints, the second of which is fused with the first of the endopodite. Can you find teeth any place on this appendage that might assist in mastication?

At first one is inclined to look upon the ambulatory appendages which have the pincers or chelæ as biramous. Compare one of these with the third maxillipede, and see if such an interpretation is correct. Imagine the exopodite removed, and compare the part that is left with one of the walking appendages. The latter might be looked upon as a biramous appendage that has lost the exopodia, the first and second joints representing the protopodite, and the remainder the endopodite. This is believed to be the case, and in the lobster, which closely resembles the crayfish, it is actually the case; for when the young lobster hatches the ambulatory appendages have both exopodite and endopodite, and later the exopodite is lost.

The second maxillipede resembles in general the third, but is smaller, and the relative size of the exopodite and endopodite is reversed.

In the first maxillipede, observe that instead of a podobranchia there is a thin leaf-like structure extending into the gill chamber.

The other three pairs of appendages, which act as mouth parts, belong to the head, and are, beginning with the posterior, *the second maxillæ, first maxillæ,* and *mandibles.*

The second maxilla is much modified, and it is hard to recognize the parts of a biramous appendage in it. Note especially the *scaphognathiti,* which is a part of this appendage, and which has already been seen in the living animal.

The first maxilla is considerably smaller than the second.

Between the first maxillæ and the mandibles are a pair of small, leaf-like plates, which are outgrowths of the border of the mouth, and are not looked upon as an appendage.

The mandible is a hard, bony structure, with a three-jointed *palp* fitting into a groove on its anterior surface. Observe the teeth along its inner edge. The mandibles form the chief organs of mastication. They are worked by powerful muscles, which will be seen later.

Between the mandibles observe the *mouth,* and note that it is situated some distance back of the anterior end of the body.

In front of the mandibles there is a considerable space free of appendages, and then come two pairs which function as sense organs, the *first* and *second antennæ.* These, of course, belong to the head. What is the total number of head appendages?

In the second antenna, note the hard, sharp-pointed plate which forms the exopodite, and the endopodite, which consists for the most part of a long, many-jointed feeler. On the ventral side of the basal joint observe a slight protuberance, upon which is a small pore, the *excretory aperture.*

The first antenna is smaller than the second. Both exopodite and endopodite are many-jointed feelers.

Make a table of the appendages, giving their function and the part of the body to which they belong.

Remove the carapace from the cardiac area and from the head region as far forward as the base of the rostrum, and about half-way down on the sides. In order to do this without injuring the internal organs, insert the point of the scalpel under the posterior edge, and, keeping it in contact with the hard part, work it forward, and break away the carapace bit by bit. In like manner remove the exoskeleton from the dorsal side of the abdomen.

If the work has been carefully done, the delicate *skin* will now be exposed. Remove this.

Beneath the cardiac area the *heart* may now be seen, a light-colored, thick-walled, muscular sac. From the anterior end are given off a median *ophthalmic artery,* a pair of *antennary arteries,* and below these a pair of *hepatic arteries,* while from the posterior end, near the ventral side, are given off, very close together, two median arteries, the *sternal artery,* which passes straight downward to the ventral side, and the *dorsal abdominal artery,* which passes backward above the intestine. All these are difficult to see on account of their delicacy and transparency, but will be studied later in an injected specimen.

On the dorsal surface of the heart look for a pair of openings, the *ostia.* Now remove the heart and look for two more pairs of ostia, one on the sides and one on the ventral surface, and at the same time look for the openings where the arteries have been broken away. Make a cut through the heart and note the cavity and the thickness of the walls.

The cavity in which the heart is situated is the *pericardial sinus.* This is an essential part of the circulatory system, for the branchiocardiac canals, which convey the blood from the gills, empty directly into it and not into the heart.

When the heart expands the blood passes from the pericardial sinus through the ostia into the heart; when it contracts it passes out through the arteries, being prevented from passing back into the pericardial sinus by the valves which guard the ostia.

In a living specimen insert a scalpel under the carapace into the pericardial sinus and collect the colorless blood which issues from the wound. Examine a drop under the microscope. Do you find any corpuscles? Allow the remainder to stand for a while. Does it coagulate?

On either side of the pericardial sinus observe a long, light-colored muscle. Find its attachment at either end; determine what effect would be produced by its contraction.

Beneath the pericardial sinus will be seen the reproductive organs. These consist in the male of a light-colored, three-lobed *testis,* one lobe being directed backward and two forward, and a pair of greatly convoluted *sperm-ducts.* Tear away the thin ventral wall of the pericardial sinus and press the sperm-ducts to either side, so that the various lobes of the testis may be distinguished. Carefully straighten out one of the sperm-ducts, tracing the one end to its connection with the testis and the other to its external opening on the basal joint of the last thoracic appendage.

In the female the *ovary* has the same relative position as the testis in the male, and like the testis is a three-lobed organ. It varies greatly in size with the time of the year, but is always much larger than the testis. Press the body-wall to one side and observe the short, straight *oviduct* passing off from the side of the ovary. Follow it down to its opening on the basal joint of the third ambulatory appendage.

Note the *stomach* which had already been seen in the caustic-potash preparation. With the finger-nail move one of the mandibles from side to side, at the same time observing that a body at the side of the stomach is caused to move up and down. This is the muscle which causes the mandible to close.

Observe the *anterior gastric muscles,* which are attached on the one hand to the anterior dorsal surface of the stomach and on the other to the carapace near the base of the rostrum, and the *posterior gastric muscles,* which are attached to the posterior dorsal surface of the stomach and to the carapace near the cervical groove. The simultaneous contraction of these muscles tend to pull the anterior and posterior ends of the stomach apart. Later we shall see what effect this produces.

Press the dorsal muscles of the abdomen away from the middle line, and observe the straight *intestine* which passes from the stomach to the anus. This, with the exception of a very small part next to the stomach, has a chitinous lining like the esophagus and stomach.

Remove the reproductive organs; they will be found to lie upon a pair of yellowish or brownish bodies, the posterior ends of the *digestive glands,* usually called the *liver.* How far forward do these extend? Each gland is made up of a great number of cæca, like glove-fingers, which unite together and empty by a common duct into the side of the intestine near where it joins the stomach. They secrete a digestive fluid, and, in addition, some of the food may pass from the intestine into the glands and from here be absorbed in the blood.

Press the posterior ends of the digestive glands to the side and observe the intestine passing between them. Try to see where the duct joins the intestine.

Remove the digestive glands, cut the anterior gastric muscles, and pull back the stomach. The *esophagus* may now be seen. Cut this near its connection with the stomach and remove the latter. As has been said, the lining of the stomach is of chitin. This has been thickened and strengthened at certain places by the deposition of lime, so as to form what are known as *gastric ossicles,* which form a sort of framework to the stomach. These may be quite readily distinguished, but may be seen to better advantage in the caustic-potash preparation.

Make a slit from the esophagus up through the anterior wall of the stomach, and wash out the contents. Look into the large anterior chamber of the stomach, and in the posterior part observe the single median and the two lateral *gastric teeth,* which may readily be distinguished by their brown color. They are connected with the framework of gastric ossicles, which are hinged together in such a way that when the gastric muscles contract the teeth are brought together. Pull the anterior and posterior ends of the stomach apart and observe the movement of the teeth.

The part of the stomach in front of the gastric teeth is known as the *cardiac* portion, and the part back of them as the *pyloric* portion.

There is a single pair of *excretory organs,* often called *kidneys* or *green glands,* situated in the head below the bases of the second antennæ. Each organ is a disk-shaped body, to which is attached a *bladder,* which lies upon it and which opens to the exterior through the excretory aperture on the basal joint of the second antennæ. With a glass tube drawn out to a point, inflate the bladder with air through the aperture, being careful to push the tube in only a very short way.

Remove the dorsal muscles of the abdomen, and observe the very heavy *ventral muscles,* noting their continuation forward on the floor of the thorax. Make out the anterior attachment of the latter to the exoskeleton of the thorax. What would be the effect of the contraction of these muscles? Remove the ventral abdominal muscles, noting the way in which the different strands are looped over one another.

The abdominal portion of the *ventral nerve-cord* will now be seen extending along the mid-ventral line. Along this cord observe a number of slight swellings, the *ganglia*, from which pass off fine, white cords, the *nerves*. How do the ganglia compare in number with the segments? Is there a ganglion in the telson? In the posterior part of the thorax the cord will be seen to enter a sort of tunnel. Examine this tunnel in the caustic-potash preparation, and observing its anterior opening.

Break away the roof of the tunnel and expose the cord. How do the ganglia compare in number with the appendages? The cord is pierced by the sternal artery. Look for this, or if the artery has been removed, for the opening through which it passed.

With stout scissors cut away the body-wall on one side to a level with the base of the appendages, and follow the large nerves from the ganglia into the appendages. In the region corresponding to the mouth-parts a number of nerves will be seen given off close together. This has been brought about by the crowding together and fusion of several ganglia into one.

Just anterior to this the cord divides into two commissures which pass forward on either side of the esophagus and reunite in the *cerebral ganglion* in the very anterior part of the head.

Break away the exoskeleton down to the level of the cerebral ganglion and look for the nerves passing to the eyes and to the first and the second antennæ. Are there any other nerves given off from this ganglion?

Remove one of the first pair of antennæ, and under the low power of the microscope look for little bunches of hairs on the exopodite, the *olfactory setæ.* These are thought to be connected with the sense of smell.

On the dorsal side of the basal joint of the same appendage look for an opening guarded by a thick bunch of setæ. This leads into a sac which forms the *ear* or organ of hearing. Break away the wall from the ventral side of this joint and expose the sac.

Remove one of the eyes, and with a lens—or, better, with the low power of the microscope—examine the dark surface. It will be seen to be divided into a great number of square areas called *facets.* With a scalpel divide the eye longitudinally and observe the dark mass within. This is made up of a great number of complicated, rod-like elements, called *ommatidia,* each ommatidium corresponding to a facet. Scrape out some of this mass, tease it out a little in a drop of water, and examine under the microscope. Possibly the whole or parts of some of the ommatidia may be seen. An eye like this is called a compound eye.

The arteries may be quite easily injected by passing the needle of an ordinary hypodermic syringe forward under the posterior edge of the carapace into the pericardial sinus. The specimen should be left some hours for the injection mass to set. Open the specimen as in the previous dissection, and trace out the arteries which have already been mentioned (p. 40), the ophthalmic, the antennary, the hepatic, and the dorsal abdominal. Follow the sternal artery ventrally, observing that it pierces the ventral nerve-chain and then divides into two branches, one running backward, the *ventral abdominal artery,* and another running forward, the *ventral thoracic artery.* From the ventral thoracic artery are given off branches which may be traced out into the appendages.

THE GRASSHOPPER

Grasshoppers are familiar insects found in great abundance in the fields during the summer and fall. There are a number of different kinds, but any kind will do for study, the larger specimens, of course, being preferable for dissection.

The body of the grasshopper is divided into three regions: *head, thorax,* and *abdomen.* Of these the head is easily distinguished; the thorax is the part which bears the legs and wings, while the abdomen is the long, distinctly segmented posterior region. These parts will be studied more in detail later.

With forceps seize the *wing* by the lower edge, and pull it outward and forward. A second wing will be disclosed, which is attached to the body back of the first. Pull this out in like manner. Let it go and observe that it folds up like a fan. Does the first wing fold also? Which wing is the larger? Which is the stiffer? The first wings are sometimes called the *wing covers.* Cut off one of the second pair of wings close to the body, spread it out on a slide, and examine with a lens. Observe the thickened ridges, the *veins,* diverging outward from the base. They give strength to the wing. The main veins are connected by numerous small transverse veins, and in this way the wing is divided into a great number of clear areas called *cells.* Do you find veins and cells on the first wings also?

On the front of the head observe the single pair of many-jointed *antennæ,* special organs of feeling which contain in addition the olfactory organs or organs of smell.

At the lower end of the head are a number of structures, known collectively as *mouth-parts.* These are the *labrum,* one pair of *mandibles,* one pair of *maxillæ,* the *labium,* and the *hypopharynx.*

First find the unpaired flap-like upper lip or *labium*, which is movably articulated to the lower part of the front of the head.

Cut this away and expose the strong, dark-colored jaws or *mandibles*. These are powerful organs of mastication. Insert a scalpel between them and open them, noting their toothed inner edges, and also the direction in which they move. Compare this with the direction in which your own jaws move.

Break away the mandibles. They are followed by a second pair of jaws, the *maxillæ*. In which direction do they move? A maxilla is not so simple a structure as a mandible, but is made up of a number of parts. Of these note the sharp, dark-colored biting part, and the jointed *palp*.

Break away one of the maxillæ, being careful to get all of it and examine more carefully.

Following the maxillæ is the median lower lip or *labium*. Though unpaired, it is formed by the fusion of a pair of structures resembling the maxillæ. Do you find any indication of this fusion? The labium is made up of a number of parts. Of these note the jointed palps.

Just in front of the labium is a median tongue-like structure, the *hypopharynx*.

Of the mouth-parts the mandibles, maxillæ, and labium are modified appendages, while the labrum and hypopharynx are not. The antennæ are also appendages, so that there are in all four pairs of appendages on the head.

There are three pairs of appendages on the thorax, the legs. The wings are not reckoned as appendages, being of an entirely different structure.

Each leg is made up of a single series of joints. Examine one of the first pair. The first joint—that which joins the body—is the *coxa*. This is followed by a still smaller joint, the *trochanter*. Next comes a stout joint, the *femur*. Next another long joint, but more slender, the *tibia*. The part beyond the tibia is the *tarsus*, and consists of more than one joint. Of how many? On the tarsus observe a pair of sharp hooks and a series of pads. Would these pads rest on the ground in the natural position?

Now return to a study of the body. First cut off the wings, leaving short stumps. The head joins the thorax by a short neck. Is any movement possible between head and thorax? One might think the head represented a single somite, corresponding to one of the somites of the abdomen, but it is thought to have been formed by the complete fusion of several segments.

The thorax consists of three divisions, each corresponding to a segment: The *prothorax*, which bears the first pair of legs; the *mesothorax*, which bears the second pair of legs and the first pair of wings; and the *metathorax*, which bears the last pair of legs and the last pair of wings. With this in mind, are you able to find the boundaries between the different divisions? Is there any movement between prothorax and mesothorax? Between mesothorax and metathorax? The prothorax is covered on the sides and back by a structure, called the *pronotum*, the free edge of which extends back a little over the mesothorax.

Examine any one of the segments in the middle region of the abdomen. It will be seen that the exoskeleton—that is, the outer covering—is made up of a larger dorsal piece, the *tergum*, and a smaller ventral piece, the *sternum*, the two being joined together on either side by an infolding of the wall. These infoldings of the various segments give rise to a conspicuous groove extending along either side of the abdomen.

How many abdominal segments are you able to distinguish? You will have trouble in determining just what are segments at the posterior end. This is really a difficult point, and has led to a difference of opinion as to the number of segments in the abdomen.

The tergum of the anterior segment is easily distinguished, but the sternum is dovetailed into the sternum of the metathorax, so that it looks more like a part of the thorax than of the abdomen. Then the tergum and sternum of this segment do not come together on the sides, the bases of the last pair of legs intervening, so that at first sight one might think the legs belonged to the first abdominal segment rather than to the metathorax.

Thus the boundary between thorax and abdomen is not very clear, especially on the ventral side. Examine some other insect, such as a fly, ant, bee, or wasp, and see if the division into the three body regions—head, thorax, and abdomen—is any more clearly marked than in the grasshopper. At the same time see if the number of legs is the same.

On the sides of the upper part of the head observe the pair of large *compound eyes.* In addition look for three small *simple eyes,* one in the middle line between the antennæ and one just in front of the upper part of each compound eye. With a scalpel slice off one of the compound eyes, place it on a slide, and scrape out the dark soft part within. First examine the hard outer part under the microscope. It will be found to be transparent and to be divided into a great number of hexagonal areas called *facets.* Corresponding with each facet is a complicated rod-like element of the compound eye called an *ommatidium.* Tease out the soft part of the eye in a drop of water and examine under the microscope. Possibly you may be able to see some of these, or at least parts of them.

On the side of the first abdominal somite look for a rather large oval opening across which is stretched a thin membrane, the *tympanic membrane.* This is thought to be an organ of hearing.

Just in front of the tympanic membrane find with a lens a small opening, a *stigma* or *breathing-pore.* Find another above and a little back of the base of the second leg, and still others on the abdomen just above the groove running along the side of the body. How many do you find on the abdomen? Do you ever find more than one pair on a segment? In breathing, air passes through the stigmata into tubes called tracheæ, which will be studied later. No air is taken in through the mouth.

Every part of the grasshopper—body, wings, and appendages—is enclosed in a tough, more or less flexible *exoskeleton,* formed of a substance called chitin. The exoskeleton is not the skin, nor is it formed of cells, but is secreted by the cells of the true skin beneath. While the animal is growing it casts off the exoskeleton at intervals, and develops a new and larger one. This casting of the exoskeleton is called the *ecdysis.*

Examine a living specimen, observing the movement of the antennæ and mouth-parts, the breathing movements of the abdomen, the way in which the animal walks and leaps, and the way it holds to an object with its feet.

Examine a number of specimens, either living or preserved, and observe that in some the end of the abdomen is more pointed, in others more blunt and rounded. The former are females, the latter males. At the end of the abdomen in the female observe two pairs of pointed processes, the *ovipositors.*

If possible use a fresh specimen for studying the internal anatomy; but if not, a preserved specimen will do.

Cut away the labium, spread the mandibles wide apart, and with a lens look for the mouth between the base of the mandibles and in front of the base of the hypopharynx.

Cut away the exoskeleton from the front of the head, and between the eyes observe the large light or yellowish *cerebral ganglion* or *brain.*

Below the brain find the dark-colored esophagus extending upward from the mouth and passing beneath the brain. In order to see this it may be necessary to pick away some of the soft parts.

Cut away the exoskeleton from the dorsal side of the thorax and abdomen, bend out the body-wall a little on either side, and with pins fasten down to the wax of the dissecting pan. Cover with clear water. In the anterior part of the thorax a part of the dark-colored alimentary canal may be seen, but part of the canal will be covered by the reproductive organs—so it will be necessary to first study these.

In a female the *ovaries* are conspicuous yellow bodies, occupying a large part of the dorsal region of the abdomen and even extending into the thorax. The size varies, however. Each ovary is made up of a series of *ovarian tubules* lying side by side and extending obliquely backward, outward, and downward from the middle line.

Separate the ovaries along the middle line and turn the tubules of each outward. All the tubules of a side will be found to be attached to a rather large, light-colored *oviduct,* which extends backward under the alimentary canal, where it joins its fellow of the opposite side. The single tube thus formed leads to the exterior. A part of each oviduct will be seen to extend forward beyond the point where it is joined by the first tubules.

The free end of each ovarian tubule will be seen to become suddenly very slender and light in color. Remove a tubule and examine under the low power of the compound microscope. It will be found filled with eggs, the one nearest the base being large, elongated, and yellow, while the others are much smaller and decreased in size toward the end. The very end of the tube is a slender filament which contains no eggs.

In the male the two *testes* are closely bound together, forming a conspicuous body lying above the alimentary canal in the middle region of the abdomen. From either side is given off a *sperm-duct,* or *vas deferens,* which, like the oviduct, passes beneath the alimentary canal and unites with its fellow of the opposite side. Tease out the testes, and with a lens observe the numerous tubules of which they are composed. In both male and female there are accessory parts of the reproductive organs, but these will not be studied.

If you have been studying a fresh specimen, you have doubtless already noticed some of the bright, silver-colored *tracheæ,* or *breathing tubes.* Examine with a lens and note their branching. In a preserved specimen the tracheæ are far less conspicuous and may perhaps not be detected with the naked eye. In either case mount a little of the soft tissue and examine under the compound microscope. You can scarcely fail to have some of the tracheæ, as they go to every part of the body. They look something like a closely wound spiral spring, an appearance due to the spiral thickening of their chitinous lining. The tracheæ communicate with the exterior through the stigmata, and here their chitinous lining is continuous with the chitinous covering of the body.

If it has not already been done, remove the ovaries or testes, and expose the alimentary canal along its entire length.

In the region of the thorax some rather large light-colored bodies, the *gastric cæca,* will be seen lying on the alimentary canal. Each is made up of a larger anterior and a smaller posterior cæcum, which are free at their ends but unite with each other at their bases and open together into the alimentary canal.

Farther back observe a tangled mass of long, slender, brown tubules arising in a circle from the alimentary canal. These are the *Malpighian tubules,* and serve as excretory organs or kidneys.

Cut the alimentary canal in the anterior part of the thorax, turn it back, at the same time breaking or cutting the tracheæ which bind it to other parts. Free it along its entire length and place it in a small vessel of water.

The alimentary canal is divided into a number of regions. First is the esophagus, which was seen leading upward from the mouth and passing beneath the brain. Just back of the brain it enlarges into the *crop* or *ingluvies.* This is the part that was cut. The crop passes without any marked change of size into the *ventriculus,* but the boundary between the two may be determined by the fact that it is into the very beginning of the ventriculus the gastric cæca empty. Following the ventriculus comes the *intestine.* Here, again, there is no well-marked boundary to be seen from the outside, but it is just in front of the openings of the Malpighian tubules, they arising from the intestine. Three regions are recognized in the intestine: the *ileum,* the first straight portion; the *colon,* the portion where the intestine makes a sudden bend; and the *rectum,* the enlarged terminal region.

With scissors slit open the alimentary canal along its entire length, remove the contents, and under water float it out on a slide with the inside up. Examine with the naked eye or with a lens. Are you able to determine the boundary between crop and ventriculus, and between ventriculus and intestine? The esophagus and crop and the intestine have a delicate chitinous lining, while the ventriculus has not.

One part of the *central nervous system*—the brain—has already been seen. Now look for three rather large ganglia on the floor of the thorax, and, extending from one ganglion to another, a pair of slender nerves, called *commissures.* Do you find any nerves passing out from the ganglia? Find commissures extending backward from the last thoracic ganglion and follow them until you come to a swelling, the first *abdominal ganglion.* Proceed in like manner to the end of the abdomen. How many abdominal ganglia do you find? Do they give off any nerves? Follow the commissures forward from the first thoracic ganglion. In the head, just back of the esophagus, they unite with a *subesophageal ganglion,* and connecting this with the brain are two *circumesophageal commissures* passing on either side of the esophagus.

The grasshopper has a circulatory system, the principal part of which is a long pulsating heart situated along the dorsal side of the abdomen. Its walls are thin, and the blood which it contains is colorless, so that it is quite hard to make out.

THE FRESH-WATER MUSSEL

The fresh-water mussel is a bilaterally symmetrical animal, much compressed from side to side, and enclosed within a shell composed of two parts or valves, hence called a *bivalve shell.* The shell is never shed, but continues to increase in size as long as the animal lives. It does not grow itself, but is secreted by the soft parts beneath. On the outer surface are a number of concentric lines, called *lines of growth,* which mark the size and shape of the shell at various stages of its growth. These are seen to converge toward a slight protuberance known as the *umbo,* situated at the dorsal side of the shell and near the anterior end. The umbo is the oldest part of the shell.

Place a living specimen in a vessel of water containing 3 or 4 inches of fine sand. In a little while the shells will open slightly at the two ends and along the ventral side, and from the anterior ventral side a white, tongue-shaped body, the *foot,* which is the organ of locomotion, will be protruded. This will be sent down into the sand, and immediately the animal will begin to turn with its dorsal side up, at the same time moving forward and burying itself. With an active individual this may require only a few minutes.

The burying will not be complete, the posterior end remaining above the surface of the sand. At this end observe two rather large openings leading into cavities within the shell. The lips of the more ventral opening are beset with numerous short *tentacles.* With a pipette place a few drops of water containing powdered carmine near these openings. It will be found that a current of water is steadily passing in through the more ventral opening, hence called the *inhalant aperture,* while a current is at the same time passing out through the more dorsal opening, the *exhalant aperture.* The water thus taken in serves for the purpose of respiration, and at the same time carries microscopical animals and plants which form the food of the animal. Touch the lips of the exhalant or inhalant aperture. The shell will be immediately closed.

Before proceeding with the dissection it will be best to study the inner surface of an empty shell. Note the smooth iridescent surface. Some shells have ridges and projections near the dorsal edge on either valve, which fit into corresponding depressions of the opposite valve, thus forming a sort of hinge. These belong to the genus *Unio.* In others, belonging to the genus *Anodonta,* the ridges and projections are entirely wanting.

Concentric with the ventral edge and a little distance from it is a well-marked line, the *pallial line.* This ends anteriorly at an oval area, the *anterior adductor impres-*

sion, and posteriorly at a somewhat similar area, the *posterior adductor impression.* During life the muscles which close the shell, the anterior adductor and the posterior aductor, are attached at these points. Near-by are other smaller impressions to which muscles that assist in protruding and retracting the foot are attached.

In a preserved specimen in which the shell is gaping observe the thin lamella, the *mantle lobe* or *pallial lobe,* lining each valve. Insert the point of a scalpel between this and the shell, and determine whether it is simply in contact with the shell or whether it is attached to it, and if so, where. If any attachment is found loosen it, and then, keeping the point of the scalpel in contact with the shell, sever the anterior and posterior adductor muscles, and the other muscles near them, from their attachment with the shell. As soon as this is done the valves will open more widely than before. Press them together and notice that some resistance is offered, and that when released they at once spring apart. This is due to the elasticity of the *hinge-ligament,* an uncalcified part of the shell joining the two valves along the dorsal line.

Break off the loosened valve and place a piece of the broken hinge-ligament and a fragment of the shell in acid to determine whether they contain lime, the presence of which will be indicated by effervescence or bubbling.

The body proper is now visible, lying in one-half of the shell. Note the position of the *adductor muscles,* and observe that they extend from one valve to the other.

Make out the attachment of the mantle lobe to the body. Is it of equal thickness throughout? Does it line the entire shell?

Observe that the inhalant opening leads into a large chamber, the *branchial cavity,* which is bounded laterally by the mantle lobes, and that the exhalant opening is connected with a much smaller cavity, the *suprabranchial* *cavity,* which extends forward below the posterior adductor. During life the edges of the mantle lobes are in contact every place except at the inhalant and exhalant openings, so that the branchial cavity is virtually completely closed except for the inhalant opening.

The posterior end of the alimentary canal is on the dorsal side of the posterior adductor, and opens through the *anus* into the posterior part of the suprabranchial chamber. This part of the chamber is sometimes spoken of as the cloaca. Just back of the anterior adductor is the *mouth.*

Turn back the mantle lobe. A number of important organs will be seen suspended in the branchial cavity. In the anterior half is a large median body, the ventral part of which is the *foot,* previously seen projected from between the valves in the living specimen; the larger, thicker, dorsal part is the *visceral mass,* within which will be found later several important organs. The anterior part of the foot projects somewhat beyond the visceral mass.

Extending from the posterior end of the branchial cavity to beyond the middle of the visceral mass will be seen on either side two leaf-like bodies, the *gills.* On the floor of the suprabranchial cavity observe four rows of openings, and make out the relation of these to the gills by passing a pin into some of them. Each gill is really a sort of pouch or pocket, divided into a great number of compartments by cross-partitions. These cross-partitions may easily be seen from the suprabranchial cavity. Can you see any markings on the surface of the gills corresponding to the internal divisions?

The walls, or *lamella,* of the gills are pierced by many fine pores through which the water passes from the branchial chamber into the compartments of the gills. From these it passes up into the suprabranchial cavity, and thence out through the exhalant opening.

Anteriorly the suprabranchial chamber divides into four parts, one for each gill. Make this out by passing a seeker forward in the cavity above the base of each gill. In the angle between the inner gill and the visceral mass there is a direct communication between the branchial and suprabranchial chambers, and through this the seeker will pass into the branchial chamber. Make out the extent of this opening.

In front of the gills on either side are two triangular bodies, the *labial palps,* which might be taken for small gills, but which are entirely different structures. The outer palp of one side is joined to the outer palp of the other side by a narrow fold extending around in front of the mouth, while the inner palps are similarly connected by a fold passing back of the mouth. The surfaces of the palps are covered with cilia, which move in such a way as to sweep food particles toward the mouth.

The *pericardial cavity* is a median chamber situated in front of the posterior adductor muscle and dorsal to the attachment of the mantle lobe with the body. The lateral walls are very thin, so that its size and location may be easily determined.

Make an opening into the cavity. It contains the *heart,* consisting of two *auricles* and one *ventricle,* and in addition is traversed by a portion of the intestine. The ventricle surrounds, and looks like an enlargement of the intestine.

An artery is given off from either end of the ventricle, the one passing forward above the intestine, and the other passing backward below it. They can not be seen at this stage.

But one auricle can now be seen. It has a narrow attachment to the side of the ventricle on the one hand and a much broader attachment to the lateral part of the floor of the pericardial cavity on the other. Its walls are very thin, and are usually collapsed, so that it presents the appearance of a thin triangular membrane.

The blood, which is colorless, is received into the auricles, these contract and send it into the ventricle, the ventricle then contracts and sends it through the two arteries above mentioned and their branches to all parts of the body. That which goes to the mantle lobes is returned directly to the auricles, while that which goes to other parts of the body has to pass through both the gills and the kidneys before it again reaches the auricles.

Take out the portion of intestine within the pericardial cavity together with the ventricle. In order to do this the auricles will have to be severed. Now with scissors make a transverse section, passing through the openings between auricles and ventricle. Look into the cut ends and make out the relation between ventricle and intestine. Is there any communication between the two? See if you can find valves which would allow blood to pass from the auricles to the ventricle, but would prevent its flowing in the opposite direction.

Make a section through the intestine in front of the heart, and look at the cut end for the artery given off from the ventricle.

It will be well at this stage to open a living specimen and observe the beating of the heart. (A single specimen will likely answer for an entire class.) With scissors cut off small pieces of the gills and labial palps and examine them under a compound microscope for the action of the cilia. With a scalpel scrape off cells from the surface of the visceral mass, foot, and mantle, and determine whether these parts are also ciliated. It is the action of the cilia which causes the currents of water to pass into the branchial cavity and out of the suprabranchial cavity.

Returning to the preserved specimen, note the dark color of the floor of the pericardial cavity, due to the presence of the *excretory organs*, which are situated immediately beneath the floor of this cavity.

Look for two small openings, a right and a left, on the anterior part of the floor of the pericardial chamber near where the intestine enters. These are the *renopericardial openings*, leading from the pericardial cavity into the excretory organs.

Cut away the mantle lobe close to its union with the body, turn back the gills, and look for two small openings, very close together, in the angle between the inner gill and the visceral mass, and just below the renopericardial opening. The anterior of these is the *renal aperture* leading from the excretory organ, and the posterior the *aperture of the reproductive organ.* There are two similar openings on the other side.

The excretory organs consist of a single pair of wide, thin-walled tubes. Each tube begins at the renopericardial opening and extends back as far as the posterior adductor muscle. This part has dark irregular walls and is often called the *kidney.* At its posterior end the tube turns and runs forward above the kidney and below the floor of the pericardial cavity, ending at the external opening mentioned above. This part is sometimes called the *ureter.* Through part of its course it communicates with the ureter of the other side. Make an opening into the bend of the excretory organ just in front of the posterior adductor muscle, and pass one seeker forward in the ureter and another in the kidney. Then open the two parts, noticing the relation of one to the other, and also the difference in their walls.

Cut through the floor of the suprabranchial chamber, and on the ventral surface of the posterior adductor muscle just beneath the skin observe the *visceral nerve ganglia*, two ganglia united into one body.

Pull away the skin from the side of the body opposite the corner of the mouth and look for the *cerebral ganglion,* a small spindle-shaped usually orange-colored body from which several branches are given off. One of these branches, the *cerebral commissure,* will be seen to pass forward and around to the cerebral ganglia of the opposite side. Does it pass above the mouth or below it?

Follow another branch, the *cerebro-visceral connective,* which proceeds at first upward and backward, and then arches around to unite with the visceral ganglion. This will require care and patience.

Trace another branch, the *cerebro-pedal connective,* downward and backward to its connection with the *pedal ganglion,* situated at the boundary between the foot and visceral mass. This is quite difficult, as the connective passes through tough muscle almost the color of itself. There are two pedal ganglia, a right and a left, closely joined together.

Pare away the wall from the side of the visceral mass and expose a granular substance which appears to fill the entire visceral mass. This forms the reproductive organs —*testes* in the male, *ovaries* in the female. In either case the structure is the same, there being a great number of little sacs, called follicles, in which the sex cells develop, and which communicate with the exterior on either side through ducts opening at the reproductive aperture. Tease out some of the reproductive organ in water and examine with a compound microscope. If a female, the *ova* may be distinguished as large spherical cells, but in a preserved male the *spermatozoa* can hardlly be distinguished.

When ripe, the eggs pass into the cavity of the outer gill, where they remain for a long time and undergo the first part of their development. Perhaps some individuals with thick outer gills have been met with. If so, examine the contents under the microscope. Eggs or young in some stage of development will be found. When the young leave the gills they attach themselves to the body of a fish, where they remain for some time and undergo a metamorphosis. They then drop into the mud as young mussels. Those that do not become attached to a fish perish.

Continue to pare away the side of the visceral mass toward the anterior end. In this region a greenish body will be found, the *digestive gland.* This was partly exposed in tracing back the cerebro-visceral connective. The gland secretes a digestive fluid, which is poured into the stomach through several ducts.

Pass a seeker into the mouth and up through the short *esophagus,* which lies just back of the anterior adductor muscle. Open up the esophagus from the side and trace it to its opening into an enlarged cavity, the *stomach.* Open the stomach, and on the side wall find the openings of the digestive gland, and on the floor the opening into the *intestine.*

Under water scrape away the reproductive organ and expose the intestine. Its walls are so tender and it is so closely invested by the reproductive organs that there is danger of scraping away the intestine itself. Do you find the intestine straight or convoluted? Trace it to its connection with the stomach on the one hand, and into the pericardial cavity on the other. The part passing through the pericardial cavity as well as the extreme posterior end which passes over the posterior adductor muscle have already been seen.

Remove a well-hardened specimen from the shell, place it upon a board, and with a scalpel—or, better, with a razor—cut it into a series of transverse sections about a quarter of an inch thick. Place these in order in the dissecting pan under water. A number of points of the anatomy will be better understood from the study of the sections than from the dissection.

Find the anterior and posterior adductor muscles. Observe the relation of the mantle lobes and of the gills to the body.

Study the relation of the suprabranchial chamber to the gills, and find sections where it shows as a single chamber, where it is divided into three parts, and where it is divided into four, one for each gill.

Note the relation of the foot to the visceral mass, and observe that the latter is almost completely filled by the reproductive glands.

Embedded in the reproductive glands find sections of the various coils of the intestine. Look for sections of the intestine in which the lumen is crescent-shaped. This is due to the fact that for some distance in front of the heart the wall of the intestine folds down into the lumen, forming what is known as a *typhlosole*.

In the more anterior sections find the stomach and the digestive glands, and observe the position of the latter relative to the reproductive glands. Examine with a lens looking for the very numerous *cœca* of which the digestive glands are composed.

In a section passing through the heart region observe the relation of the heart to the pericardial cavity, of the auricles to the ventricle, and of the ventricle to the intestine.

Just below the floor of the pericardial cavity observe two smooth-walled tubes, the ureters. Possibly the section may be taken through the place where the ureters connect with each other, in which case there would be a single wide tube. Below the ureters observe two tubes with folded walls, the kidneys.

In the middle line between the ureters a small tube may be seen, one of the blood-vessels. Other blood-vessels may be seen at the base of the gill lamellæ.

You may possibly be able to distinguish parts of the nervous system also.

THE TOAD

Kill a toad by placing it in a tight jar with a piece of cotton saturated with chloroform. This specimen may be studied in the fresh conditon for a day or two, depending on the temperature, but after that it should be placed in 70-per-cent alcohol or 2-per-cent formalin to preserve it.

A white secretion will be poured out from glands of the skin. Wash this off. Do you find any scales on the skin?

The body is made up of head and trunk, there being neither neck nor tail.

Compare the hind leg with the leg of man and the fore leg with the arm. Do you find parts corresponding to thigh, leg, and foot? and to arm, forearm, and hand? and joints corresponding to knee and ankle, and elbow and wrist?

How many toes has the fore foot? The hind foot? Have the toes either claws or nails? Observe that the hind feet are webbed. What is the use of this? Are the fore feet webbed?

Note the wide *mouth*, and at the posterior end the *anus*, or, more correctly, the *cloacal aperture*. This one opening serves as the outlet for the alimentary canal, kidneys, and reproductive organs.

On the dorsal side of the snout note the two small *external nostrils*, at the side of the head the *eyes*, and a little back of each eye a circular, tightly stretched patch of skin, the *tympanic membrane*, a part of the organ of hearing.

Open the mouth and observe the *tongue.* What is there peculiar about its shape and attachment?

Do you find any teeth?

In the anterior part of the roof of the mouth observe the *internal nostrils.* Pass a fine probe into one of the external nostrils and see if it can be made to come out through the corresponding internal nostril.

Just back and a little above the angle of the jaws on either side observe the aperture of the very short *Eustachian tube,* which leads into the *tympanic cavity.* Insert a probe through this aperture, and observe that the tympanic membrane may be pushed out. While looking at the roof of the mouth, press on one of the eyes. What do you see?

On the floor of the mouth, or rather of the *pharynx*—for the posterior part of this cavity is called pharynx—find a median longitudinal slit, the *glottis,* through which the air passes to and from the lungs.

Posteriorly the pharynx is continued into the *esophagus.* This may best be made out by pushing a large probe into it.

In a living toad observe the alternate opening and closing of the nostrils and the elevation and depression of the floor of the mouth. Both movements are connected with the act of respiration; when the floor of the mouth is lowered air passes in through the nostrils; when it is raised the nostrils are closed, and the air, being unable to escape, is forced through the glottis into the lungs. Could a frog take air into the lungs if the mouth were held open? Hold open the mouth and see if the nostrils can be closed. While the mouth is open, press upon the tip of the upper jaw, at the same time observing the nostrils. What is the effect?

Are the eyes closed by the movement of an upper or a lower eyelid? Would it be possible for the toad to see or to distinguish light from darkness when the eyes are closed? When closed tightly the eyes are pulled back somewhat into the head. Look at the roof of the mouth while this is being done.

At the posterior end of the back, on either side of the middle line, observe a pulsation, due to the beating of the *posterior lymph-hearts,* situated just beneath the skin. (There is also a pair of *anterior lymph-hearts,* but they can not be seen from the surface.)

Return to the dead specimen, and with scissors make a longitudinal incision through the skin the full length of the body along the mid-ventral line. Observe the space between the skin and body, which is divided by partitions into various compartments, the *subcutaneous lymph sinuses.* Note the moisture in these, due to the presence of *lymph,* a fluid resembling blood without the red corpuscles. The lymph is pumped from the sinuses into the veins by the lymph-hearts.

With scissors cut through the body-wall a little to one side of the mid-ventral line and near the posterior end. An opening will thus be made into the *pleuroperitoneal cavity,* a division of the *body-cavity* or *cœlom.* Carry the cut forward to the anterior end of the cavity, and then make transverse cuts both to the right and left near the anterior and posterior ends of the longitudinal cut, and turn back the flaps thus formed. In dissecting from the ventral side you must bear in mind that the ventral side is up and the dorsal side down, that the animal's right side is to your left and its left to your right.

Insert a tube into the glottis and inflate the *lungs.* These will appear as large sacs on either side of the pleuroperitoneal cavity. Hold the glottis open, the air will pass out, and the lungs collapse, owing to the elasticity of their walls.

Possibly a large, transparent, bilobed sac, the *urinary* *bladder,* filled with a clear fluid, may be seen at the posterior end of the pleuroperitoneal cavity. If not, insert a tube just within the cloacal aperture and inflate with air.

The *heart,* situated in the middle of the body and near the anterior end, may still be beating. It seems to be in the pleuroperitoneal cavity, but is really in another division of the cœlom, the *pericardial cavity,* the walls of which are formed by a thin, transparent membrane.

With forceps pick up this membrane, and with scissors slit it open. The heart will now be seen more clearly.

The posterior part of the heart is the *ventricle.* It is somewhat cone-shaped, the blunt apex being direct backward.

Joining the base of the ventricle, and therefore directed forward, are the large, dark-purple right and left *auricles.* Externally these look like a single division of the heart, but we will see later that they are completely separated by an internal septum.

Starting from the right side of the base of the ventricle and extending obliquely to the left across the auricles is the *truncus arteriosus.* Note that this gives off a right and a left branch.

Lift up the ventricle and observe the *sinus venosus,* which is attached to the auricles. It is the same color as the auricles and is not quite so easily distinguished as the other divisions of the heart.

The divisions of the heart beat in the following order: Sinus venosus, auricles, ventricle, and truncus arteriosus. See if you can make this out.

If kept moist the heart may continue to beat for several hours, and this even when removed from the body. The dissection of the heart will be taken up later.

At either side of the heart are the large dark-red right and left lobes of the *liver.* Is either lobe subdivided into smaller lobes? Lift up the heart and see if there is any connection between the lobes.

Lift up the left lobe of the liver and observe the *stomach,* the size of which varies greatly with the amount of food contained. Anteriorly it joins the short esophagus, while the smaller posterior end makes a U-shaped bend and is continued into the *small intestine.* The junction between the esophagus and stomach is called the *cardia,* and the upper end of the stomach is called the *cardiac end,* while the junction between the stomach and small intestine is called the *pylorus,* and the lower end of the stomach the *pyloric end.*

Follow out the much-convoluted small intestine. It is divided into two parts, the first part being the *duodenum* and last the *ileum.* Externally there is no marked difference between the two.

Posteriorly the small intestine joins the much-enlarged *large intestine* or *rectum.*

Posteriorly the rectum is continuous with the *cloaca,* the external opening of which has already been seen. This division will be studied later.

The long tube formed by the mouth, pharynx, esophagus, stomach, duodenum, ileum, rectum, and cloaca, is called the *alimentary canal.*

It will have been observed that the parts of the alimentary canal within the pleuroperitoneal cavity are suspended by a thin membrane, the *mesentery.*

In the mesentery suspending the small intestine look for a rather small, round, dark-red body, the *spleen.* This is not a part of the digestive system.

Again, lift up the heart and observe the greenish *gall-bladder.* The color is due to the bile, a fluid secreted by the liver. A small duct, the *bile-duct,* leads from the gall-bladder and empties into the small intestine not far from the pylorus. Gently squeeze the gall-bladder. Some of the bile will be forced into the bile-duct, which can now be distinguished by its greenish color. Make a longitudinal slit along the intestine opposite the opening of the bile-duct. Again, squeeze the gall-bladder and observe the bile flowing into the intestine.

Along the bile-duct in the mesentery will be seen a light-colored, irregular-shaped body, the *pancreas*. This secretes an important digestive fluid, the pancreatic fluid. In many vertebrates the pancreas has a duct of its own emptying into the intestine, but here the bile-duct serves for both liver and pancreas.

Cut the rectum in two near its posterior end, lift it up and cut a little of the mesentery suspending it, observing that the mesentery consists of two sheets of membrane lying side by side. These will be found to be continuous on the one hand with the smooth lining of the pleuroperitoneal cavity, and on the other with the outer layer of the alimentary canal. This membrane, which lines the pleuroperitoneal cavity, forms the mesentery, and surrounds the alimentary canal and several other organs, is the *peritoneum*.

Pass a probe dorsalward and forward between the layers of the mesentery; it will enter the large *subvertebral lymph-sinus*.

Now remove the alimentary canal by cutting the mesentery and the esophagus. Slit it open along its full length, wash out the contents, and if possible determine from this the kind of food the toad lives upon.

Carefully examine the mucous membrane lining the alimentary canal. Do you find any marked change in this in going from the stomach to the small intestine? or from the small intestine to the rectum? Observe that in the first part of the small intestine, the duodenum, the mucous membrane presents a velvety appearance, while in the posterior part, the ileum, it is thrown into longitudinal folds. From this can you tell where the duodenum ends and the ileum begins?

Remove the liver, taking care not to injure a large vein, the *posterior vena cava,* lying dorsal to it.

The posterior vena cava will be seen to join the sinus venosus. Find two large veins, the right and left *anterior venæ cavæ,* coming from toward the head and joining the sinus venosus on the sides. Now find the short and rather small right and left *pulmonary veins* passing from the lungs to the left auricle.

Cut all of these veins, and also the branches given off from the truncus arteriosus, and remove the heart.

Cut into the sinus venosus, wash out the blood, and find the openings of the posterior and the two anterior venæ cavæ, and also the opening leading from the sinus venosus into the auricle.

Cut away the walls of the auricles on the sides, wash out the blood, and observe the *septum* between the right and left auricles. Does the sinus venosus open into the right or into the left auricle?

Cut off about two-thirds of the ventricle, noting its thick spongy walls. Slit up the walls on either side, and look for an opening leading from the auricles into the ventricle, and another leading from the ventricle into the truncus arteriosus. The opening between the auricles and ventricle look to be single, but is really divided into two by the edge of the septum separating the auricles. To prove this, pass a probe from the right auricle into the ventricle and another from the left.

Pass one blade of the scissors from the ventricle up into the truncus arteriosus, and cut open. Find a fold called the *longitudinal valve* hanging down into the truncus and partially dividing it into a right and a left half.

Look at the cut ends of the branches passing off from the truncus and observe that each is divided internally into three divisions. Pass fine probes down these into the truncus.

Cut off about a third of the end of one of the lungs, and observe the central cavity and the honeycombed walls.

Cut away the ventral wall of this and also of the other lung, and pass a probe forward from each into a median chamber, the *laryngotracheal chamber,* which opens out through the glottis, and which is kept from collapsing by the cartilaginous framework in its walls.

Cut away a little of the ventral wall of the laryngotracheal chamber, pass one blade of the scissors forward and out through the glottis and cut. The chamber will now be laid open. On either side, a little back of the glottis, find two folds of mucous membrane extending into the cavity. The anterior of these are the *true vocal cords,* by the vibration of which the voice is produced; the posterior are the *false vocal cords.*

If the specimen is a female, and it is near the breeding-season, a large part of the pleuroperitoneal cavity will be taken up by the dark-colored right and left *ovaries,* each one of which is suspended, like the intestine, by a double fold of peritoneum, here called the *mesovarium.* Each ovary is a sort of closed sac divided into a number of compartments. Tear into the ovary and, if you can, make this out. Note the great number of dark eggs, about the size of fine shot, and in addition, note the smaller, light-colored eggs. The dark eggs would have been laid the next breeding-season, the light ones a year later. Tear away a piece of the ovary, mount in water, and, under the microscope, see if you can find more than two sizes of eggs.

After the breeding-season the ovaries are very much smaller and of a light color, but even then are quite conspicuous.

Attached along the dorsal wall of the pleuroperitoneal cavity on either side observe the long, much convoluted *oviducts*. These increase greatly in size at the breeding-season, but are always conspicuous. Follow one of the ducts forward to its end, and find the opening by which it communicates with the pleuroperitoneal cavity. The opening into the cloaca at the posterior end will be seen later.

As has been seen, there is no connection between the ovary and oviduct. When ripe the eggs break away from the ovaries and become free in the pleuroperitoneal cavity. They are then worked forward to the anterior end of the cavity, where they pass into the oviducts through the openings above mentioned, and then down and out through the cloaca. While passing through the oviduct they become surrounded by a white, albuminous covering.

At the anterior end of each ovary, near its attachment, observe a yellowish body, the *fat body*, which is produced into several finger-like processes. This varies greatly in size, being sometimes quite small, at others large and conspicuous. Fat bodies are found also in a corresponding position in the male.

In a male specimen observe the light-colored, elongated *testes*, at either side of the middle line and somewhat nearer the posterior than the anterior end of the pleuroperitoneal cavity. Each testis is suspended by a double fold of peritoneum, the *mesorchium*.

Cut off a little piece of a testis, tease in water and examine under the high power of the microscope. If near the breeding-season, the male reproductive cells, the *spermatozoa*, may be seen as small, elongated bodies. If taken from a fresh specimen, these will swim about actively in the water by means of the lashing of the very slender tail.

Hold up the mesorchium to the light and observe a number of fine lines passing from the testis. Some of these are blood-vessels supplying the testis, others are delicate tubes, the *vasa efferentia,* which carry the sperm from the testis to the kidney. From here the sperm passes out through the duct of the kidney, the ureter.

In the position corresponding to the oviduct in the female observe a small, slightly convoluted white tube, the rudimentary *oviduct.* Here it is entirely functionless.

Dorsal to the ovaries or testes, as the case may be, observe the elongated, flattened, dark-red kidneys. They are not suspended by folds of peritoneum, as are the reproductive organs and alimentary canal, but are covered on their ventral surfaces by it.

Observe a light-colored streak, the *adrenal body,* extending along the ventral surface of each kidney. They are not really a part of the kidneys.

Along the outer edge of the posterior half of each kidney, in the peritoneum, is a duct, the *ureter,* which extends back and opens into the cloaca. They are not easily distinguished on account of the transparency of their walls. In the male, as was mentioned above, the ureters serve a double function, carrying off the excretion of the kidneys and the sperm from the testes.

With a scalpel cut through the bone and cartilage along the mid-ventral line where the thighs come together and expose the *cloaca,* the posterior part of the alimentary canal.

With scissors slit this open a little to one side of the mid-ventral line. On the ventral side find the rather large opening leading from the bladder, and on the dorsal side about opposite to this, the openings of the oviducts and ureters. It may not be very easy to find these. When found insert a fine-pointed tube into the openings of one of the ureters and blow in a little air. The ureter may now be seen distinctly.

Slit the sheet of peritoneum which extends from the outer edge of the kidneys to the body-wall, and continue the cut forward as far as possible. The large subvertebral lymph-sinus will be fully exposed, and along the middle line the vertebral column will be seen to project as a prominent ridge.

Lift the kidneys and observe a number of delicate white threads, branches of the *sympathetic nervous system*, which are distributed to the heart, the blood-vessels, and the various organs in the pleuroperitoneal cavity.

Trace these branches dorsally, pulling on them gently, and observe that they spring from two delicate *sympathetic nerves* which lie along either side of the vertebral column and extend forward into the head. Scattered along each nerve are a number of slight swellings, the *sympathetic ganglia*, which, however, are rather hard to make out.

Coming out from the body-wall along either side of the spinal column are a number of white threads, the *spinal nerves.*

The four posterior spinal nerves, the last one being small and inconspicuous, will be seen to proceed directly backward. Follow them, cutting the tissues where necessary, and observe how they anastomose—that is, unite with one another. To what part of the body are they distributed? Are you able to trace any of the small terminal branches directly to muscles?

In front of the nerves just studied will be seen three much smaller ones going to the body-wall.

Find a large nerve passing out to the fore leg, and two smaller ones, one just in front and the other just back of this. Do either of these unite with the large one?

How many spinal nerves do you find in all?

The spinal nerves give off very short branches which join the sympathetic nerves.

Before proceeding to the study of the central nervous system examine a prepared skeleton, and observe the *neural canal* extending through the vertebral column, and in the skull the *cranial cavity,* which is continuous through an opening at the posterior end, the *foramen magnum,* with the neural canal.

Return to the specimen before studied. Remove the skin from the dorsal side of the head, then, beginning a little back of the nostrils, force the point of a stout knife or scalpel under the bones forming the roof of the cranium, and break these away bit by bit, keeping the point in close contact with the bones, so as to avoid injuring the parts beneath. Proceed in like manner to break away the roof from the neural canal.

Lining the cranial cavity and neural canal is a rather dark, tough membrane, the *dura mater,* which should now be pulled away.

The *central nervous system* will now be exposed, consisting of the *brain* in the cranial cavity, and the *spinal cord* in the neural canal.

Beginning at the anterior end, the parts of the brain seen from the dorsal side are: *Olfactory lobes, cerebral hemispheres, thalamencephalon, optic lobes, cerebellum,* and *medulla oblongata.*

The olfactory lobes are the most anterior part of the brain. They are so closely joined together in the middle line that they seem to form a single body. Slight transverse constrictions mark the boundary between them and the cerebral hemispheres.

The cerebral hemispheres lie side by side, but are separated from each other by a longitudinal fissure.

Posteriorly the cerebral hemispheres diverge, and partly enclose the median thalamencephalon.

Next follow the rounded optic lobes, easily distinguished by their dark color.

Just back of the optic lobes is a narrow band, the cerebellum.

The medulla oblongata forms the posterior division of the brain; it tapers slightly, and is directly continuous with the spinal cord, there being no distinct boundary between the two.

On the dorsal side of the medulla and just back of the cerebellum is a triangular-shaped body, usually of a pinkish color, the *choroid plexus.* With forceps pull this away. A cavity will be exposed, called the *fourth ventricle* of the brain. The cerebellum will now be seen more distinctly.

How far does the spinal cord extend posteriorly?

Observe a slight longitudinal groove, the *dorsal fissure,* extending along the median line. There is a similar *ventral fissure* along the ventral side.

Break away the side walls of the neural canal and observe the union of the spinal nerves with the cord. Each arises by two roots, a *dorsal root* and a *ventral root.* These may be seen best in the large nerve passing to the fore leg.

On the dorsal root observe a slight swelling, the *spinal ganglion.*

Observe the two short *olfactory nerves* passing from the anterior end of the olfactory lobes to the nose.

Break away the side walls of the cranial cavity, cut the olfactory nerves, and gently lift up the brain. On the ventral side and back of the hemispheres observe the two *optic* nerves passing out to the eyes.

There are in all ten pairs of *cranial nerves*—that is, nerves given off from the brain; but only the olfactory and optic will be mentioned.

Remove the entire central nervous system, cutting the nerves when necessary, and place it in a small vessel of water. With sharp scissors cut across the brain in the regions of the cerebral hemispheres, the thalamencephalon, and the optic lobes.

Look at the cut ends of the cerebral hemispheres, and in each observe a rather large cavity, the *lateral ventricle.*

In the thalamencephalon will be found a single, median, slit-like cavity, the *third ventricle.*

In each optic lobe is an *optic ventricle,* while in the same section and ventral to the optic lobes is a small round opening, the *iter.*

The cavity of the medulla, the fourth ventricle, has already been seen.

All these cavities of the brain are continuous with one another, and are also continuous with the *central canal* of the spinal cord, a small canal extending through the full length of the cord. In order to see this, cut across the spinal cord and examine the cut end with a lens.

An instructive preparation may be made by placing a specimen from which the skin and the contents of the body-cavity have been removed in 20-per-cent nitric acid for about twenty-four hours. The bones will be decalcified, the muscles and connective tissue macerated, and everything may be picked away leaving the nervous system intact. After removing from the acid, the specimen should be left in running water for an hour or so to get rid of the acid.

Insert the point of a scalpel through the external nostril and cut forward, opening up the relatively large *nasal* or *olfactory sac* with which both the external and internal nostril communicate. The olfactory nerve terminates in the cells of the membrane lining this sac.

Examine the eye of a living toad. The exposed portion of the outer wall is the transparent *cornea.* Back of the cornea is the *iris,* the part that gives color to the eye, and in the center of the iris is a dark area, the *pupil.*

Compare the shape of this with the shape of the pupil of your own eye. Place the animal first in the darkness and then in the light. Does the size of the pupil change?

In a preserved or recently killed specimen cut away the eyelids and remove the eye. The corners will be seen to be continuous with the bluish *sclerotic,* the part corresponding to the white of our own eye. The cornea and sclerotic together form the *outer coat* of the eye.

Attached to the back part of the eye will be found the ends of the eight *eye muscles,* by means of which the eye is moved. Cut these away and find the *optic nerve* joining the back of the eye a little distance from the center.

With a sharp scalpel cut the eye in two a little back of the line where the cornea and sclerotic meet. The *vitreous humor,* a jelly-like substance, transparent in the recently killed specimen, will be found filling the back part of the eye.

Remove the vitreous humor and observe the *retina,* a delicate membrane, pinkish in the recently killed specimen, gray in the preserved specimen, which forms the *inner coat* of the eye. It may be loosened every place except at one point where it is continuous with the optic nerve.

Between the retina and sclerotic comes the dark *middle coat* of the eye, the *choroid.* This may be loosened from the sclerotic.

In the front half of the eye find a relatively large, rather firm, spheroidal body, the *crystalline lens,* which is transparent in the recently killed toad, but opaque in the preserved specimen. It may have fallen out when the eye was first cut in two.

The lens divides the cavity of the eye into a large *posterior chamber,* containing the vitreous humor, and a smaller *anterior chamber,* containing a clear watery fluid, the *aqueous humor.*

Remove the lens and observe that the iris is a continuation forward of the choroid, and that the pupil is a hole in the iris. It appears black in the living animal because one looks through it into a dark chamber.

The tympanic membrane and tympanic cavity have already been seen. The essential part of the organ of hearing, the *membranous labyrinth* or *internal ear*, is a complicated structure located within the bones of the head, and is difficult to dissect.

In order to study the blood-vessels it will be necessary to inject the arteries. This is easily done, the only instrument necessary being an ordinary medicine-dropper, although an injecting syringe is a little better.

Kill the animal with chloroform and open the pleuroperitoneal cavity to the left of the mid-ventral line as in the previous dissection, taking especial care not to cut the anterior abdominal vein, which is attached to the body-wall along the mid-ventral line. Inflate the lungs, slit open the pericardium. With scissors make a longitudinal cut through the tip of the ventricle. Fill the medicine-dropper with the injection-mass and insert the end through the ventricle into the truncus arteriosus. Hold the ventricle with the thumb and finger of the left hand so that the injection-mass will not escape, and gently squeeze the bulb. When empty the dropper may be withdrawn, refilled, and the operation repeated. From one to three droppers full will be enough, depending upon the size of the specimen. When through, tie a string around the ventricle so as to prevent the escape of the injection-mass. The specimen should be left for a few hours for the injection-mass to set. Before doing this, however, tie one of the lungs in two places near the base and remove it by cutting between the ligatures. After it has dried cut it in two and observe the blood-vessels in its walls.

After the injection-mass has set cut through the shoulder girdle, the part of the skeleton to which the fore legs are attached, along the median line, lift up the cut ends, and observe a number of veins and arteries going to and from the heart. The arteries are the ones filled with the injection-mass, while the veins are filled with blood. Expose these vessels still further by cutting away some of the muscles and the membrane around the base of the heart, using great care not to cut any of the veins, for in that case the blood would escape, and it would then be almost impossible to follow them.

Pull the heart to the right and find the large left anterior *vena cava,* which, as has been seen before, empties into the sinus venosus. Follow this anteriorly a short distance, and observe that it is formed by the union of three veins: the *external jugular,* which may be traced straight forward for a little distance; the *subclavian,* coming from the fore leg; and between these the *innominate,* extending upward and forward. Trace these as far as you can. It will be seen that each is formed by the union of still smaller veins. Work out the anterior vena cava and its branches on the right side. They will be found the same as on the left.

Now carefully free the *anterior abdominal* vein from the body-wall, observing that it receives branches from the body-wall and also from the bladder. At the posterior end of the pleuroperitoneal cavity it will be seen to arise from the union of a right and left *pelvic vein,* which will be studied later. Anteriorly it divides into right and left branches, which enter the corresponding lobes of the liver.

Lift up the intestine, and in the mesentery notice the arteries and veins which supply the alimentary canal, spleen, and pancreas. The veins unite to form a large trunk, the *portal vein,* which may be traced to the liver, where, like the branches of the anterior abdominal vein, it breaks up into capillaries. Thus the liver receives venous blood both from the anterior abdominal vein and from the portal vein. When veins thus break up into capillaries within an organ it is called a portal circulation. In the case of the liver it is called the *hepatic portal circulation.* As will be seen later, the liver also receives arterial blood.

Cut the mesentery suspending the rectum and between the kidneys observe the large *posterior vena cava,* arising by the union of the short *renal veins* from the kidneys. Trace the posterior vena cava forward to its union with the sinus venosus, observing that it receives large *hepatic veins* from the liver.

The *pulmonary veins,* returning blood from the lungs, have already been seen, but should be again observed.

Along the outer edge of each kidney observe a rather large *renal portal vein,* the blood from which enters the kidney, thus forming another portal circulation, in this case called the *renal portal circulation.* The kidneys also receive arterial blood. Observe that there are veins entering the renal portal from the side.

Follow one of the pelvic veins from the point where it unites with its fellow to form the anterior abdominal, dorsalward. It will be seen to be connected with the renal portal. Actually both the renal portal and the pelvic are branches of the *femoral vein,* a large vein returning blood from the hind leg. Thus part of the blood returning from the leg passes through the renal portal vein to the kidney, and part through the anterior abdominal vein to the liver. The *sciatic,* another vein returning blood from the leg, unites with the renal portal.

The arteries will be found much easier to study than the veins. Those given off from the heart are already well exposed. Each branch given off from the truncus arteriosus will be seen to divide into three arteries, the anterior of which is the *carotid trunk,* the middle the *aortic trunk*, and the posterior the *pulmo-cutaneous* trunk.

Follow the pulmo-cutaneous trunk a short distance, and observe that it divides into two branches, the short *pulmonary artery* going to the lung, and the *cutaneous artery* which supplies the skin. Follow this to a point a little back of the tympanic membrane. Now make a longitudinal incision through the skin along the mid-dorsal line, free it from the body, and find a large branch of the cutaneous artery running backward in the skin along the side of the body. Follow this forward to its union with the main cutaneous artery.

The carotid trunk will be seen to divide into two branches, a smaller *lingual artery* passing directly forward to the tongue, and a larger *carotid artery* which bends dorsally around the pharynx. Just at the beginning of the carotid artery there is a slight enlargement called the *carotid gland.* Now cut through the angle of the jaws, loosen the mucous membrane from the roof of the mouth, and observe that the carotid runs forward a little distance just beneath the mucous membrane.

Trace the aortic trunk around to the dorsal side of the esophagus, and then backward to its union with the aortic trunk of the opposite side. Each aortic trunk gives off three branches: the short *vertebral artery,* which enters the body-wall and sends branches forward and backward along the vertebral column; the *subclavian artery,* which is given off close to the vertebral and which supplies the fore leg; and the *esophageal artery,* which supplies the esophagus. Trace out the branches of the subclavian.

Posteriorly the two aortic trunks unite to form the *dorsal aorta,* which runs backward along the middle line. Just where the aortic trunks unite, the large *cœliaco-mesenteric artery* is given off. Trace this out into the mesentery. What organs does it supply? Farther back the dorsal aorta gives off several branches which supply the kidneys and the reproductive organs. Posteriorly it divides into two branches, the *right* and *left iliac arteries.* Trace one of these out and find what parts it supplies.

In addition to the arteries and veins there are myriads of very fine vessels, called *capillaries,* through which the blood flows from the small arteries into the small veins. They may be seen in the tail of a tadpole, and here it is only necessary to place the animal in a watch-glass and bring it under the compound microscope. But as tadpoles can be had only at certain times of the year, it will likely be necessary to use the web of a frog's foot, the web of a toad's foot being too thick.

Take a thin board 2 or 3 inches wide and 6 or 8 inches long, and cut a wide notch in one end. Wrap a frog in a piece of cloth so it will not be able to struggle, leaving one hind leg out. Tie threads to two of the toes, place the animal on the board, pull the threads around on the opposite side of the board so that the web is stretched over the notch, and tie. Now bring the web under the microscope. The arteries may be distinguished from the veins by the fact that in the arteries the blood flows from larger vessels into smaller, while in the veins it flows from smaller vessels into larger. The capillaries are the vessels connecting the smallest arteries with the smallest veins. They are usually just large enough to allow the corpuscles to pass through single file.

The skeleton of the toad is made up of a large number of bones and cartilages, some of which are movably, others immovably, articulated with one another. It is on the inside of the body, and is hence known as an *endoskeleton.* In the present description only the more general features of the skeleton will be noted.

Remove the skin and viscera from a toad and then clear away the muscles. This is rendered easy by occasionally dipping the specimen into boiling water. Be careful not to separate any of the bones. However, the shoulder-girdle to which the fore legs are attached will come away, as it is not articulated to the rest of the skeleton, being held in place by muscles. After the skeleton has been pretty well cleaned allow it to dry for a few hours. This will bring out the individual bones much more clearly.

Observe that the backbbone is made up of a number of separate pieces called *vertebræ.* How many are there? Given off from the sides of a vertebra are the long *transverse processes.* Do they occur on every vertebra? The neural canal extending through the vertebræ has already been seen. Find the openings between the vertebræ along the sides through which the spinal nerves pass. The posterior part of the vertebral column is not segmented, but consists of a long, rod-like bone, the *urostyle.*

Has the toad any ribs?

In the *skull,* or skeleton of the head, observe the upper and lower jaws, the latter of which is movably articulated with the rest of the skull.

The *brain-case,* containing the cranial cavity, has already been seen. At either side of the brain-case is a large round opening where in life the eyes are situated. In front of the brain-case are the *nasal capsules,* in which the olfactory sacs are lodged, and joining the posterior end of the brain-case at right angles are the *auditory capsules,* in which the internal ear is located.

Break away the skull from the vertebral column, and at the sides of the lower part of the foramen magnum, or opening through which the cranial cavity communicates with the neural canal, observe two oval prominences, the *occipital condyles,* which fits into corresponding depression in the first vertebra.

The different divisions of the skull are made up of a number of separated bones and cartilages which may be separated by boiling.

The *shoulder-girdle* will be seen to be made up of several closely united bones and cartilages.

At either side of the shoulder-girdle is a cup-shaped depression into which fits the rounded head of the *humerus* or first bone of the fore leg. Following the humerus is the *radio-ulna,* a bone that has been formed by the fusion of two bones lying side by side. Do you find any indication of this fusion? Next comes the *carpus,* or wrist, which is made up of several small bones. How many? Following the carpus are the four *metacarpals,* corresponding to the bones of the palm; and following these are the *phalanges,* or bones of the fingers. How many pieces are there in each finger?

Articulated with the transverse processes of the last vertebra is the *hip-girdle,* which has something the shape of the wish-bone of a chicken. This is made up of several bones immovably articulated with one another.

The first bone of the hind leg is the *femur.* Following the femur comes the *tibio-fibula,* which, like the radio-ulna, has been formed by the fusion of two bones. The *tarsus,* or ankle, is made up of two long bones followed by two very small bones. Following the tarsus are the five *metatarsals* lying side by side, and following these are the *phalanges,* or bones of the toes. How many pieces are there in each toe?

SUGGESTIONS TO TEACHERS

THE success of a laboratory course in zoology, as well as the peace of mind of the teacher, depends to no inconsiderable extent upon having at hand an abundance of material, and having it just at the time it is needed. For this reason it is well to lay in a supply of the different forms considerably in advance of the time they are to be used, and it is all the better if this can be done at the very beginning of the year. Most of the forms needed are widely distributed, and may be found in any locality, but where this is not the case they may be had from regular dealers in laboratory materials. The ideal way would be to have each student collect, and, when necessary, preserve his own material, but in practise this does not always work well. However, it is an excellent plan to take the entire class out and have them help with the collecting. In this way they learn where and how the material is obtained, and will not have to think of a hydra, for instance, as an animal found exclusively in a certain aquarium in the laboratory.

The cell.—In Chapter I a study of the blood-corpuscles and a few other cells has been introduced, partly for the sake of a knowledge of the cells themselves and the aid it will give in understanding the Amœba and Paramœcium, and partly that the student may learn to use the microscope in studying objects that are easily found, and which can be studied at rest. If the teacher so desires, a few plant-cells may be shown in connection with this work, such as the cells in the hairs of flowers, the leaves of moss, and the filaments of Spirogyra.

The Amœba.—Amœbæ may occur in the mud and ooze of almost any body of fresh water, and are often found in the most insignificant puddles where water trickles out from a spring or a hydrant. Yet they are not always easy to get just at the time they are wanted. Besides this, they are always relatively scarce, never increasing with that amazing rapidity characteristic of the infusoria.

Fill a dozen or more shallow dishes with water, mud, ooze, dead leaves, etc., from the bottom of a pond or puddle of water, and allow these to stand in the laboratory for a day or two. In all probability, some of the dishes will be found to contain Amœbæ. It is well for the teacher to find an Amœba and show it to the students before setting them to look for the animals themselves.

Paramœcium.—If a jar be filled with water and water-weeds, either dead or alive, from any pond or stream, and allowed to stand until putrefaction sets in, a number of different kinds of infusoria will appear, first one kind predominating, and then another. Among these, though not the first to appear, will be the Paramœcium. The process of putrefaction may be hastened by adding a very small piece of meat, though this is not usually necessary. In order to be sure of plenty of material when wanted, cultures such as those described above should be started about three weeks before the time when they are to be used, and others later, a new one every two or three days. This is necessary, because one can not be sure just how long the Paramœcia will be in coming, that depending upon the temperature and other conditions; and further, because after they do come, they may not remain indefinitely; what was a fine culture at one time often being found worthless a few days later. Then, too, if a culture be examined from day to day, it will be found that at one time multiplication is very rapid, every slide examined showing dividing individuals, while later division will almost cease, and instead numerous cases of conjugation will occur. In order that the class may observe both these processes it will be necessary to have cultures in different stages at the same time.

After Paramœcia have appeared in the earlier cultures new ones may be hastened by pouring a little water from one of the old cultures into the new one.

It would be well to have each student start a culture of his own, and observe the progress of putrefaction, and the various kinds of animals that appear. Only a very short time each day need be given to this. It might be well for the teacher to state in advance that he will not undertake to give the name of every creature found.

In almost every Paramœcium slide studied there will be numerous bacteria, and although these are plants and not animals, the attention of the students should be called to them, on account of the general interest attached to them.

Hydra.—Hydra are widely distributed, and may be had in almost any locality. They are found attached to sticks, dead leaves, algæ, and in fact to almost anything in fresh-water ponds and pools and in quiet portions of streams. Although so widely distributed, they are by no means present in every pool or stream, and one may have to search some time before finding them. When found they may occur in such numbers that there will be thousands in a pool a few yards square, every stick or weed in it being covered with them, but usually they are far less abundant, and may escape the notice of even an experienced collector.

If you have not had experience in collecting, start out with a number of glass jars—the more the better—and wherever you come to a quiet pool, place a handful of weeds, sticks, etc., in one of the jars, together with a little water. Label each jar, so that in case it is found to contain Hydra you may know from what pool it came.

On returning to the laboratory, add enough water to each jar to fill it, and after it has stood for a few hours or a day or two, examine the surface of the water and the sides of the jar for Hydra.

Fortunately Hydra thrive and multiply rapidly in an aquarium, so that, starting with even one or two individuals, in the course of three or four weeks there may be enough for a large class. In one instance where a record was kept, a Hydra began producing buds the third day after breaking away from the parent, and ten days later had produced ten new individuals.

If placed in a jar of pure water containing small crustacea for food and a few green water-plants, such as Chara or Spirogyra, Hydra may be kept in the laboratory indefinitely. There is danger, however, that putrefaction may set in and kill them, so that in case your supply is limited and you are keeping them for class work, it will be well to change the Hydra to a fresh vessel of water every five or six days, being careful always that there are plenty of small crustacea for food. These may be caught in troughs or pools with a small net made of fine cheesecloth.

It would be an excellent plan to have each student keep one Hydra under observation for a number of days or weeks, noting the length of time required for a bud to develop and the number of buds produced, and keeping a sharp lookout for the formation of reproductive structures. It would also be well to observe the renewal of lost parts. For this purpose place the Hydra in a shallow vessel of water with wax or paraffin in the bottom, and with a sharp scalpel cut some of them in two crosswise, others lengthwise, or, better, cut them for only half or two-thirds of their length, so that a two-headed Hydra will be produced.

To show the process of feeding, get a number of Hydra hungry by keeping them for two or three days in a vessel containing nothing but water. Then let each student transfer one of them to a watch-glass containing a little water and a few small crustacea.

The Starfish.—Starfish are exclusively marine animals, as are all the Echinoderms, the group to which the Starfish belong; consequently the living animals can be studied only at the seashore. Most teachers will therefore have to depend for material upon the dealers in laboratory supplies. It is well to have, in addition to the specimens preserved in alcohol or formalin, a few dried specimens, as these may be used year after year for the study of some of the external features.

Starfishes are usually easily collected, as they live near the shore, and are found at low tide, either exposed or in shallow water. They are killed by leaving them for a few hours in fresh water. Before placing them in the hardening fluid, either formalin or alcohol, cuts should be made in one or two of the rays, so that the fluid may reach the soft internal organs. If alcohol is used they may be left in 70-per-cent for a day or two, and then transferred to 85-per-cent.

The Earthworm.—Perhaps no animals studied in the laboratory are so easily obtained as earthworms. They occur in every locality, and may be found almost anywhere by digging in moist earth. As is well known, they come to the surface after a rain, and they also come to the surface at night, when they may be collected by the aid of a lantern.

For dissection, as large specimens as possible should be selected. Two different methods may be employed in killing them, one slowly with alcohol and the other with boiling water. In the first case, place the worms in a flat pan with enough water to cover them well. Then with a medicine-dropper slowly add alcohol until they are killed. This should occupy an hour or more. With the second method, drop the worms into a vessel containing enough water almost up to boiling-point to cover them. In a few seconds—that is, as soon as the worms are dead—pour in a large quantity of cold water. This method may seem cruel, but it is not so, since death is almost instantaneous. Whichever way they are killed they should next be carefully stretched out, one by one, in 70-per-cent alcohol and held in this position until they show no inclination to curl up. After a few hours they should be transferred to 85-per-cent alcohol and left for twenty-four hours. They should then be put into 95-per-cent alcohol for three or four days, and finally back into 85-per-cent, where they may be kept indefinitely.

As the worms may be studied at a time of year when living specimens are not accessible, a number should be placed in a box or jar of earth, which should be kept moist and in a place where it will not freeze. The vessel must be kept covered to prevent the worms from escaping.

Cut a few segments off the anterior end of some worms and off the posterior end of others, and keep them in loose moist earth for several weeks to see the regeneration of the lost parts.

At the beginning of the year take the class out to look for egg capsules. These are usually found without difficulty by looking through shovelfuls of earth in which worms abound. Some may be placed in a bottle of alcohol for future use, others opened and their contents examined, and still others kept in a bottle of loose earth and observed from time to time until the young worms hatch. This may help to overcome the prejudice which so many feel toward worms.

Do not fail to read Darwin's Vegetable Mould and Earthworms, and, if possible, have the students read it also.

The Crayfish.—Crayfish are absent in the New England States east of the Housatonic River as well as in the Great Plains to the east of the Rocky Mountains and in Southern California. In most other parts of the United States they are found in abundance. They may be obtained by turning over stones in the bottoms of sluggish streams. To kill a crayfish pass a scalpel forward under the carapace into the pericardial sinus and allow them to bleed to death. Before preserving, break away a little of the posterior part of the carapace, so that the fluid may reach the internal organs. Either formalin or alcohol may be used. If the latter, place the animals in 70-per-cent for a day or two and then transfer them to 85-per-cent.

Crayfish may be kept alive in the laboratory for a long time, in which case it should be so arranged that they may stay in the water or out of it as they choose. They will eat meat, worms, etc. They may be transported for long distances. Some were bought in the market at Portland, Ore., and shipped in a box to central California, being three or four days on the way. Several died soon. Others were kept alive for almost two months.

Along the seaboard and in cities, lobsters may be used instead of crayfish, as their structure is almost the same.

If crabs are available it is an excellent training to have the students study these for a little while without any aid from books, noting the resemblances and differences between them and the crayfish.

The teacher should by all means have Huxley's The Crayfish: An Introduction to the Study of Zoology.

The Grasshopper.—Grasshoppers are usually abundant in the fields during the summer and fall, so that no difficulty will be experienced in finding them. If they are to be dissected in the winter it will be well to have the students observe the living animals in advance. Kill them by placing them in a tight jar with a piece of cotton saturated with chloroform, or, better, by immersing them for a few seconds in water that is almost boiling. Then place them for a day in 70-per-cent alcohol, first making an incision through the body-wall to the side of the mid-dorsal line. Those intended especially for the study of the external features need not be slit. Next transfer them to 85-per-cent alcohol, using a relatively large quantity, and stirring them about in it a few times during the first two or three days.

It would be well for the teacher to have for reference The Anatomy of the Carolina Locust, by Prof. Robert E. Snodgrass, published by the Washington Agricultural College, Pullman, Wash.

The Fresh-Water Mussel.—Fresh-water mussels are found partly buried in the sand and mud in the quiet portions of rivers and large creeks, and also in lakes and ponds where the water stands the year round. They may be easily drawn out with a garden rake. Formalin is an excellent hardening and preserving agent for mussels. Before they are placed in it insert a wooden wedge between the valves, so that the fluid will reach the body.

Mussels are quite tenacious of life, and may be transported long distances out of water. They may be kept alive for months in an aquarium with mud in the bottom in which they can bury themselves. The water should be changed every week or two unless there is a large quantity, in which case no change will be necessary.

The Toad.—Toads and frogs are very much alike, and it makes little difference which is used, the directions for dissecting the one answering in almost every particular for the other. We have chosen the toad because in our experience they are more easily obtained than frogs. Toads conceal themselves during the day, but come out at dusk in search of food. If one walks about in a garden or along the streets of a village or in the suburbs of a city in the early evening he is almost sure to find a number. When it becomes too dark to see them they may be detected by the rustling of the grass as they hop about. Often a good place to find them is in the street under the electric light. During the breeding-season in the spring they go to the ponds and streams, where they may be found in numbers, and where their dark-colored eggs may also be found enclosed in transparent albuminous strings several feet long.

Fresh specimens are better for dissection than preserved ones, but it is well, nevertheless, to have a stock of preserved material on hand. The toads should be killed by placing them in a tight jar with a piece of cotton saturated with chloroform. They may be hardened in either formalin or alcohol. If the latter is used, place them first in about 50-per-cent or 60-per-cent for a day, and then transfer them to 70-per-cent, using a relatively large quantity of this, and moving them about in it two or three times in the course of the first three or four days. Before placing the specimens in the formalin or alcohol cut into the body-cavity, so that the fluid may readily reach the internal organs.

Toads may be kept alive in a box of moist earth set away in a cool place, but if the earth is allowed to dry up they will soon die. They may be fed by placing insects, such as beetles, in the box with them. If the box were placed in a cellar in the fall it is likely that the toads would stay alive so that they might be used for dissection at any time during the winter, but we have never tried this.

Microscopes.—It is highly desirable that there should be a compound microscope for each student, and where this is not possible the number should approach this as nearly as may be. Fairly satisfactory instruments may be had at a comparatively small cost, but the better grades give better satisfaction, and are cheaper in the long run.

Dissecting microscopes are a great convenience; but where only a limited amount of money is available for laboratory equipment it is better to spend it for compound microscopes, as hand lenses can be made to take the place of the dissecting microscopes.

Dissecting Pan.—Each student should be provided with a dissecting pan, having in the bottom a layer of about half an inch of paraffin or beeswax, which may be run in while melted. Some device for holding the wax in place will be necessary, and for this a wire placed diagonally across the bottom and soldered at both ends will answer. A convenient size of pan is one nine inches long by six inches wide and two inches deep, with flaring sides and ends, although the exact size and shape make little difference.

Miscellaneous Supplies.—A few wide-mouthed fruit-jars of various sizes will be found convenient for collecting, for aquaria, and for storing preserved material. A few glass tumblers and sauce-dishes will be found useful for various purposes.

A good injection-mass is easily made as follows: Place about half a pound of white glue in a vessel, and add considerably more than enough water to cover it.

Allow this to stand for several hours. To a saturated solution of bichromate of potassium, a quart or more, add an equal volume of a saturated solution of acetate of lead. A bright yellow precipitate will form. Allow this to settle, and then pour off the fluid. Now pour off the water from the white glue, and melt it in a double boiler—one of the kind used in cooking will answer admirably—and stir in the precipitate. It will be well also to stir in a few drops of carbolic acid to keep the mass from molding. This material may be kept indefinitely. When used it must be heated, always using the double boiler.

Methyl green comes in the form of a powder. It is prepared for use by making a strong solution in water and adding a little acetic acid, about 1 per cent.

Alcohol and formalin are the two fluids used for preserving material. They should both be used in relatively large quantities. The strength of alcohol to be used is given in connection with the directions for preserving the different animals. Formalin is generally used in 2-per-cent solution, which is made by mixing one part of commercial formalin with nineteen parts of water. Thus, with one quart of formalin, five gallons of the preserving fluid can be made. It is well to wash specimens preserved in formalin in running water for a while before they are given out for dissection.

In addition to the articles already mentioned the following will be needed: Some caustic potash, a small bottle of acetic acid, a large bottle of nitric acid (the cheap, crude acid answering very well), and a bottle of carmine, which comes in the form of small lumps or powder.

It is an excellent plan for the teacher to illustrate by the use of models the structure of such forms as the Amœba, Paramœcium, and Hydra, and also some of the more difficult points in the anatomy of other animals. For making these, nothing is so satisfactory as composite clay, a material that never dries, is always ready for use, and may be used over and over for years. It is also well to have the students do some modeling, as this fixes structure even better than by drawing. The clay may be had of the C. H. Chavant Manufacturing Company, Jersey City, N. J., and probably elsewhere. It is not expensive, and every teacher should have at least a few pounds.

Each student should be provided with a drawing-book, a note-book, a drawing pencil, a scalpel, a pair of fine pointed scissors, a pair of fine forceps, two dissecting needles, one or two seekers made of bristles tipped with sealing-wax, a medicine-dropper, a few slides and cover-glasses, a watch-glass, and a hand lens. The cheap tripod form of lens is a good kind, as it may be used instead of a dissecting microscope.

The order in which the different forms should be taken up is largely a matter of convenience and personal preference.

The method of beginning with the simpler forms and going to the more complex has been pursued, but there is no important reason why this order should not be changed if the teacher so desires.

No matter how well the teacher may be acquainted with the forms taught, he should spend at least a little time in going over the laboratory work in advance of the class.

Here, as elsewhere, it is not so much the amount of work that counts as the thoroughness with which it is done, and the skill of the teacher will show best in his ability to keep the students working and interested in a thing until it is thoroughly understood.

No attempt has been made to indicate the number of drawings that should be made, this being left to the judgment of the teacher; but in general all the important structures should be carefully drawn. However, the object of this is not for the sake of the drawings themselves, but to enable the student to see accurately. No one should be discouraged because he finds it hard to draw.

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