LABORATORY MANUAL OF ZOÖLOGY

BURNET

A LABORATORY MANUAL

OF

ZOÖLOGY

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BURNET, LABORATORY MANUAL.

W. P. I

TO THE TEACHER

SINCE the conditions under which laboratory work is done vary exceedingly, it is impossible to outline a course which will be equally acceptable to all teachers. This little book, therefore, presents more forms than any teacher will be likely to want, in the hope that from among them a selection may be made that is fairly satisfactory.

The frog is taken up first among the vertebrates, and very fully, so that, if preferred, it may be used as an introductory study instead of the crawfish. In this case, however, the pupil will need the teacher's help in answering a few questions referring to work in the earlier part of the book. In the opinion of the author the crawfish is much the best form that can be used for such a study, since it is remarkably well adapted to bring out many fundamental ideas, while being less specialized in its organs than either frog or grasshopper, and standing more nearly midway between the highest and the lowest forms.

The studies in experimental chemistry and physiology which follow this are to be used at the discretion of the teacher in those classes where no work has been done along this line in connection with human physiology. The experiments may be given as demonstrations by the teacher, or the simpler ones may be assigned to pupils for performance before the class. It is scarcely possible or even advisable to spend much time upon them, yet they help greatly to give a clear understanding of the vital

processes of all animals. My own plan is to devote to them one period per week from the beginning of the year, both as a relief from the more intensive work of the introductory study and as being less tiresome to pupil and teacher taken so than in consecutive lessons.

In my text-book "School Zoölogy" are lists of books for supplementary reading, and these lists have lately been revised; but I wish especially to recommend to the teacher a book not mentioned there, Lloyd and Bigelow's "The Teaching of Biology," published by Longmans, Green & Co. In this may be found full and clear instructions for obtaining, preparing, and caring for material of all kinds; advice as to apparatus and equipment; lists of dealers in zoölogical material and apparatus, and other most valuable information.

CONTENTS

THE COMPOUND MICROSCOPE

Make out the following parts:

a. The **base**, supporting a **vertical column** or **pillar.**

b. The curved **arm**, attached to the pillar by a hinge.

c. The horizontal **stage** (with its circular opening), fastened to the lower part of the arm. Upon the stage is placed the glass slide which holds the specimen to be examined. Of what use is the opening?

d. The pair of **clips** upon the stage. Of what use?

e. The **diaphragm** below the stage. Rotate the diaphragm and determine its use.

f. The **double mirror**, attached to the arm behind the stage by a movable bar. Determine what movements are possible for mirror and bar. How do its two faces differ? Which will throw a more concentrated light?

g. The **cylinder**, attached to the upper part of the arm.

h. The **draw tube**, which slides in the cylinder.

i. The **coarse adjustment**, which moves the draw tube up and down. This is regulated by a pair of large milled heads. Turn the milled heads of the coarse adjustment around halfway and back, and observe the distance traveled.

j. The **fine adjustment**, regulated by a single milled head or **thumbscrew**. Compare the action of the fine adjustment with that of the coarse. What difference? Make several turns in one direction. In which direction does the cylinder move if you turn the milled head in the direction of the hands of a clock?

k. The **eyepiece**, at the upper end of the draw tube. Lift it out and examine it. How many lenses and how placed? Why called eyepiece? Return it to its place in the draw tube.

l. The **objectives**, sets of lenses which may be attached by screwing to the lower end of the cylinder. They differ in magnifying power, and as two usually accompany the instrument, they are distinguished as high power (h. p.) and low power (l. p.). Why are they called objectives? When not in use they should be kept in their brass cases. Each is marked with a number (usually a fraction) upon its side, a corresponding number being upon the lid of the case.

m. The **nose piece** (which may be double or triple), screwed to the lower end of the cylinder, having place for two or three objectives, which may be brought in turn under the cylinder without the necessity of unscrewing and replacing.

Lenses should never be touched, either with the hand or with any other object. They should be carefully protected from dust when not in use. To wipe them, use clean, soft linen or chamois.

All parts of the instrument must be kept dry, clean, and bright.

In lifting, grasp the double pillar.

To attach the objectives, raise the cylinder by the coarse adjustment until its lower end is two inches from the stage. Then use both hands to hold and screw in the objectives. If a double nose piece is present, attach both high power and low power.

Place the microscope with the pillar towards you, grasp the base with one hand and the arm with the other, and move the arm towards you till the cylinder is so inclined

that the eye can be brought over the eyepiece with the least effort. Be careful not to incline it so that the neck must bend when the eye is close to the eyepiece. Bend the body below the waist instead.

With the right hand move the mirror till the concave side faces a point about halfway between the source of light and the hole in the diaphragm. Then, with the eye over the eyepiece, move the mirror slowly in various directions till a bright light shines up through the tube.

Never use the instrument in the direct sunlight.

Mount some object on a slide in a drop of water, and place over it a **cover glass**, a tiny thin piece which gets its name from its use.

Place the slide upon the stage, cover glass up, bringing the object directly over the center of the stage opening.

Use first the low power.

Watching the objective from one side, lower the cylinder by the coarse adjustment until the lens is within a sixth of an inch of the stage; then, looking through the eyepiece, turn the milled head slowly in the opposite direction until the object comes in sight.

Then by the fine adjustment raise or lower the cylinder until the outlines are sharp and clear. Turn the milled head back and forth until you are sure the focus is exact.

To focus with the high power, repeat these operations, beginning, however, with the lens as close to the slide as is possible without touching. The cover glass is likely to break if the lens strikes it, injuring both slide and lens.

If the microscope has a double nose piece, focus with l. p., then swing around the h. p. and focus again.

In examining objects under the microscope, use the right and the left eye alternately and always keep both eyes open. At first this is difficult to do, but one may soon

learn to see only what is under the lens and with much less strain than when constantly squinting.

Test the relative magnifying powers, size of field, and position of parts of objects examined, under tripod lens, low power, and high power.

To do this, write in the center of an inch square of white paper, with a fine pen and as small as possible, the letter "h."

Upon a sheet of drawing paper write at the left-hand side a duplicate letter. Then side by side across the paper to the right of this make three circles the size of the opening in the tripod lens.

Place the square slip under the lens and examine the "h." Copy it in the first circle as near as you can as it looks under the lens.

Place the slip on a slide and examine with l. p. What difference in the position of the letter? Can you see the whole letter? Move it until as much as possible of the upper part is in the field, and reproduce in the second circle.

Now examine with h. p. Draw what you see in the third circle. How does this compare with what you saw with l. p.?

If you should wish to examine details carefully, which power should you use? Which should be used in finding an object? Why?

Practice mounting and focusing, using a hair, a bit of cheese cloth, some pond scum, a few starch grains, etc.

In mounting objects in water, be sure that both slide and cover glass are very clean.

Put the object to be examined as near the center of the slide as possible, and if the object is thin, place not far from it a tiny bit of filter paper.

Drop over the object a large drop of water.

Taking the cover glass with forceps, place one edge on the slide at one side of the drop, and very slowly lower it. If it is carefully done, all air bubbles will be excluded. If any should be present, lift the edge of the cover glass and lower it again. Then absorb any water outside the cover glass with filter paper.

It requires care and practice to mount objects for microscopic examination.

INSTRUCTIONS FOR DRAWINGS REQUIRED IN LABORATORY WORK

Read carefully the instructions given in the lesson, and decide the answers to all questions referring to the object to be drawn.

Then decide how large the drawing should be and where on the page it should be placed. If several drawings are to go on one page, decide the position and space to be given to each to make a fairly symmetrical page.

Draw the *outlines* first in *sharp, clear lines.*

Put in only such details as are necessary to illustrate the points of structure given in the lesson or called for in the questions. *Do not waste time* on any others. They detract from the clearness of your drawing.

Do not shade any parts unless shading is absolutely necessary to show differences in structural features.

These drawings must be *scientific* rather than artistic.

They are not intended for practice in drawing, but to show whether you see and understand the structural peculiarities of the objects studied.

INSTRUCTIONS FOR WRITING UP AN EXPERIMENT IN THE NOTEBOOK

The following order should be observed in writing up an experiment:

a. Heading, a brief statement of the purpose of the experiment.

b. Description of experiment, including materials and apparatus in the order in which used.

c. Results obtained and time necessary to obtain them.

d. Conclusions drawn from these results.

AN INTRODUCTORY STUDY

THE CRAWFISH

Habits and Environment.

(Field work)

Go out and look for crawfishes and try to catch a few for closer study. While doing so, see how many of the following questions you can answer, and make a note of the others. Make excursions to several places and at different hours of the day.

When you have gathered all the information you can in regard to the habits of the animal, compare your conclusions with those of other pupils. You will probably then have a fairly correct idea of the habits of crawfishes in your own neighborhood, and the conditions which are favorable to them. But remember that as conditions vary not only in different parts of the country, but even in a limited region, the results of a few observations are not reliable. No fact should be accepted in science that has not been attested by repeated and varied observations or experiments.

Where did you find crawfishes?

In what ways did you capture them?

Did you find them active in the daytime? If so, at what hours?

What depths of water do they seem to prefer?

Why are they found under rocks and shelving banks?

Why do they sometimes dig holes? How can you recognize the holes?

When disturbed, how does the crawfish retreat? How is its retreat covered?

What is its food? What organs are used in getting it?

Has the crawfish any enemies? How does it defend itself?

Is it solitary or gregarious in its habits?

In what ways is the crawfish a beneficial animal?

External Features.

(Alcoholic specimens)

Compare the upper — **dorsal** — surface of the body with the lower — **ventral** — surface as to general shape and coloring. What is the general coloring? Is there any advantage in such a color? What difference between dorsal and ventral coloring? Can you think of any advantage in this?

Into how many general regions is the body divided?

The forward — **anterior** — consists of **head** and **thorax** and is called the **cephalothorax**. The hinder — **posterior** — is the **abdomen**. Which is the more flexible? Why?

Examine the ventral side of the cephalothorax. Can you see any evidence of segmentation? What prevents its being flexed? The shell or crust covering the cephalothorax is called the **carapace**.

Examine the covering of other parts. Is the crust of these continuous? How is it modified at the joints to permit movements? Compare this shell with that of an oyster or clam. What advantages to the crawfish is such a body covering? What disadvantages?

Which is the right and which is the left side of the body? How can you determine this for any animal?

Are the two sides alike? Any animal with right and left sides corresponding and equal is **bilaterally symmetrical**.

Mention several animals, belonging to different groups that are bilaterally symmetrical.

Examine the abdomen. Of how many ringlike segments does it consist? How are they arranged to permit the bending of the abdomen?

In which direction do they overlap? What advantage in this? Can they bend so as to give a sidewise movement to the abdomen? Examine a joint carefully and explain.

The last division of the abdomen is the **telson**. This is the central piece of the tail, or **caudal fin**. Describe its shape.

Every segment of the body bears a pair of appendages. Those of the abdomen are called **swimmerets**. How many pairs? To which segment are the side pieces of the caudal fin attached? Are they swimmerets?

The appendages that project from the sides of the carapace are legs. How many pairs? The first are called **chelipeds**. How do they differ from the other appendages, or **walking legs?** Compare right and left chelipeds as to size and shape. Of what advantage is it that they are rough on their inner edges? Sometimes one cheliped is much smaller than the other. How can you account for this? (In many of the lower animals lost parts grow again.)

How many and which walking legs have pinchers? What terminates the others?

Examine the carapace. The head region is separated from the thoracic by the **cervical groove**. In which direction does it run?

The anterior penlike projection is the **rostrum**.

Draw a dorsal view of the crawfish, natural size, and indicate carapace, rostrum, cervical groove, right cheliped, anterior abdominal segment, 6th right swimmeret, and telson.

The Abdomen.

Carefully separate the 3rd abdominal segment from those before and behind it. The crust is composed of the following parts: a dorsal **tergum**, with lateral extensions called **pleura**, and a ventral **sternum**.

Find the peglike processes on this segment that articulate in pits in the next to form a hinge joint. Where are they?

Examine the swimmerets. To what part of the segment are they attached? Each has a main stalk, **protopod**, and two branches, an outer, **exopod**, and an inner, **endopod**.

How many joints in the protopod? How do exopod and endopod differ?

Lay the segment on its anterior edges, spread out the swimmerets, draw (natural size), and indicate the parts of the ring and its appendages.

Compare the swimmerets of the 4th and 5th segments with those of the 3rd. Has each an exopod, endopod, and protopod?

Compare with these the 6th pair. Do the parts differ in number and arrangement or only in size and shape?

Can you account for these differences of development in any way? Will an organ grow larger or smaller with exercise?

What advantages result from these differences in development?

Compare the swimmerets of the 1st and 2nd segments with those of the 3rd. If larger and peculiarly modified, they belong to a male; if smaller and poorly developed, to a female. Which sex is your specimen?

Compare with those of other pupils until you can recognize male and female by these peculiarities. Which has the broader abdomen?

Organs of the same general plan and position are **homologous.** Is this true of the swimmerets?

Examine the under side of the telson for the **anus**, the exterior opening of the intestines.

The Cephalothorax.

Examine from the ventral side. Are the legs borne upon segments? How many to each? What part of the segment lies between their bases? What replaces tergum and pleura for these segments?

Compare the 2nd and 3rd pairs of walking legs. Are there the same number of joints in each? Is the extra claw in the 2nd an extra piece or a prolongation of a part present in the 3rd?

Compare the chelipeds with the 2nd pair. Do they differ in number and arrangement of parts or only in their development? Are they homologous?

To what use is each pair of legs put? What advantage is gained in each case by its peculiarity in development?

Examine the joints of the legs. Are they capable of free movement or are they hinge joints? Is the movement of two successive joints in the same direction? What advantage in this arrangement?

On the inside of the basal joints of one pair of legs are small openings, the outlets of the ducts from the reproductive organs. Upon which pair are they found in the male? In the female?

With scissors cut away the loose part of the carapace on the right side, exposing the gills. What parts form the gill cavity?

Lay your specimen in water with the gills up and move each leg in turn freely. What effect has this upon the gills?

Study the arrangement of the gills. What is their position in relation to the legs? To the length of the body? Are any attached to the legs? If so, how many? To what are the others fastened?

What is the general character of the gills?

Find, towards the anterior end of the gill cavity, a double spoon-shaped organ, the **gill scoop**, or gill bailer, whose attachment and use will be determined later.

Remove the 5th leg on this side. To do this separate this leg from the next, cut the membranes attached, and holding it by its basal joint pull it off. In the same manner remove the other right legs with the gills attached and lay them aside for comparison with other parts.

The Mouth.

Next examine the appendages immediately in front of the chelipeds. What position have they in relation to the mouth opening? What relation does this opening bear to the length of the body? (Is it longitudinal or transverse?)

Lift the outermost appendage, a **maxilliped**, or foot jaw, to see a 2nd and 3rd pair. Are these directed forward, backward, or sidewise when at rest?

Compare the 3rd or outer maxilliped with the 3rd swimmeret. Has it a protopod? Are exopod and endopod present? How many joints has its protopod? Is anything attached to it? Is it homologous to the swimmeret?

Now compare this maxilliped with the 3rd leg. What part is present in the maxilliped that is absent in the leg? (In the leg the exopod has disappeared.) What is attached to these two that is absent from the swimmeret?

Remove the 2nd maxilliped and compare with the 3rd. Is any part lacking? Which parts are differently developed?

Remove the 1st maxilliped and compare with the others. What part is not present that was found in connection with the other two? What peculiar appendage is attached that is not found on the others?

The maxillipeds complete the thoracic appendages. How many segments in the thorax, as indicated by appendages?

The Head.

The two pairs of appendages just beneath the maxillipeds are **maxillæ**. How do they differ in texture from the maxillipeds?

Remove the maxillæ one at a time, being very careful to get them entire. The remaining pair of mouth parts are the true jaws, or **mandibles**. How do they differ in texture and color from the maxillæ? Look for a small appendage, a **palpus**, attached to and lying close to the mandible. On which surface does it lie? Is it segmented?

What peculiarity have the opposed edges of the mandibles? Remove them and add to the series of mouth parts. How many in all? The mandibles and maxillæ are homologous with the other appendages but are so modified that the homology is difficult to trace.

Arrange all the mouth parts of the right side in a series and draw ($\times$ 2). In connection with this draw the 3rd leg and 3rd swimmeret.

The two longest appendages of the head are called **antennæ**.

Compare them as to flexibility and length with the legs.

What difference in structure accounts for difference in flexibility? Are protopod, endopod, and exopod present? To find the exopod, look for a piece just under the eye. What shape? What probable use?

The other "feelers" are called **antennules.** Describe their structure.

On the basal joint of each antennule look for an opening formerly supposed to be auditory, though there is doubt now whether hearing is the function of the organ to which it leads. How is the opening guarded?

Examine the eye. Is its stalk segmented? Is it movable? Can it be protruded and retracted? What is its range? Of what advantage to the animal is this arrangement?

Remove an eye and examine the black tip, or **cornea,** first with a lens and then with the compound microscope. Describe its appearance. Is it simple or compound? Draw a group of its **facets.**

There is some doubt as to whether the eyes and antennules are homologous with other appendages. Both of them are attached to the first segment of the body, while other segments bear but one pair of appendages.

If they are excluded from the count, how many pairs of homologous appendages are there? How many segments in the whole body? Parts that are modified to serve different uses are said to be **specialized.** Can this be said of the appendages of the crawfish? What parts are specialized for swimming backwards? For defense?

Remove any remaining appendages of the cephalothorax, and examine the sternal region of the head. What is its position? Can you see any segmentation? It is supposed to consist of five parts fused together.

Next, carefully remove the carapace and examine the under side of the head region for the points of attach-

ment of the eyes, antennæ, and antennules. Are they dorsal or ventral?

The Skeleton.

Clean out the soft parts from what remains of the thoracic segments and examine the interior. The partial partitions noticed there are inward projections of the crust.

The crust of the crawfish is called an **exoskeleton**, or external skeleton. Is there any **endoskeleton**, or internal bony framework?

To test the character of the crust, first place a piece of the carapace in diluted hydrochloric acid, and note results. Hold a piece in a flame for a short time. What results?

Test in the same manner bits of clam shell and compare results. The substance dissolved by the acid is lime. What is the office of lime in a shell?

What is the character of the remaining material of the crust after the lime has been removed with hydrochloric acid? It consists of a horny substance called **chitin**. This was burned away in the flame. Of what use to the shell is this?

The Live Crawfish.

Place a live crawfish in water deep enough to allow it to swim, and watch its movements. How does it use the caudal fin? The swimmerets?

Catch the crawfish by the cephalothorax, and lift the head out of water. How does it use the various appendages?

What advantages in swimming backwards?

Watch the movements of the crawfish in walking. In which directions can it move? What appendages are used? How many together? In what order? Are the chelipeds used? What difference between the way in which it uses legs with pinchers and those without?

Test the strength of the muscles of the chelipeds by letting the crawfish grasp a pencil. Can it hold and bear its own weight? Can it bear more?

Let it crawl upon a table. Does it move more or less easily than in water?

Place the crawfish in a bowl of clear water. With a pipette put a small drop of ink or carmine near the hinder edge of the carapace. Is it drawn towards the gill cavity or expelled? Put another drop near the mouth. In which direction does the water circulate? This movement is kept up by the action of the gill bailer.

To feed a crawfish, try bread, cheese, vegetables, bits of liver, earthworms, and other things. Does a crawfish prefer some kinds of food to others? Will it eat a varied diet? What appendages are used and how?

Test the sense of taste by placing sour or bitter substances on the mouth parts.

What other senses might be excited if one used a pungent or irritating substance? Would it make a good test? Has a crawfish a sense of taste? Would an animal that is omnivorous need a keen sense of taste?

To test the sense of smell, what sort of substances should be avoided? Think of substances that would be likely to give reliable results and test. Has the crawfish a keen sense of smell? What is the chief use to an animal of a sense of smell?

To test the sense of touch, use a bristle upon crust, appendages (especially the fringes), eyes, antennæ, and antennules. Which parts are sensitive?

What is the position of the antennæ when the animal is swimming? When walking? When at rest? Of what use? What is the probable use of antennules?

Watch a crawfish moving about. Is its sight keen? When

it is swimming, can it see behind it? Can it see food when it is feeding?

Bring your hand close to it. What results? Touch one of the eyes with a pencil. What follows? Do the two eyes act in unison?

Put the aquarium where one end will be in a strong light and the other well shaded. Which does the crawfish prefer?

Crawfish may be captured at night by bringing a light to the edge of a stream and using a net to catch those attracted by it.

Test the sense of hearing by various noises, being careful, however, not to cause perceptible vibrations of the air. What sense would be affected by such vibrations? What would be the use of the sense of hearing to an animal like the crawfish?

If a female with eggs can be found, it is very interesting to watch the development of the young.

How are the eggs carried? Describe them. How large is the young crawfish when first hatched? Does it resemble the parent in structure, or does it undergo a metamorphosis?

Do the young leave the mother at once? When they separate, do they ever return to her care? Does she feed them? What do they eat? Do they ever kill one another?

If crawfishes are found ready to molt, watch the process. What is their condition just before molting occurs? Record the various stages of the process.

Test the body covering of an animal that has just cast its shell. What is its condition? Test it frequently for several days. How long does it take to harden? What substance makes it hard? What is meant by "soft

shell"? Why is molting necessary? Why is molting more frequent the first year of life than afterwards?

THE CRAB

Compare with the crawfish in general plan of external parts.

What differences in general form? In relationship between cephalothorax and abdomen as to form, size, and position? In abdominal segments? In number and form of thoracic and abdominal appendages?

In some species what peculiarities has the 5th pair of legs? Has a crab a caudal fin?

Judging from the development of appendages, what differences must there be in the locomotion of crawfish and crab?

Compare the *lobster* and the *shrimp* or *prawn* with the crab and crawfish. With which are they more closely related?

THE PILL BUG

Compare the pill bug with the preceding forms.

Does the carapace cover the thorax? How can you distinguish thorax from abdomen? How many segments in each?

How many pairs of legs has the pill bug? Are they segmented? Are they specialized for different uses as they are in the crawfish?

Look for a series of thin overlapping plates under the abdomen. These are gills.

Examine the head. Are the eyes stalked? Are they compound?

Are there any antennæ? Antennules? In what external

features does the pill bug resemble the crawfish? What are the chief differences between them? Which do you think the higher form?

THE CRAWFISH

(Dissection of alcoholic specimen)

Pin the crawfish dorsal side up in a dissecting pan, putting the pins through telson and each great claw.

The Gills.

Remove the carapace over the right gills, as before, and review your survey of the gills. How many are directly attached to the legs? Remove a gill, and study it under a lens. What is its plan of structure?

Now remove the carapace over the left gills, and cut off the gills from both cavities. Examine the walls separating the gill cavity from the internal organs. Can you see any vertical canals? Were they connected with the gills? These are blood vessels.

The Heart.

Remove the strip of carapace remaining over the thorax, being careful not to injure the delicate organs beneath.

The organ first noticed is the heart. Describe its location. What shape and color?

Is there any space around the heart? The sac in which the heart lies is the **pericardium**. The membrane forming its walls is so delicate that it is easily torn, and in preserved specimens is often hard to find. It incloses colorless fluid. Examine the walls of the heart.

Look for blood vessels, **arteries**, leading from the heart. In which direction do they run? Can you find branches? How is the heart held in place?

Reproductive Organs.

Look for the reproductive organs beneath the heart. In the male they are called **spermaries**, in the female **ovaries**. What difference in shape, size, and color? (Compare a number of specimens.)

Examine a number of females. If any dark-colored ovaries are found, they contain eggs. The duct from the ovary is called the **oviduct**; that from a spermary is the **vas deferens**. These ducts are difficult to trace, but their external openings were found in an earlier lesson. Where does each end?

Make a drawing of heart, arteries, and reproductive organs as far as you can see them from above, and designate each organ.

Digestive Organs.

Remove the heart and reproductive organs carefully and cut away the carapace over the head. The first organ noticed will be the **stomach**. What is its location? Shape? Color?

Unpin the chelipeds, and with some flat, blunt instrument probe the mouth opening. The passage thus explored is the **esophagus**, or gullet. In what position does it lie? With what does it connect?

Pin the specimen in place again. Find the **pylorus**, or outlet of the stomach. It connects with the **intestine**.

On each side of the posterior border of the stomach lie glands, sometimes called "livers." Since their use or function is somewhat different from that of a true liver, they may more properly be called **digestive glands**. Find the duct from each gland. Where does it empty?

Draw the digestive organs of the thorax as seen from above,

leaving space to add the intestine later. Designate all parts.

Remove the stomach, and examine its walls more carefully. What indications can you find that food is ground there? Describe the apparatus.

What peculiar provision is close to the pylorus? What use should it serve?

Remove the digestive glands and pick one to pieces and examine with a lens. What is its plan of structure?

The intestine, the remaining digestive organ, being in the abdomen, must be studied later.

Excretory Organs.

In the front part of the body find the pair of glands whose openings are found at the base of the antennæ. What color? What shape? These are the green glands, or organs of excretion. They correspond to the kidneys of the higher animals.

The Abdominal Organs.

Remove the tergal portions of the abdominal crust down to the telson. Examine the muscles which lie immediately beneath. What color? In which direction do they lie? Their anterior attachment is to the walls of the thorax; the posterior, to the terga of the segments of the abdomen.

Which part is moved by them? Is the movement controlled by the animal? If so, they are **voluntary** muscles; if not, **involuntary**.

They shorten when in action. Do they bend or straighten the abdomen? Why are they called **extensors**?

Lift them away and trace the intestine from pylorus to anus. Locate it. What shape? Is it of uniform diameter?

Add the intestine to your drawing of digestive organs, and designate it.

The parts of the body through which food passes together form the **alimentary canal.** Mention them in their order. What outside or **accessory** organs are there? The function of these is to furnish a fluid **secretion** to aid in digestion.

Now remove the intestine and examine the muscles remaining. These muscles flex or bend the abdomen. Are they voluntary or involuntary?

How do **flexors** compare with extensors as to arrangement and thickness? Which needs greater power? Why?

Nervous System.

Cut through the middle line of the flexor muscles, being careful not to cut too deep. When the muscle has been divided, push the halves apart and look for the nerve cord. Can you find any enlargements or **ganglia?** If so, how many? Where are they? Are there any branches? These are called **nerves.** Where given off?

Trace the nerve cord forward into the thorax. Is it as exposed in this region?

Break away any hard parts that cover it and trace to the head. Is the cord single through abdomen and thorax?

How many ganglia in the thorax? Are there nerve branches from these?

Just behind the esophagus find a large ganglion whose nerves supply the mouth parts. Trace forward from this two divisions of the cord. Why is this division necessary? Where is the ganglion in which they again unite?

From which ganglion do nerves originate to supply eyes and antennæ? This is sometimes called the **brain.**

Draw a diagram of the nervous system, marking the various ganglia and their branching nerves.

Reproduction.

The germ cell or **oösperm** of any animal is produced in the following manner. A minute and active male reproductive cell called a **sperm** reaches and penetrates a larger female reproductive cell called the **ovum**, and fusing with its nucleus is said to fertilize it. In what organ are the sperms developed? In what organ are the ova developed?

The development of the oösperm of the crawfish is very peculiar, and since that of starfish or mollusk eggs is much more typical of the process in most animals, it is better to study one of these.

Examine a slide showing starfish or mollusk eggs. Look for a single cell. Is it nucleated? Has it a distinct membranous wall? Look for cells in process of dividing. Has each division a nucleus?

Look for a group of four cells. How produced? Is the second division in the same plane as the first?

Can you find any groups of eight or more cells? How arranged? A mass of cells forms the **morula** stage.

The cells next become arranged in a hollow sphere, the **blastula**.

Following this, one half of the sphere doubles in to line the other half. This forms a cup-like body, the **gastrula**, of two cell layers.

Beyond this the process differs greatly in different animals, the cells becoming more and more specialized to form the various tissues.

The developing young animal is called the **embryo**.

Make drawings to show the successive stages in the embryo you have been studying.

CHEMISTRY

(Optional)

To understand the various vital processes going on in the body of an animal, such as digestion, circulation, respiration, etc., some knowledge of elementary chemistry is necessary; the following experiments will be found helpful.

Acids and Alkalies.

(Materials needed: several jars or common tumblers, soda, potash, vinegar, hydrochloric acid, starch paste, olive oil, white of egg, sugar, and pink and blue litmus paper.)

Make a strong soda solution. Taste it. Test with pink and blue litmus paper. Which changes color in the soda solution? Does the other change?

Test in the same way a potash solution. Any substance which changes pink litmus paper to blue is an **alkali**, and a solution containing it is **alkaline.**

Now make a weak solution of hydrochloric acid (HCl). Taste a drop of the solution. Test with the pink and blue litmus paper. Which is affected by the **acid**?

Test in the same way another acid solution, such as a vinegar solution. What is the effect of acids on the litmus paper? How would you define an acid?

Now test for the presence of acid or alkali, white of egg, sugar solution, starch paste, olive oil, etc.

Any substance which changes neither pink nor blue litmus paper is said to be **neutral.** Which of the substances just tested are neutrals?

Chemical Combinations.

(Materials needed: a glass, a cup, lime phosphate, soda, and hydrochloric acid.)

Mix with water a little lime phosphate, shake well, and allow it to stand a few minutes. Does the lime dissolve?

Now add a few drops of dilute HCl and shake. What change takes place?

A combination has taken place which is a chemical one.

Another experiment to illustrate the same sort of action is the following:

Into half a cup of soda solution pour slowly a small amount of solution of HCl. What happens?

Keep adding the acid with a pipette till foaming ceases. Test with pink and blue litmus paper and continue until the acid and alkali neutralize each other.

Taste the resulting solution. Boil it until all the water has evaporated. Is the residue soda? Is acid left?

Besides the common salt thus left a gas was formed whose escape into the air causes effervescence.

When substances which are put together lose their original characteristics and form new substances, the combination is a chemical one and the force which causes it is called **affinity**.

In nature such combinations and their resulting changes are constantly occurring, and the vital processes of both plants and animals depend upon them.

OXIDATION

(Optional)

Carbon.

(Material and apparatus needed: several test tubes, a match, some sugar, starch, white of egg, and lard or tallow.)

Burn a match until it is charred. Describe the substance left.

Heat in a test tube a little sugar. Watch the tube carefully for moisture and when that has disappeared examine the contents of the tube.

In the same way examine fat, starch, and white of egg. What characteristics common to the residue of each?

The element remaining is **carbon**, which is found in combination with other elements in the substances tested.

What substances did they give off while being heated? Water consists of two elements, **hydrogen** and **oxygen.**

What three elements, then, enter into combination in wood, starch, sugar, fat, and white of egg?

The Burning of Carbonaceous Substances.

(Material and apparatus needed: two flat-bottomed dishes, two bell jars whose diameter is slightly less than that of the dishes, two tumblers, a candle, some limewater.)

Set a vial of clear limewater in each of two flat-bottomed dishes, and beside one of the vials put a lighted candle, stuck in place by a drop of the wax.

Now put an inch of water in the bottom of each dish and cover the vials and candle with bell jars whose edges will be immersed in the water.

Does the water rise in the jars to the level of that outside? Explain.

As the candle burns, watch the inside surface of the jars. Does either change?

What happens to the candle? Is there any change in the outside water?

After a moment or two lift the bell jars. Has any change occurred in the limewater in either jar? If limewater becomes milky, this is due to carbon dioxide gas which has been absorbed by it.

Whence came this gas? What two substances are formed in burning the candle?

Why did the water rise in one jar and not in the other?

The substance used up was oxygen gas (O) which forms about 21% of air. This unites with carbon (C) to form carbon dioxide gas (CO_2). Where does the carbon come from?

Moisture also was formed. This consists of hydrogen (H) and oxygen.

Where were these elements obtained?

What happens to the candle as it burns?

The union of O with other elements is called **oxidation.** The substance of the candle was oxidized.

What two substances are the result of the oxidation of carbonaceous material?

The Gas Exchange in Breathing.

(Material and apparatus needed: a glass, a glass tube, a physician's thermometer, a little limewater.)

Put a little limewater in a glass. Into this put one end of a glass tube and blow through the tube into the water.

After a moment what change takes place in the limewater? What gas is given off in the breath?

Is this gas present in the same quantity in inspired air? How can you tell?

Where is the CO_2 formed that is breathed out? Where does the O come from? The C?

Breathe in a cold glass. What results?

Is there as much moisture in inhaled as in exhaled air? How can you prove this? Whence came the moisture?

What two substances are formed in the body and given out in the breath?

What process is going on in the body in connection with breathing?

What elements does the body lose?

What common term is applied to the oxidation of the candle?

If we shut off air, will burning take place?

What are the beneficial results of burning in the case of a furnace? What in the case of an engine?

Could an engine run without heat? Could heat be obtained without O?

With a thermometer test the temperature of the body under the tongue. How high is the mercury? Is it about the same for all pupils?

Compare this with the temperature of the air in the room. Whence comes the extra heat?

Exercise vigorously for a moment with the thermometer in the mouth. Does the mercury rise any? What is one result of exercise?

If all of the oxygen were exhausted from the air we breathe, would the body remain warm?

What process is increased in the body by exercise?

What is the purpose of breathing?

Animals which breathe by gills get O from air dissolved in the water. Can they use as much as man?

Is oxidation an essential life process?

To understand further how oxidation occurs in the body of any animal, it will be necessary to understand how O gets from the inspired air to the tissues of the body, which involves several other steps or processes.

FOODS

(Optional)

How does an animal replace the materials exhausted from the body in oxidation?

Give two reasons why a young animal needs more food in proportion than an average adult.

What elements have your experiments shown to be necessary to the body?

Would you consider water a food?

Can you think of any mineral substance greatly needed by the crawfish?

There is another element which enters into combination with others to form part of our bodies, the gas *nitrogen* (N). It forms about 77% of the air, and when the oxygen is exhausted is left nearly pure. Will it burn? Will it assist burning?

Nitrogen enters into combination with other elements to form **protoplasm**, of which all animal cells consist.

State all the reasons why an animal needs food.

Are the elements needed taken free or in compounds?

The compounds which contain nitrogen are called nitrogenous or albuminous foods, or **proteids**; those that contain only carbon, hydrogen, and oxygen are called **carbonaceous.**

To test for Proteids.

(Material and apparatus needed: four test tubes, Millon's reagent, an egg, sugar, starch, mutton tallow, seeds, fruits, vegetables, white muscle of some animal, milk curd.)

Boil an egg hard and place the white, which is nearly pure albumen, in a test tube. Pour a little Millon's reagent on it and heat over a flame. What results?

Put into separate test tubes dilute starch paste, grape sugar, and mutton tallow, and treat each with the reagent.

Are the results the same? What do they show?

Why is Millon's reagent a reliable test for albumen?

Now test in the same manner various seeds, vegetables, and fruits, having first boiled and crushed them. What are your conclusions? Do they contain albumen?

Test the white muscle of the crawfish or some other animal, or any other light-colored animal tissue.

Test milk curds.

What class of foods is most strongly nitrogenous?

The carbonaceous foods are starch, sugar, and fat or oil.

To test for Starch.

(Material needed: four test tubes, solution of iodine, foods as above.)

Make a thin boiled starch paste, and when it is cool drop into it a few drops of weak solution of iodine and note the color reaction.

Test, in the same manner, white of egg, sugar, and mutton tallow. Do they show the same reaction?

What is the only one of these four foods that turns blue when tested with iodine?

Now test in the same way (after boiling and crushing) a number of seeds, vegetables, and fruits (both ripe and green); also some light-colored animal tissue. Is starch present in quantity in any one? Is it present in animal tissues?

To test for Grape Sugar.

(Material needed: four test tubes, Fehling's solution, foods as before.)

Make a saturated solution of grape sugar or glucose, put a little in a test tube, and add about 20% of a strong caustic soda solution, followed by a few drops of a 1% solution of copper sulphate, which together constitute Fehling's solution. What color results?

Bring to a boil and note changes in color. What is the final color?

Can you see any deposit of sediment?

Test in the same way dilute starch paste, white of egg, and tallow. Does any one show the color reaction of the grape sugar?

Is this a good test for grape sugar? Why?

Why do we use grape sugar instead of ordinary sugar?

Test a number of foods for grape sugar, first boiling each in a test tube, adding the caustic soda and copper sulphate, and boiling again.

Is grape sugar found in animal substances? In all vegetables and fruits?

To test for Fats or Oils.

(Materials needed: two plates, unglazed paper, foods as before.)

Place on a piece of unglazed paper a bit of tallow and heat it. What effect on the paper?

Test in the same way sugar, starch, and boiled white of egg, putting them on a plate lined with the paper and covered with another plate, and heating in a slow oven for half an hour.

Remove and shake off the paper. Can you see any stains? If so, do they resemble those made by the tallow?

Test in the same way various foods. Which contain oil or fat? Do vegetables? Do fruits? Whence come most of our fatty foods?

DIFFUSION AND OSMOSIS

(Optional)

Apparatus and material needed: For experiment (*b*), long, shallow dish, teaspoon, sugar, salt.

For experiment (*c*), two tall, wide-mouthed bottles fitted with tight corks, two thistle tubes, parchment paper, bits of marble, hydrochloric acid.

For experiment (*d*), several small, wide-mouthed vials, as many flat-bottomed dishes, parchment paper, salt, grape sugar, raw and boiled starch paste, raw white of egg, olive oil, soda, vinegar, Millon's reagent, iodine, Fehling's solution, litmus paper.

(*a*) Shut off all drafts in a room. Turn on the gas in one burner for a minute, and determine how soon its presence may be detected at some distance.

How soon will the gas be so dispersed that its odor is about equally distributed all over the room?

This mingling of gases is called **diffusion**.

(*b*) Make a strong sugar solution in a long, shallow dish. Introduce as gently as possible into one end a teaspoonful of a strong salt solution, and taste the liquid at the other end after a moment or two. Does the salt solution diffuse in the sugar solution?

What kinds of substances may diffuse?

(*c*) Perforate the corks of two bottles and insert through each the tube of a thistle tube, making the perforation as air-tight as possible, but be careful not to push the tube very far through.

Cover the bulb end of each thistle tube with animal membrane or parchment paper, and keep one moist and the other dry.

Fill each bottle about one third full of bits of lime. Cover with water, add a teaspoonful of strong hydrochloric acid, cork tightly, and observe results. Account for them.

(*d*) Fill a wide-mouthed vial with strong salt solution, cover its mouth with membrane, and lay it on its side in a dish of pure water.

At the end of twenty-four hours taste the water in the dish. What has occurred?

In the same way set up bottles containing grape sugar solution, raw and boiled starch, white of egg, oil or melted butter, soda solution, vinegar, or other acid solution. Set up one bottle containing soda solution in a dish containing vinegar.

Take a little of the outside liquid from the vessel in which the grape sugar solution was placed. Test for grape sugar. Does grape sugar diffuse readily through a membrane?

Test also the liquid outside of each of the other vials for the solution within the vial. Which solutions pass readily through the membrane? Which do not pass at all? Will two fluids mingle through a membrane? Such mingling is called **osmosis.**

To show the direction in which the greater flow takes place, cover the bulb end of a thistle tube with parchment paper. Then through the tube end half fill the bulb with thick sugar sirup, and support the thistle tube in a vessel of water so that the fluids inside and outside the tube are at first at the same level.

Examine every fifteen minutes for an hour or two. Is the current greatest toward the denser or thinner liquid?

These experiments in diffusion and osmosis will help to explain how food and oxygen reach all parts of the body and how wastes are removed.

DIGESTION

(Optional)

In order that starch, fat, and proteids may pass through the membranes of the alimentary canal and the walls of

the blood vessels into the blood, it is evident that some change must occur in them.

Such a change occurs in the processes of digestion by means of various digestive fluids, which have the power of transforming these foods into liquid or soluble substances which can easily enter the blood and pass again from that to the cells of the body or be oxidized in it to give heat and energy.

Experiments to show the action of the various digestive fluids may be found in Eddy's "Experimental Physiology and Anatomy."

CIRCULATION

(Optional)

Examine a drop of human blood under the microscope.

To obtain this, bind a finger tightly at its base for a few moments till it looks dark and slightly swollen. Then, with a sharp needle that has been sterilized in a flame, prick the finger and put the drop with a drop of water on the slide. Use first l. p. and then h. p.

The solid bodies are the blood cells, or **corpuscles.**

What two kinds?

Describe the more numerous ones, giving shape, size, and color. These are the **red corpuscles** and give the color to the blood of all the higher animals. They take up O readily and as readily give it off.

If the drop is carefully examined, other less numerous and larger **white corpuscles** may be seen. What shape? Is the shape constant?

The fluid of the blood is **plasma**, and in it are carried the dissolved foods.

By what processes does food enter and leave the blood? By what process does oxygen enter and leave it?

The flow of blood may be seen under the microscope in the webbing of a frog's foot or a fish's tail where the vessels are tiny and their walls thin. The same arrangement will serve for either.

Get a thin board or a heavy cardboard, 8 or 10 inches long by 6 wide.

One inch from the center of one end, cut a hole about the size of the opening in the stage of the microscope.

Lay the board with this end on the stage and the hole properly adjusted, and prop the other end so the board will be level.

Now wrap a small live minnow or goldfish in a piece of wet cloth, leaving the tail free.

Lay the fish on the board, bringing the tail over the hole.

Spread it out and with a couple of pins fasten it so as to stretch it as tight as possible.

Examine with h. p. Can you see the movement of the corpuscles?

Can you see the direction in which the blood flows in the tiny vessels?

Find two vessels which unite to form one. The two smaller are **capillaries,** the one larger a **vein.**

Find a blood vessel which divides to form capillaries. This is an **artery.**

Identify as many arteries and veins as you can see.

Instead of the fish's tail, a frog's foot may be used, in which case, however, it will be necessary to use ether to keep the animal from jerking and tearing the foot.

Hold the frog in a wet towel, leaving it loose over the head and the feet free.

Pour a little ether on a bit of cotton, put it over the frog's nostrils, and cover closely with the towel.

When the legs will hang limp and no longer jerk when

pulled, lay the frog in the towel on the board, spread the foot over the hole, and pin so as to stretch it tight.

Examine as above.

If the flow is too slow, move the cotton away from the frog's nostrils for a time.

By moving the cotton nearer to or farther from the nostrils as the case requires, renewing the ether, etc., the animal may be kept for hours in condition to demonstrate for circulation.

The heart is a pump to force the blood about the body.

To show the pumping of the heart, kill a frog by means of ether and quickly open the cavity containing the vital organs by cutting just to the left of the median line on the ventral side.

Touch the heart with the points of the forceps and observe results.

Study and describe the movement of the heart.

Cut all connecting blood vessels and remove the heart to a watch glass containing a 1% salt solution. Observe that its beating is renewed.

Open the heart and observe its cavities; the upper is the **auricle**; the lower is the **ventricle**.

The blood vessels carrying blood away from it are called **arteries** without regard to the kind of blood carried.

Vessels carrying blood towards the heart are **veins.**

Connecting them are tiny vessels called what?

Through the walls of which will diffusion and osmosis take place most easily?

Which will reach all the cells of the body?

In the crawfish where are the capillaries distributed which receive O and give off CO_2?

Where are those which absorb digested food?

What exchanges take place between the blood in the

other capillaries of the body and the tissues among which they lie?

TISSUES AND CELLS

(Optional)

Each different substance of which the body of an animal is composed is called a **tissue.**

In order to understand its composition, it should first be examined with the naked eye and then a bit should be mounted and examined under the microscope.

Frequently it is necessary to stain a section for examination, since it would be too nearly transparent to be easily seen. When a stain is used, some portions darken more than others, and thus details are more perceptible.

(Materials needed: set of slides showing animal tissues; same tissues obtained from a butcher's.)

Cartilage.

One of the simplest tissues found in the higher animals is **cartilage**, which forms a padding at the joints and is the earliest stage of bone.

Examine a bit obtained from a butcher. What color? Is it opaque? Is it soft? Elastic or inelastic? Can you think of any other properties it possesses?

Place under the microscope a prepared slide of hyaline cartilage and examine carefully with the l. p.

Can you see any dark dots? Are they numerous?

Are they uniformly scattered? Describe their arrangement.

Examine with h. p. Each dot is called a **cell.** What is the shape of a cell?

Make out a smaller spot in each cell, the **nucleus.**

The substance of the cell is albuminous and is called **protoplasm.**

Can you find any cell with more than one nucleus? If so, the cell is beginning to divide.

Can you find two cells that have just divided?

Can you find any group of more than two?

Cells multiply or propagate themselves by division.

The substance in which the cells are imbedded is called the **matrix** and is built by them. What is the appearance of the matrix of cartilage?

Draw a group of cells.

Epithelium.

Examine with l. p. and then with h. p. a prepared slide.

What shape are the cells? Are they imbedded in a matrix? How arranged?

Can you find a nucleus in each cell?

Draw a group of cells.

Epithelium lines the internal organs of every animal. It also covers the gills of water animals.

Put a bit of the gill from a live oyster or other gill-breathing animal under the microscope and examine the epithelium. Can you see any parts in movement?

The very slender threads are called **cilia** and are merely prolongations of the protoplasm. Do they seem to have any definite rule of movement? Describe it.

Draw a few cells much enlarged.

Muscle.

To determine some of the characteristics of muscle, put your left hand over the upper inner part of the right arm, and flexing and then straightening the elbow, feel the changes that take place in the biceps muscle.

The soft part of the muscle is called the **belly.**

The cords which fasten it to bone are called **tendons**.

The end which moves the least is the **origin**, the other end the **insertion**.

Flexing and straightening the elbow joint, try to find the origin and insertion of the biceps.

The work of a muscle consists in **contraction**; its rest is **relaxation**.

When is the muscle longest? Thickest? Firmest?

When the caudal fin of the crawfish is bent under the body, which set of muscles is contracted and which relaxed?

Where is the origin and where the insertion of each set?

How does the color of the muscle of the crawfish differ from that of lean meat? The muscles of the higher animals?

Examine a bit of muscle. Can you see any divisions? These divisions are bundles of cells.

What keeps the bundles distinct?

What is the shape of a bundle? In which direction does it lie in the muscle?

Examine a bit under l. p. and then h. p.

Can you see any divisions? What shape? These divisions, although cells, are called fibers. Why?

Can you see any cross markings? These are called **striæ** and muscle having such markings is said to be **striated**.

Draw several fibers much enlarged to show striations.

Since striated muscles are controlled by the will of the animal, they are also said to be **voluntary**. Muscles that are not are **involuntary**.

What parts of the body of any animal are moved by voluntary muscles?

Where are the involuntary found?

Examine a slide of involuntary muscle tissue with l. p. and

then h. p. Are the cells striated? Nucleated? How arranged?

Draw a group.

Tendon.

Examine a bit obtained from a butcher's. Its color. Is it elastic? Is it easily torn or broken? What properties does it possess?

Examine a bit under h. p. Of what does tendon chiefly consist? This is inelastic connective tissue.

Examine a slide showing a bit of the membrane lining the internal organs. This is elastic connective tissue.

Can you make out fibers? How arranged?

Can you see any cells? How distinguished from the fibers?

Are the fibers of connective tissue cellular or intercellular?

Draw a bit of elastic tissue showing cells and fibers.

Liver.

Examine a bit with a lens. Compare with the texture of muscle; of cartilage. Examine under l. p. and then under h. p. a slide showing liver. Is it composed of cells?

Draw a few. If nucleus is visible, indicate it in your drawing.

Bone.

Examine a cross section under h. p. How does it differ in appearance from cartilage?

The dark spots show the location of bone cells. What is the character of the matrix of bone cells?

The larger spots or openings show the location of the **Haversian canals,** through which run blood vessels. How are the cells arranged in relation to these canals?

Nervous Tissue.

What is the color of the nervous tissue of the crawfish? It is the same in all animals.

Of what parts is the nervous system of the crawfish composed?

The ganglia are collections of cells.

Examine with l. p. a slide showing nerve cells. Are they a compact mass as in muscle, side by side as in epithelium, or imbedded in a matrix as in cartilage?

Examine with h. p. How do nerve cells compare in shape with muscle cells? With cartilage cells?

Can you see any prolongations? These extend as fibers, either connecting one nerve cell with another or with some other part of the body.

Draw a group of cells much enlarged and mark parts.

Examine a cross section of a nerve. It is simply a bundle of fibers. Can you make out cut ends of fibers?

Of what minute structures are all animal tissues wholly or in part composed?

How do they resemble each other? How do they differ?

Can you think of any causes for their differentiation? Any advantages in it?

PARAMECIUM, THE SLIPPER ANIMALCULE

Paramecium is a microscopic form that feeds chiefly on bacteria and other forms of plant life or decaying organic matter in the water. Will it be found in pure or in stagnant water? How may Paramecium be cultivated in the laboratory?

Examine with l. p. a drop of slime from a culture for rather slipper-shaped, swiftly moving forms. Are they alike? Which end is anterior and which is posterior?

Can they swim backwards? Sidewise? Is the movement aimless or does it evince any definite purpose? Describe it.

Can you distinguish an oblique groove on one side of the body? This connects with the interior of the body by means of the **gullet** and constitutes a sort of **mouth.** In which direction does its external opening point?

Can you discover in the interior of some Paramecia large clear spots that are not seen in others?

Watch one animal closely, and if possible see that this spot comes and goes. It is called the **pulsating vacuole.** Its function is believed to be excretory.

Some species of Paramecia have one and some two pulsating vacuoles. How many has the one you are examining?

Examine with h. p. [1]Can you make out any **food balls,** dark round masses often surrounded by a little water?

[1] To bring out the food balls make a strong carmine solution, add it to a culture, and examine after twenty-four hours.

Are they confined to any definite region of the body? Compare several animals to be sure of this.

Can you see any distinction between parts of the body substance?

It consists of a jellylike protoplasm of which the outer thin layer is called the **ectosarc**, and the more fluid interior the **endosarc**. Which is the more granular?

[1] Can you distinguish a membrane covering the ectosarc?

Can you make out **cilia** by means of which the animal moves? Are there cilia in the mouth opening? Are all the cilia of equal length? How is food obtained?

Examine a slide that has been stained [2] and look for a lens-shaped body, the **nucleus**, near the center of the animal.

If possible find a smaller body, the **micronucleus**, near the nucleus.

Draw a Paramecium, making your drawing two inches in length, and put in all parts that you have seen.

Reproduction.

Possibly you may have seen, among the Paramecia you have examined, forms that seem to be dividing in half. If so, make out if possible a division into halves of nucleus and micronucleus.

When this division is complete, the other material of the body, the **cytoplasm**, divides also, and thus two individuals are formed. This is reproduction by **fission** or division.

[1] To slacken the movement of these swiftly moving forms, make a mucilage of gelatine or gum arabic of about the consistency of a thick sirup. Upon a slide put a ring of this about the size of the cover glass, and in its center a drop of the culture containing Paramecia. If the mucilage is of the right consistency, the movements of these animals will be retarded sufficiently for the eye to follow them easily.

[2] To bring out the nucleus and micronucleus, make a 1% solution of acetic acid to which add 10% of methyl green and run a drop or two under the cover glass.

Can you find two Paramecia with their grooved surfaces closely applied to each other? When this occurs, a process known as **conjugation** is taking place. The nucleus of each animal breaks up. This is followed by the division of each micronucleus into four parts. Two of these and all of the parts of the nucleus disappear, being absorbed into the substance of the cytoplasm.

There are still two parts of the micronucleus visible in each Paramecium. One of these from each animal passes over and unites with the remaining part of the micronucleus of the other animal.

Then the two Paramecia separate after this exchange. The new nucleus formed by the union of parts of the micronuclei of the two conjugating individuals divides to form nucleus and micronucleus. After a time reproduction by simple division occurs.

AMŒBA

In Protozoan cultures may sometimes be found another form, the Amœba, which seems a mere quiet drop of protoplasm.

Watched closely its form will be seen to change with a slow movement.

Does it possess ectosarc and endosarc? Body membrane? Nucleus? Contractile vacuole? Cilia?

How does it move? Has it any mouth? How is food taken in?

Bulging parts are called **pseudopodia.**

Draw an Amœba an inch in diameter and mark all parts.

Draw several forms to show successive changes as it moves.

VORTICELLA, THE BELL ANIMALCULE

Sometimes Vorticella may be found in the cultures with other Protozoans. Look for bell-shaped forms. Are they free-moving?

Describe shape and attachment.

Has the animal ectosarc and endosarc? Body membrane? Nucleus? Contractile vacuoles?

If cilia are present, locate and describe.

Locate the mouth and gullet.

Tap on the slide with a pencil. What happens? Can the Vorticella change its shape?

Draw a Vorticella as large relatively as Paramecium and Amœba.

Can you see any evidences of division into cells in the bodies of the animals you have just studied?

What is their food? How and where digested?

How transformed into new substances?

Where do they get the energy by which they move?

How do they obtain O?

How are wastes eliminated?

Can they direct their movements? Can they distinguish food?

Advanced Work. Topics suggested for further investigation, supplementary reading, and discussion:

Examination of material from cultures for other Protozoans and comparison with forms already studied.

Colonied Protozoans.

Reproduction in Vorticella and in such colonied forms as Gonium, Pandorina, and Volvox.

General characteristics and classification of Protozoans.

GRANTIA, A CALCAREOUS SPONGE

(Optional)

Grantia is one of the simplest sponges. Compare several specimens and describe color, shape, and size.

Is it divided into dorsal and ventral, right and left, anterior and posterior parts? Is it bilaterally symmetrical?

How do the two ends differ? Can you see evidence of attachment?

Examine the outer end with a lens. Look for an opening, the **osculum**. The needlelike fringe surrounding it consists of limy **spicules**.

Examine the surface of the body carefully. Is it smooth? Can you see any other spicules?

Look for other openings, **inhalent pores**. Are they numerous?

Draw a sponge (× 10).

Cut a specimen in half lengthwise and look for a body cavity, the **cloaca**. What shape? What is its outlet?

Examine its walls. How are they marked off?

Can you make out pores? These are called **ostia**.

In the substance of the body find **radial canals** connecting the inhalent pores and the ostia.

Water enters the inhalent pores and is ejected through the osculum. What is its course?

Examine specimens for young sponges budding from the larger ones. Where do the buds form?

Examine some sponge spicules with l. p. and then with h. p. How many different kinds can you find?

The needlelike spicules form around the pores; the others, imbedded in the flesh of the sponge, form a skeleton.

Draw the dissected sponge (× 10) to show radial canals, ostia, etc. Draw spicules as seen under the lens.

THE COMMERCIAL SPONGE

The animal whose skeleton we know as the sponge of commerce is much more complex.

What qualities make the household sponge valuable?

Compare a wet sponge with one that is dry.

Select a specimen that has large pores which do not completely perforate the sponge. Probe the larger pores with some slender blunt instrument. Do they communicate with each other directly? Hunt for smaller pores.

Examine a sponge that has been cut in two through one of the large pores. Look for grooves on the surface and for tubes running parallel to the surface. How many classes of tubes or pores have you found?

Examine some fibers of this sponge and compare with the spicules of Grantia. What differences have you found between Grantia and the commercial sponge?

Sponges reproduce, not only by budding, but also by eggs. Certain cells in the mesoderm become ova. Certain other cells divide into a number of active sperms. The sperm fertilizes an ovum and forms an oösperm, which remains imbedded in the mesoderm close to a pore until it reaches the blastula stage. Then the cells of half the blastula become ciliated and the young sponge, freeing itself from the surrounding tissue, escapes into the pore and out through the osculum, to float about till the gastrula stage is reached. Then it settles on the sea bottom to develop a form like the parent.

Advanced Work. Topics suggested for further investigation, reading, and discussion:

Examination of a fresh-water sponge.

Glass sponge skeleton.

Methods of obtaining and preparing sponges for market.

THE FRESH-WATER HYDRA

Alcoholic Specimens.

Naked eye characteristics: Shape? Color? Size?

At one end note the **tentacles.** Examine with a lens. How many? The mouth opening is between them. Make a drawing of your specimen (× 5) and mark parts.

Microscopic features: Examine with l. p. the tentacles. Note the **lasso cells** dotting the surface. Describe their appearance and arrangement.

Examine a cross section with l. p. Note the central or **gastric cavity** surrounded by the body wall. Of how many layers does the latter consist? The outer is called *ectoderm;* the inner, *endoderm.*

Can you see a **supporting layer** between them? Is this divided into cells?

How do ectoderm and endoderm differ?

Draw (× 5) and mark ectoderm, endoderm, supporting layer, and gastric cavity.

Examine a longitudinal layer and identify the same features. Draw (× 5) and mark parts.

Examine a specimen that is **budding.** Where on the body is the bud formed? Is the cavity of the bud connected with that of the parent body?

Sexual Reproduction.

Look for slight elevations on the sides of the body. Can you see any near the base? If so, what shape? These are **ovaries,** and each contains a single **ovum.**

Are there any elevations near the mouth? If so, what shape? These are **spermaries,** from which are discharged numerous **sperms** that swim actively in the

water. When one of these sperms enters the ovary of another hydra, it fertilizes the ovum and forms an **oösperm.**

Segmentation then begins and after a small mass of cells is formed it becomes covered with a layer of tough protective cells. The young **embryo** then breaks away and drops to the bottom, where it lies quiet for a time and then completes its development into a form like the parent.

The Live Hydra.

Examine Hydras in an aquarium and note the movement of the tentacles. For what purpose used? In what ways is locomotion effected?

Arrange the aquarium so that one end will be in a strong light and the other in the shade. What happens? Is Hydra sensitive to light?

Touch a tentacle with a pencil. What conclusions do you draw?

What is the food of Hydra? Try feeding one with bits of water plant and meat, or with small crustaceans. How is its prey captured? Where digested?

Has Hydra any respiratory, circulatory, or excretory organs? How are these functions of the body performed?

Where are Hydras found? They are prey of other, larger animals, especially some species of pond snails. Why are they not found in all fresh-water ponds?

A CAMPANULARIAN HYDROID

(Optional)

Notice the slender branching stem with its rootlike base for attachment to some support, and the hydralike buds, **hydranths** or zoöids. Look near the base for other vase-like buds without tentacles. These are **gonangia.**

Examine a branch with l. p. and notice the **perisarc,** a transparent chitinous sheath covering the stem. Does it also cover the hydranth?

Within the perisarc is a hollow tube of the same layers as in Hydra, and the hydranths are buds that, instead of becoming free as in Hydra, remain attached to the parent. Examine a hydranth carefully and compare its structure with that of Hydra. How do they resemble each other and how do they differ?

Since the hydranths are connected by a hollow stalk whose endodermal cells are ciliated, food and water circulate freely through the colony.

Examine a gonangium with l. p. and h. p. Identify the perisarc and a slender hollow axis bearing **medusa buds.** These medusa buds escape from the gonangium to become free-swimming.

Make a drawing of the whole colony; of a hydranth; and of a gonangium enlarged to show all features.

Examine a **medusa** from one of the colonies. Of what sort of material does the body consist? What is its shape?

The convex surface is called the **exumbrella,** the other the **subumbrella.** Are there tentacles? If so, where and how many?

Find the proboscis at the end of which is the mouth. Locate it. It contains part of the stomach.

Make out four radial canals extending from the stomach to a circular canal near the edge of the umbrella.

Examine the edge of the umbrella and notice extending from it a shelf-like **velum.**

Among the bases of the tentacles look for marginal sense organs. How many? These are probably balancing organs.

Find on the subumbrella side of the body, four reproductive organs containing either ova or sperms. A sperm from a male medusa finds it way to the ovary of a female and, entering, fertilizes the ovum. The oösperm develops into a free-swimming embryo which finally settles down, and by budding builds up a colony which resembles the grandparent.

Thus every other generation is a colonied form. Its reproduction is by what process?

What sort of reproduction has the alternate jellyfish generation?

Of what advantage to the colony to have every other generation a free-swimming form?

THE SEA ANEMONE

(Optional)

Compare the shape of the body of a sea anemone with that of Hydra. Locate the mouth. What is its shape? How is it surrounded? Describe the arrangement of the tentacles.

Examine a section of the body cut across near the top. Identify an outer wall. Of what cell layers composed? Is there a supporting layer?

Identify a central cavity, the stomach. This is an infolding of the outer wall. Which layer is ectoderm and which endoderm?

How are stomach and body wall connected? How many spaces are separated by these **primary partitions,** or **septæ**?

Are there any other partitions besides the primary? How are they arranged?

Make a drawing to show this arrangement of parts.

Examine a longitudinal section of the body taken through the center of mouth and stomach. Does the latter extend to the base of the body? Is it closed at the lower end? How can digested food and oxygen reach all parts of the body?

A STAR CORAL

Examine the skeleton. Of what substance composed?

Examine the skeleton of a single **polyp**. Can you see any relationship between its plan and that of the sea anemone? This skeleton was formed between ectoderm and endoderm.

Has the body of the sea anemone any such supporting layer?

Did the skeleton of the coral polyp extend into its stomach? Into the tentacles?

Is it heaviest in walls, base, or partitions?

Compare a branching coral with the Campanularian hydroids.

Corals have no alternate generation.

THE STARFISH

(Optional)

Alcoholic Specimens. Dorsal Side.

How many rays and how arranged? Is the surface concave or convex? Examine the skin. Is it thin or leathery? Smooth?

Look for **spines.** Are they movable?

Look for small elevations between the spines. What do they resemble? They are breathing organs.

Find a wartlike, light-colored elevation on the central disk — the **madreporic plate.** Locate and describe it.

The ray opposite is the **anterior ray.**

Bend a ray to test its flexibility. Search with a lens for a red or yellow **eye spot** on the end of the ray.

Find a **tentacle,** the organ of smell, just above it.

Find a tiny hole near the center of the disk, the **anus,** or outlet of the intestine.

Draw a dorsal view and mark madreporic plate, anterior ray, eye spot, organ of smell, and anus.

Ventral Side.

Find the mouth. Where? By what surrounded? This is the **peristome.**

Note the **furrow** along the center of each ray. Look for four rows of **tube feet.** Describe their arrangement. Examine a specimen whose water vascular system has been injected to see these more clearly.

Note the spines. Are they movable? Locate them. How do they compare in size with the other spines?

Draw a ventral view of the central disk and anterior ray and mark the mouth, furrow, tube feet, and movable spines.

Dissection.

Find the anterior ray and with scissors cut a slit across the dorsal side near the tip.

Insert the point of the scissors and cut the dorsal wall along the edge on each side to the angle of the rays, being careful not to cut anything but the body wall.

Turn back the loose piece and see, fastened to its under surface, a double gland, the "**liver**," held in place by a delicate membrane, the **mesentery**.

Its secretions can digest starch, fat, and albumen. To what organ in the human body does it most nearly correspond?

Examine the floor of the ray. Notice the ridge corresponding internally to the external furrow.

Look for membranous sacs, the **ampullæ**, each connected with a tube foot. An injected specimen will show these more clearly also.

Remove the "liver" from the anterior ray, cut off a piece of the dorsal wall, and examine for tiny flat **plates** imbedded in the skin. Compare them with the plates in the ventral wall.

Look for depressions in the dorsal wall between the plates. To what on the outside do they correspond?

Above what are the spines fastened?

Bend the ventral surface to see the furrow more plainly.

Find a **nerve cord** running along the center to the end of the ray. With what does it connect there?

Trace it back towards the mouth. It connects with a ring around the mouth.

Cut across the ray and find in the furrow just above the nerve cord a tiny hole. You have cut a tube that carries water to fill the ampullæ, which in turn fill the tube feet.

Next cut loose the dorsal wall of the ray on each side of the anterior one, following the same method as with the anterior ray. Connect the cuts at the angles between the rays.

Gently lift the central disk so as to expose the **stomach.** Note its five-lobed arrangement.

Find in each ray two tiny, clear, threadlike **muscles** which run from the exterior of the stomach. Where is the other end of each attached? These aid in the protrusion from the mouth of the lower part of the stomach.

Note at the angles of the rays, close to the "liver," the **reproductive organs.** Describe their appearance. These open by ducts whose tiny outlets are upon the dorsal disk close to the angles between the rays.

The sexes are distinct, but **ovaries** and **spermaries** are so much alike that they can be distinguished only by careful microscopic examination.

Look for the ducts leading from the "livers." They empty into the **pyloric sac** of the stomach.

Above this is the **intestine.** Describe it.

Cut across this and remove the stomach.

Cut off the dorsal disk except the portion around the madreporic plate. Note leading down from this a whitish tube. What letter does it resemble? This is the **stone canal.**

Find its connection with a circular tube around the mouth. Leading from this are the **radial vessels** which fill the ampullæ.

Examine an injected specimen for these parts.

Trace the course of the water in this **water vascular** system.

Also connecting with the circular vessel, there is in each ray a pair of organs, whose function is the formation of white corpuscles or blood cells.

Close to the "stone canal" find a muscular bulb, the "heart" of some authorities.

This connects at each end with a circular vessel which in turn connects with other vessels and other organs. There is some difference of opinion in regard to these parts and their functions.

The space between the organs of the starfish and its body walls is filled with a fluid, principally sea water, in which are white blood corpuscles. These are also found in the water vascular system.

THE SEA URCHIN

(Optional)

Describe its shape. In what respects does its body covering resemble that of the starfish? How do they differ?

Locate the mouth. How many teeth? How arranged?

What difference must there be between the food of the sea urchin and that of a starfish?

Locate the madreporic plate.

Examining a skeleton, look for elevations upon which the spines articulated.

Holding it to the light and looking in at the mouth opening, locate rows of tiny holes. These are apertures through which the tube feet protruded. How many sets and how many rows in each?

How does the sea urchin compare with a starfish in this respect?

Does a sea urchin show any signs of radial symmetry?

Why is it classed in the same branch but in a different class from the starfish?

Advanced Work. Topics suggested for further study and discussion:

Food of starfish and methods of feeding, and economic relation of starfish to the oyster industry.

Power of regenerating lost parts.

Brittle stars, sand dollars, etc.

The sea cucumber.

The crinoid (both fossil and alcoholic specimens).

General characteristics of branch as shown by forms studied.

THE EARTHWORM

The Live Animal.

What is the shape of the earthworm's body?

Identify anterior and posterior ends. How can you tell which is anterior in any animal?

Is there any difference in shape between anterior and posterior in the earthworm? Of what advantage?

Notice the division into segments, or **somites**. Is any part of the body not segmented?

Has a worm distinct dorsal and ventral surfaces?

Can you see any difference in color? In shape? In marking?

Draw it through your fingers and see if you can feel any difference. If so, to what due?

Has an earthworm right and left sides? How can you determine right and left for any animal? What kind of symmetry has an earthworm?

Describe the color. Would any other color do as well? Explain. Note the iridescence of the skin.

Watch an earthworm crawling. Describe the changes in the shape.

Does the whole body move at once?

There are two sets of muscles concerned in this movement. When the body shortens, are **circular** or **longitudinal** muscles contracting? Which set must contract to lengthen the body?

Observe a **dorsal blood vessel**. Does it pulsate? Can you tell in which direction it carries blood?

What color is this blood? Can you see a **ventral vessel**?
Hold the worm in the light and notice dark food masses in the **alimentary canal**.

Special Senses.

Using a toothpick, determine which part of the body has the keenest sense of touch.
Dip a toothpick in sugar solution, move it towards the anterior end, being careful not to touch it, and see if the earthworm shows any sense of smell.
Repeat with beef extract. Try other substances, but be careful not to use any irritating substance. Why? Does the worm distinguish between odors?
Put the worm in a test tube, and covering one half of the tube to darken it, decide whether any part of the body is sensitive to light. If so, which?
Take a lens and focus the light along the body, beginning with the tail. Does the result coincide with the preceding?
Place the worm on a paper, part of which is damp and part dry. Does the worm prefer damp or dry places?
With the breath blow upon the worm. Fan it or blow with a tube. Is it sensitive to a breeze?

Habits and Environment. (Field work)

Where do earthworms live? How can you recognize their burrows?
How deep do they go? Does temperature affect this depth?
In what kind of soil most numerous? Why?
Why do we see so many after a rain?
Do we usually see them on the surface of the ground? Explain. At what time might we find them?

External Features of Alcoholic Specimens.

Examine more carefully the segments of the body. Notice folds in the skin apparently doubling the number of segments. Can you suggest a use?

Count the segments in your specimen and compare the number with that in several others. Is it always the same?

Look for the **mouth.** In front of it find the **lip.** How arranged?

At the posterior end of the body find the **anus.**

A short distance from the anterior end note the **clitellum,** a thickening of the body. Is it found on all specimens? Is its location the same whenever found? It is developed only on full-grown worms and secretes upon its surface a viscid fluid which envelops the eggs and hardens into a capsule for their protection.

Examine with a lens for tiny bristles called **setæ.** How many on each segment? Location and arrangement? Does every segment bear them? What is their use?

Look with the lens for the openings of ducts from the reproductive organs.

The **oviducts** open on the 14th and the **vas deferens** or **spermiducts** on the 15th segment.

Cross Sections.

Examine a cross section and note cuticle, muscular body wall, body cavity, and alimentary canal.

Examine a slide showing same, and note again the same structures, identifying the two sets of muscles.

Note the extension or infolding of the dorsal wall of the intestine, diminishing the space but increasing the surface of the lining.

Make a drawing and mark all parts.

Internal Organs. (Optional)

With scissors cut the skin of a specimen along the median dorsal line, lay it in a dissecting pan, and pin the skin back to show the internal organs.

Note the parts of the **alimentary canal**.

a. The **pharynx**, in segments 2–6 inclusive.

b. The narrow **esophagus**, hidden by other organs.

c. The soft-walled **crop**, in the 14th or 15th segment.

d. The hard-walled and white **gizzard**, in segments 17, 18, and 19.

e. The **stomach-intestine**, which runs through the rest of the body. Is it of uniform diameter? Describe it.

Above the pharynx find the **cerebral ganglion**. Describe it. Can you find connecting with it a nerve cord encircling the pharynx?

Above the intestines note the **dorsal blood vessel**.

In segments 10–13 note the whitish reproductive organs, the **sperm sacs**.

In segments 7–11 see also the red **aortic arches** connecting the dorsal and ventral blood vessels.

How is the alimentary canal held in place? Are there any internal features corresponding to the external segments?

Make a drawing to show the alimentary canal and mark its parts.

Remove the organs observed and look for the **ventral blood vessel**.

Find in the 13th segment the small **ovaries**. What shape?

Look for the **ventral nerve cord**. Has it any ganglia? If so, how many? How are they located?

Can you see any branches? Where are they given off?

Find on the ventral body wall small glands, threadlike and coiled. How many? These are organs of excretion. To what organ in man do they correspond?

They open by tiny pores on the ventral surface, a pair to each segment.

Trace the nerve cord forward to the anterior region. It connects by means of the circular collar with the cerebral ganglion.

Make a diagram of the nervous system and mark its parts.

THE LEECH

(Optional)

In what respects does its form resemble that of the earthworm? How do they differ?

What adaptations to its environment and mode of life can you find?

Look for five pairs of eyes and locate them.

Locate and describe the mouth.

Locate the anus.

THE SANDWORM (NEREIS)

(Optional)

Compare with the earthworm.

How can you distinguish anterior from posterior? Dorsal from ventral?

Look for eyes. How many and how located?

What is the arrangement of the appendages? Does every segment bear a pair? They are called **parapodia**.

Cut off and examine one with a lens. The larger fleshy portion is a **gill**; the tuft of hairlike bristles are **setæ**.

Which is the dorsal part of the parapodium?

The sandworm has tentacles and palpi. How many pairs of each? Locate them.

Slit open the eight anterior segments and find the large proboscis, which is capable of being reversed and protruded.

Find a pair of jaws. Is the sandworm herbivorous or carnivorous?

Advanced Work. Topics suggested for further study and discussion:

Life history of the earthworm and its economic importance.

Flatworms: Planarians and tapeworm.

Roundworms: vinegar eel, trichina, Gordius.

Rotifers.

Parasitism and degeneration.

THE FRESH-WATER MUSSEL

The Shell.

How many pieces has the shell? Each is called a **valve,** and the animal is a **bivalve.**

Note the leathery elastic ligament joining the valves at the hinge.

Identify **lines of growth** marking successive additions to the shell. The point around which they center is called the **beak,** or umbo. This points toward the **anterior margin.**

The animal moves by means of a fleshy lobe, the **foot,** thrust out of the anterior margin. Is the hinge dorsal or ventral?

Note the **epidermis** covering the shell and giving its color. If this is removed, what substance is exposed?

The composition of the shell? Test a piece in dilute HCl, for twenty-four hours. Does anything remain? If so, of what character? What substance was dissolved by the acid?

Roast a shell in a bed of hot coals and break in halves from ventral to dorsal margin. Examine the layers of which it was composed. How arranged?

Draw the exterior of the right valve with the dorsal side up and mark beak, hinge, dorsal and ventral margins, and lines of growth.

Examine the interior of the shell. Note the pearly **nacre** lining it. Is its color the same in all shells?

Examine the prominences near the hinge, the **teeth.** Their use? What two kinds? Position of each? Are they alike in both valves? Of what use?

Identify two scars near the teeth, the anterior and posterior **adductor muscle scars.** Each marks the attachment of a muscle which joins the valves. Of what use is this?

What would open the shell?

Note the pallial line parallel with the edge of the shell. Where does it begin and where does it end?

Draw the interior of the right valve and mark teeth, muscle scars, and pallial line.

The Live Mussel.

Put about three inches of sand in a tub or aquarium and cover with three inches of water. When this is clear, drop gently into it several mussels and note carefully the position of each. At the end of twenty-four hours observe their positions.

If the shells have opened, look for any protruding parts. Locate and describe each.

When a mussel is lying with shell slightly open and hinge up, is anterior or posterior end more exposed?

Can you see two elliptical openings? These are **siphons.**

Diminish the water till it barely covers the siphons, and watch the surface of the water for currents. Can you see any?

With a dropper gently introduce a little coloring matter close to the siphons and determine the currents.

Use sugar solution and then vinegar. What happens? What do you conclude from this?

If a mussel can be seen moving, study the action of the foot and the position of the shell. Is the movement regular?

Internal Organs.

Examine animals whose shells have been opened. What muscles were cut in order to open them?

Note the body covering, or **mantle**. Each half is a **lobe** or **leaflet**. Note its loose edge. What relation to the pallial line?

Note the siphons. Where located? How formed? How bordered?

Through which does water enter? This is called the **incurrent** siphon; the other is the **excurrent**.

Identify the foot. Where located?

Back of this, between the mantle lobes, observe the **gills**. Where located? How many leaflets? Describe their appearance.

With a knife scrape a gill gently, and mount the cells thus removed for examination with h. p. Observe the vibrating cilia which cover the surface of the gills.

In front of the gills find the triangular labial **palpi**.

Lift the mantle lobe and see that the two inner gills unite to inclose a channel leading into the excurrent siphon.

Look for the mouth opening below and behind the anterior adductor muscle. What surrounds it?

What sort of food must the mussel take? How does it reach the mouth?

THE OYSTER

Compare the oyster shell with that of the river mussel. Which is **equivalved** and which **unequivalved?** Identify lines of growth, beak, hinge, and right and left valves.

Is the ligament external or internal? How does it work?

Is the hinge on a long or short edge of the valve? Does it differ in any other respects?

Examine the interior. Can you see any teeth? Can you explain why the oyster and mussel shells differ in this respect?

The black spot is an adductor muscle scar. Why does the

oyster need but one adductor muscle, while the river mussel has two?

Is there any pallial line?

Examine an oyster whose shell has just been opened, and identify mantle lobes and gills.

Is there any foot?

Are siphons present?

What differences in the habits and environment of the mussel and the oyster will account for differences between the animals and between their shells?

Draw exterior and interior of right valve.

THE SNAIL

The Shell.

Why called **univalve?** Identify the point or **apex.** The turns are called **whorls.** How arranged?

The joint between the whorls is the **suture.**

How are the lines of growth arranged in relation to it?

The opening is the mouth, or **aperture**; and the free edge, the lip, or **peristome.** Is it thin, thickened, or reflected?

Look for teeth, prominences either on the body whorl or on the peristome. How many and where located? Can you think of any possible use?

Determine whether the shell is **dextral** or **sinistral** by holding with apex up and aperture towards you. If the peristome is to the right, the shell is dextral; if to the left, sinistral.

The central point of the under side is the **umbilicus.** Is it open or closed?

Compare several species of shell. In what respects do they differ?

Make drawings of the shell as seen from above, from below, and from the side, and mark all features shown.

The Live Snail.

Examine one that is crawling.

All that part of the body used for locomotion is called the **foot.**

Locate the **head**, **mouth**, and **tentacles**. How many tentacles?

Examine with a lens. Upon which pair are the **eyes?**

Touch the eye. What happens? Is its sight acute? How can you tell?

Put the snail on a piece of glass and from below watch its crawling. Describe its movement.

Does it ever crawl backwards?

Is it attached closely to the shell?

Try feeding snails with various kinds of green stuffs such as lettuce or cabbage, and also moistened bread and cake crumbs.

How does it use its tongue? Has it a sense of taste?

Test also for smell. Is that developed?

Look near the peristome for a breathing pore. Does it open and close with any regularity?

Examine a *slug*. In what respects does it resemble and in what differ from the snail?

Why are river mussels, clams, oysters, snails, and slugs, classed together as Mollusks?

Why are the first three in one Class and snails and slugs in another?

Why are the mussel and oyster placed in different Orders?

Advanced Work. Topics suggested for further study and discussion:

The squid, cuttlefish, octopus, argonaut, and nautilus.

The economic importance of mollusks.

Fossil forms.

THE GRASSHOPPER

Alcoholic Specimen.

What is its general shape?

How does its form differ from that of the crawfish, and of what advantage to each animal is the build of its own body?

Describe its coloring. Of what advantage?

Describe the body covering. It consists of chitin.

Compare with the crust of the crawfish. What advantages to each animal in the character of the covering, or what disadvantages would they suffer if the skeletons were exchanged?

Of what three great regions does the body consist?

Which two are more distinctly separated than in the crawfish?

Which parts of the body show segmentation distinctly?

The Head.

What shape? Is there any neck?

In what direction does the head move most freely and what advantage is gained by this movement?

Note the antennæ. Are they segmented?

Note a pair of eyes. Examine with a lens. Are they simple or compound?

Find three small simple eyes — the **ocelli**. Locate them in relation to other parts.

Draw a front and a side view of the head, showing these parts, and designate them.

The Thorax.

Identify three segments: **prothorax**, **mesothorax**, and **metathorax**.

What paired appendages on each?

What is the shape of the prothorax?

Examine the outer wings. To which segment are they fastened? What is their resting position?

Why is the order to which the grasshopper belongs called "straight-winged" (*Orthoptera*)?

Spread the outer wings and examine the inner or hinder pair. How folded when at rest?

Compare the fore and hind wings as to shape, size, and thickness. Note the veins in the hind wings. Where heaviest? How arranged?

Are the wings fastened to the body nearer to the dorsal or the ventral side? Why?

What is the function of the fore wing? A wing used for protection is called an **elytron**.

What is the use of the hind wing? To what segment fastened?

How are strength, lightness, and size secured together?

Why is it more necessary to a grasshopper to have a wing that will fold than it would be to a butterfly?

Draw a fore and a hind wing fully spread and put in the principal veins.

Examine the legs. What position has each pair in relation to the body?

Compare the size.

Of what advantage to have the hinder pair so different in structure and position from the others?

Observe three principal parts of a leg: the **femur**, or upper; the **tibia**, or middle; and the **tarsus**, or foot. Which is the heaviest?

Examine the tarsus with a lens and observe its jointed structure.

Can you suggest uses for hooks and pads? For the spines on the hind tibia?

Draw a dorsal view of the grasshopper with the wings folded; a side view to show the legs.

Remove the legs on the right side and draw each.

The Abdomen.

Of how many segments does it consist? (The first and last are incomplete.)

At the end of the abdomen of the female look for two pairs of wedge-shaped organs which form an **ovipositor**, or egg placer.

Look on the sides of the abdomen for holes called **spiracles**. How many on each segment?

Look for a pair on the metathorax and one below the hinder edge of the prothorax. Does every segment have them?

How many in all?

These openings are breathing pores.

They communicate with tubes called **tracheæ**, which send branches all through the body and carry air even into the legs and wings. They also fill and empty air sacs.

Examine a slide showing a spiracle of some insect. How is the opening guarded? How is dust sifted out?

Examine a slide showing tracheæ.

In order that oxygen and carbon dioxide may be exchanged through their walls, what must be their character?

How is strength secured?

Could you drown a grasshopper by immersing its head in water?

Look on the first segment of the abdomen for **ear sacs**.

Draw a side view of the abdomen to show these parts.
Examine the mouth parts. The upper lip is the **labrum**; the lower, the **labium**. Describe each as to shape and position.
Are the lips movable? What is their function?
The jointed appendages of the labium are **palpi**.
Remove labium and labrum and draw (× 5).
Examine the inner surface of the labrum for taste cups.
Examine the **mandibles**, or jaws. Describe them.
In what direction does the mouth open between them?
Observe the **maxillæ**. Their appendages are also palpi.
What is the function of the jaws? Is the mouth adapted to liquid food?
Draw mandibles and maxillæ (× 5).

The Live Insect. (Field work)

Where should you look for grasshoppers? Do they prefer woods or field?
Try to catch one. Does it escape by flying or jumping?
How many times its own length can it jump?
Can a grasshopper hear? Give reasons for thinking as you do. The sound which it makes is produced by rubbing parts of the body together.
Capture a grasshopper and put it, with some leaves on which it can feed, in a jar or box, covering that closely with netting. What is the position of each pair of legs when at rest? Try feeding it various vegetable foods, such as lettuce, cabbage, and slices of apple and potato. Has it a sense of taste?
Watch it while it is eating to see the movements and use of the different mouth parts.
What is the color of the fluid in the mouth?
What other use has this besides digestion?

Test for a sense of smell. How can you do this? What must be guarded against?

Test the sense of touch. What parts are most sensitive?

Watch the abdomen for movements. These are concerned in respiration.

Find specimens whose wings are small or undeveloped. These are the young.

Like the crawfish, the grasshopper molts or sheds its skeleton. Why? In what other respects does the grasshopper resemble a crawfish?

How do they differ?

Why are they classed in the same branch but in different classes?

Advanced Work. Topics for further study and discussion:

Reproduction.

Locust scourge and migration; methods suggested for extermination; work of government in Agricultural Department.

Locusts as food.

Other members of the order.

THE CECROPIA MOTH

(Optional)

Identify head, thorax, and abdomen.

Compare the general shape with that of the grasshopper.

Has the thorax the same number of segments and appendages as the thorax of the grasshopper?

Compare fore and hind wing with those of the grasshopper.

What difference in the use of each in the two insects?

What difference in their resting positions?

Examine the legs. Has each a femur, tibia, and tarsus?

Are the legs as well developed as in the grasshopper? What differences in use will account for differences in development?

Examine a bit of wing under l. p. Note the **scales**. How arranged? How attached?

Draw a bit of wing to show this.

Scrape off a few scales and examine with h. p. Draw to show the shape.

Examine a bit of wing from which the scales have been removed. What is its character?

Compare the antennæ of the moth with those of the grasshopper.

Compare the antennæ of several Cecropia moths. Are they all relatively as large and feathery? Those of a male are larger in proportion than those of a female. Identify male and female by the antennæ.

Compare the main divisions of the body in the two sexes as to size and shape. How do they differ?

Note the size and position of the eyes and compare with those of the grasshopper.

Examine the mouth parts. The coiled **sucking tube** consists of modified maxillæ, which, being grooved on their opposed surfaces, form a channel for the nectar which is the food of this moth.

The short feathery **labial palpi** are close to the sucking tube.

Since a moth takes only liquid food, will it need a crop and gizzard?

Draw a dorsal view of a moth and indicate whether it is male or female.

METAMORPHOSIS OF CECROPIA

(Optional)

Examine a moth's egg. If Cecropia eggs are not to be had, the egg of the imported silkworm will do. Describe its color, size, and shape. What is its covering? What sort of an animal is hatched from the egg? This is called the **larva**.

Examine a good-sized active larva. Is there a distinct head? Are antennæ present?

Identify labrum, labium, mandibles, and maxillæ. How used?

What is the food of a larva? Compare the character and amount of food taken in a day by the larva with that taken by the **imago** or winged form.

Has the larva a distinct thorax? How many segments has the thorax? What marks them?

How many other pairs of legs has the larva? Where located? These are called **prolegs** to distinguish them from the true or thoracic legs. Can you discover any differences between them?

Count the segments of the abdomen. Is the number invariable?

Look for spiracles. How many and where?

Draw a side view of a full-grown larva.

Watch a larva that is beginning to spin its cocoon. Of what material?

It is formed by the hardening of a secretion from glands. Where does the secretion seem to come from?

How is the cocoon held in place?

Examine a Cecropia cocoon. What is its shape? How was it securely suspended?

What is the character of the covering?

If the moth has emerged, from which end did it escape? Compare the size of the opening with the size of the moth's body.

Could a moth bite its way out of the cocoon?

It has been found that when the moth is ready to emerge from its cocoon a small amount of strong alkali is ejected from its mouth, which cuts the silken threads and allows the insect to escape.

Draw a cocoon.

Examine one that has been cut open. Of how many layers composed? How does the inner differ from the outer?

The stage of the insect within the cocoon is called the **pupa.**

Examine a Cecropia pupa. What color?

What is the character of the skeleton?

Can you distinguish head, thorax, and abdomen?

Examine the pupa skin. Can you see signs of wings? Antennæ? Sucking tube?

Can you find spiracles?

Draw dorsal and side views of the pupa.

What are the stages in the life of a moth? The series of changes from stage to stage constitute what is known as the **metamorphosis** of the insect; and when the stages are clearly defined, the metamorphosis is said to be **complete.** Is it complete or incomplete in the grasshopper? In the Cecropia moth?

THE BUTTERFLY

(Optional)

Examine a butterfly. How does it differ from a moth in relative size and shape of parts? In antennæ?

If a live butterfly can be found, try feeding it with sirup or honey. To do this, hold it with the wings pressed together between the fingers of the left hand.

With a needle uncoil the sucking tube, dip its end in the sirup, and watch the insect feed.

Set it free in a breeding cage or screened room. What is the resting position of the wings?

Examine the larval or caterpillar stage of a butterfly. Does it differ in any essential particulars from that of the moth?

Examine the pupal stage. This is called the **chrysalis**.

Is it protected by a cocoon? How suspended?

Has a butterfly a complete metamorphosis?

THE HAWK MOTH

(Optional)

In the same way examine and compare the stages in the metamorphosis of a hawk or sphinx moth with those of Cecropia.

In what respects do all three resemble the grasshopper?

These resemblances constitute the **general characteristics** of **Insecta**.

In what respects do moths and butterflies resemble each other and differ from the grasshopper?

These points constitute the characteristics of the Order **Lepidoptera**, to which all butterflies and moths belong.

OTHER WINGED INSECTS

Examine a number of typical insects, and compare them in respect to the following points:

a. Relative size, shape, and attachment of head, thorax, and abdomen.

b. Character of fore and hind wings, and position during flight and when resting.

c. Character and size of antennæ.

d. Development of legs and foot.

e. Sting or ovipositor.
f. Character and use of mouth parts as adapted for biting, piercing, sucking, etc.
g. Character of larva and adaptation to its environment.
h. Character of pupa. Active or quiet? Protection?
i. Metamorphosis. Complete or incomplete?

THE SPIDER

(Optional)

Compare with grasshopper and crawfish as to the great divisions of the body.
How many pairs of legs? Where located?
Are antennæ present? Compound eyes?
How many simple eyes and how located?
Examine the mouth parts. Can you see the **fangs**, by means of which the spider pierces and poisons his victim?
Can you find the long **pedipalps** which act as antennæ?
Examine the end of the abdomen for the **spinnerets.** Shape? Number? Location?
The silk is a secretion from numerous glands whose tubular openings are upon the spinnerets.
Are young spiders very different from the parent?
Does the spider have any metamorphosis?

THE CENTIPED

(Optional)

Can you distinguish any head?
Are the thorax and abdomen distinct? How many pairs of legs and how arranged?
Are there compound eyes? Simple? Antennæ?
What mouth parts? Is the food of the centiped solid or liquid?

This insect has a pair of poison glands which open on the fore feet.

In what external respects do the spider and centiped resemble other insects?

Internally they are all much alike in breathing and digestive organs, circulation, and the nervous system.

In what important respects do the three Classes differ? Why are they classed with the crawfish in the Branch Arthropoda?

Advanced Work. Topics suggested for investigation and discussion:

Insects injurious to vegetation and methods recommended for their extermination.

Beneficial insects. Cross-pollination by insects.

Protective resemblance. Mimicry.

Parasitism.

Social organization.

THE FROG

A Vertebrate Type

External Features.

Examine a live animal. What is the general shape of the body?

Is there any neck? Any external division of the trunk into thorax and abdomen?

Describe the texture of the body covering. Is it moist or dry?

Describe the coloring. How does it differ on dorsal and ventral surfaces? Can you think of any advantages in each case?

Put a frog in the dark for a couple of hours, keeping another exposed to the light for the same period. Is the color affected by light? If so, how, and of what advantage to the animal?

The Head.

Of what shape? Locate and describe the mouth opening. Are there any lips?

Look for **nostrils.** What is the character of the opening?

Examine the **eyes.** Describe them as to size and position. What is the shape of the **pupil**? The color of the **iris**?

Touch one with the finger. What happens? What advantage in this?

How does the upper eyelid differ in structure and movement from the lower? The latter is a **nictitating membrane.**

Behind the eye find the **drum membrane** of the **ear.**

The Trunk and Limbs.

Describe the position and shape of the backbone when the frog is quiet.

Compare fore and hind leg as to length. As to the length of the foot and the number and arrangement of the toes or **digits.**

When the frog is at rest what is the position of the **knee** joint? of the **elbow**? of the **ankle**? of the **wrist**?

Compare these with the position of the same joints in your own limbs when they are flexed.

Is there any advantage to the frog in having its joints flexed when resting?

Watch a frog jump. How is the leap accomplished?

Put one in an aquarium and watch it swim. In what ways is the body adapted for this?

What resemblances are there between the frog, the dog, and man in the general plan of the body, the body covering, the limbs, and the number and location of the sense organs? What kind of symmetry do all three possess?

Respiration.

Study the breathing of a frog, watching the nostrils, throat, and chest. Compare the movements concerned in the frog's respiration with those of your own. How do they differ?

What two successive stages in a frog's inspiration? How does each seem to be accomplished?

Prop the frog's mouth open. Can these breathing movements take place?

Special Senses.

Test the frog's special senses. Has it keen sight? Hearing? Smell? Touch? Taste? Give reasons for your answers.

Internal Features.

Kill a frog with ether or chloroform.[1] Open its mouth and examine the interior.

Notice the **tongue.** What shape? Where attached? In what position does it lie when not in use? How is it used? What assists it in catching prey?

Look for bristlelike **teeth.** Are they on both **jaws**? Are there any others? If so, where?

Open and close the jaws. Do both articulate with the **skull** by movable joints?

Look for the internal openings of the nostrils. Probe to find the passages. Locate them.

Cut the drum membrane and probe the passage from the ear-cavity to the mouth. This is the **Eustachian tube.** Locate its inner opening.

The rear part of the mouth constitutes the **pharynx.** In the floor of this, below the tip of the tongue, find the slitlike **glottis** through which air is forced into the **trachea,** or windpipe.

Notice the connection of the pharynx with the **esophagus.**

Dissection.

Place the frog in a dissecting pan, ventral side up. Stretch the legs fully, and secure with pins through fore and hind feet.

Cut the skin along the entire median ventral line, and make a second cut at right angles to this across its center.

Is the skin closely applied to the flesh? Can you push it away to expose the muscular wall beneath?

[1] If the circulation of the blood in the webbing of the frog's foot was not examined in connection with the introductory studies in physiology, it should be done before killing the frog. (See page 41.)

Look for a dark vein on the median line, and cut through the body just to one side of this, being careful not to cut any of the internal organs.

Continue this incision forward to the breastbone. Cut through the breastbone, also keeping a little to one side.

Stretch the fore limbs to increase the width of the opening.

Cut across the abdominal walls, at right angles to the former incision, and pin out the flaps.

Keep the body covered with clear water.

Abdominal Organs.

Notice first the dark several-lobed **liver.**

Lift its lower border and find the spherical **gall bladder,** connecting with the liver, and storing its secretion, the bile. Trace the **bile duct** to its union with the **intestine.**

Push the liver aside and look for the **stomach.**

By means of a tube inserted through the esophagus, blow into it and inflate it. Locate and describe it.

What part of the alimentary canal follows the stomach? What opening between? (See page 26.)

How is the **intestine** arranged? What is its shape? Its relative length and width?

Notice the division into small and large intestine. Why is each so called?

The enlargement close to the anus is the **cloaca.**

Examine the membrane which holds the intestines, the **mesentery.** Move the organs about gently and discover how and where this is attached.

What advantages are gained by this arrangement of the intestines in the mesentery?

In the first turn of the intestine in the folds of the mesentery find the **pancreas.** Describe it. Its secretion is called pancreatic juice. Where is it emptied?

Look also for the **spleen**, a dark body in the mesentery near the large intestine. Is it connected with the intestine? Describe it.

Look on each side of the cloaca for a flat reddish **kidney** and a duct from each leading to a bilobed **urinary bladder** at the posterior end of the body cavity. What is the function of the kidney?

Near each kidney in the male frog is the whitish or yellowish **spermary**. What shape?

In the female the pair of lobed **ovaries** are similarly placed, but when distended by eggs they are very large and crowd the other organs.

The **oviducts** are long convoluted whitish tubes which connect with the cloaca at one end and by a funnel-shaped opening with the body cavity above the stomach.

Draw all the abdominal organs ($\times$ 2).

Lungs and Heart.

Insert a tube into the glottis and inflate the **lungs**. Where are they? What is their character?

While they are still inflated, tie a thread tightly around the base of each, cut them away, and allow them to dry. Then cut them open and examine their internal structure.

Find, above and between the lobes of the liver, the **heart**. What color? Shape? In which direction does the apex point?

The membranous sac which incloses it is the **pericardium**. What is its character?

In a freshly killed frog the heart may still be beating. Time its pulsation.

When the beating has ceased, warm it with the breath. What happens?

Prick with the forceps. Does it beat?

Look for blood vessels connecting with it. The firmer ones are arteries, the soft, flabby ones are veins. What is meant by an artery? A vein?

Remove the heart and examine its interior. The two upper cavities are **auricles**, the thicker-walled lower one is the **ventricle**.

How are auricles separated?

What sort of opening between auricles and ventricle? How guarded?

Look for a large vessel, the **arterial bulb**, arising from the ventricle.

Circulation. (Optional)

Examine a frog whose arteries have been injected. Into how many branches does the arterial bulb divide just above the heart?

Trace one of these to its division into three branches. The anterior or **carotid** artery sends two branches to the head.

The posterior or **pulmonary** divides into two branches which supply the lungs and skin.

The large middle artery, or **aorta**, curves to the dorsal region, and the right and left aortic arches unite in the middle line of the back to form a single dorsal aorta, which runs to the posterior along the median line, giving off branches to the various organs of the trunk, and then divides into two arteries, one to each leg.

Find the median ventral vein which was seen in the body wall, and trace backward to see where branches enter it returning blood from the legs. How did the blood get from the arteries into the veins? What exchanges took place during the course of this circulation?

Trace the median ventral vein forward to where, leaving the body wall, it descends to send branches to the lobes of the liver.

Lift the organs that cover the kidney and find a vein coming from the posterior end of the trunk and dividing into branches which enter the kidney.

Find another set of veins coming from the kidneys and the various digestive organs and meeting in one large vein which runs to the liver. This is the **portal vein.** Draining the blood from stomach and intestines, what must it contain that was absorbed in those organs?

In the liver this blood runs through the capillaries there and comes in contact with the liver cells, which work several changes in it.

What three vessels send blood to the liver? Which brings a fresh supply of O? Which a large supply of digested food? Which CO_2 and other impurities?

Lifting the liver, find a vein running from it towards the heart.

Lift the heart and look for two large veins bringing blood from the head and forward regions. These unite with the vein from the liver in the **venous sinus,** which empties into the right auricle.

The blood from the capillaries of the lungs and skin is collected in **pulmonary veins,** which return it to the left auricle.

Through which auricle does blood containing the larger amount of O flow? Through which that containing more CO_2?

Nervous System.

A. **Spinal nerves.** Removing the abdominal organs, examine the interior of the dorsal wall for paired nerves lying against it. Where do they originate?

A union of several nerves forms a **plexus.** How many plexuses can you see?

The posterior is the **sciatic plexus**, forming the sciatic nerve. What part of the body does it supply?

The anterior plexus is the **brachial**. What part is supplied by it?

B. **Sympathetic system.** Find if possible a delicate nerve cord lying close to the spinal column on one side, but ventral to it.

Observe that this is slightly swollen at intervals into ganglia, from which are given off branches to the internal organs and also to the spinal nerves on that side.

Find a similar cord on the opposite side. Observe that the ganglia of the two cords are connected.

This double chain of ganglia, with connecting nerves, is known as the **sympathetic system**, and largely controls the secretions and the work of the vital organs.

C. **The brain and cranial nerves.** Turn the animal over and slit the skin along the entire median dorsal line. With a sharp knife carefully remove the top of the skull, and identify:

(1) The two **hemispheres** of the **cerebrum**, elongated and white bodies in the anterior region of the brain.

(2) **Olfactory lobes**, running forward one on each side of the hemispheres. In these the nerves of smell originate. What shape?

(3) **Optic lobes**, behind the hemispheres. Shape? Relative size? Find the **optic nerve**, connecting a lobe with an eye.

Does the right lobe send its nerve to the right eye?

(4) The **cerebellum**, an unpaired and very small median dorsal division.

(5) The **medulla oblongata**, extending backward from beneath the optic lobes and continuing in the **spinal cord.**

Cutting away the backbone that covers it, trace the spinal cord backward to its termination. What shape?

The brain, spinal cord, and connecting nerves constitute the **cerebro-spinal system.**

Draw the brain and spinal cord as seen from above, and mark the parts.

(Optional)

D. **Spinal cord.** Examine with lens a slide showing a stained cross section of the spinal cord. (That of the human body or of any vertebrate animal will do.) Observe dorsal and ventral grooves, or **fissures.** Into what parts do they nearly divide the cord?

Note the darker "**gray matter.**" What letter does it resemble?

Examine with h. p. What microscopic structures does it contain?

Look at the surrounding "**white matter.**" This consists of nerve fibers.

Find the roots of a pair of spinal nerves.

To what does the division of the nervous system into halves correspond?

Draw the cross section of the cord as seen under the lens.

The Eye. (Optional)

Notice the **cornea,** the glassy membrane over the front.

Examine the **sclerotic coat** over the back. What color?

Note also the colored muscular **iris,** with its central opening, the **pupil.**

Look for the dark **choroid coat** lining the eye, and for the **crystalline lens** which focuses the light.

What is the nerve of sight? Its ending in the eye is called the **retina.** On this the image is impressed.

Voluntary Muscles. (Optional)

Skin one of the hind legs and study the arrangement of the muscles. What is the thick fleshy part of the muscle called? (See page 44.)

What fastens it to bone?

What covers it?

Pull apart the muscles on the upper leg or thigh and find the sciatic nerve. With scissors cut this as close to the trunk as possible. What happens?

Examine the muscle of the calf of the leg. Where is its origin? Its insertion?

The tendon of this end is the **Achilles tendon.**

Mount a bit of muscle on a slide and examine with l. p. and then h. p. Is it striated?

The Skeleton. (Optional)

Examine a skeleton that has been carefully cleaned. (Mounted skeletons may be purchased of supply companies, but one may be cleaned by cutting away all soft tissues with sharp scissors. Be careful not to cut the joints. While you are working, keep the specimen wet with water in which is a little alcohol. When the skeleton is clean, place it upon a dark card, bending the limbs into resting position. Prop with pieces of cork any parts which need supporting. Glue or sew the specimen to the cardboard.)

Note the **axial** skeleton, consisting of the **skull** and **vertebral column**; and the **appendicular**, consisting of **shoulder** and **pelvic** girdles or arches and the attached limbs.

Study the skull. Is the lower jaw directly attached to the **cranium?** Is there any other movable bone in the head?

What is the character of the bones of the cranium?

Examine the backbone, or **spinal column.**

The long piece at the end is the **urostyle**.

How many **vertebræ** are there? Note their **lateral processes.** Are any ribs attached?

Note the medial dorsal **spine**, and the **articular processes,** joining the vertebræ.

Examine a single separate vertebra. Is the solid part, or **centrum**, dorsal or ventral to the spinal canal?

The shoulder girdle consists of the shoulder blades, or **scapulas**; the **clavicles**, or collar bones; the **coracoids**; and the **sternum**, or breastbone.

Which pairs are attached to the sternum? The lower of these is the coracoid. Is the girdle fastened to the spinal column?

Identify in the shoulder girdle some cartilaginous regions. Where are they?

Locate the pelvic girdle. Of how many pieces composed?

What makes the frog humpbacked?

Compare shoulder and pelvic girdles. In what respect do they resemble each other, and how differ? Are they homologous?

Examine the fore limb. The bones in order of position are:

a. the upper bone, or **humerus**;

b. the united **radius** and **ulna**, between elbow and wrist, the radius being on the thumb side;

c. the **carpals**, or wrist bones;

d. the **metacarpals,** or hand bones;

e. the **phalanges**. How many of each?

Examine the hind limb. It consists of:—

a. the upper bone, the **femur**;

b. the united **tibia** and **fibula**;

c. the **tarsals**;

d. the **metatarsals**;

e. the **phalanges.**

Compare hand and foot as to number and arrangement of phalanges.

Are fore and hind limbs homologous? How can you account for their differences?

Why has a frog's hind limb so much freer motion than the fore limb?

Embryo and Tadpole.

If freshly laid eggs are to be found, place some in each of several large jars of water with some water plants, and set in as many different conditions of light and heat as possible.

What is the color of the eggs? How are they held together and protected?

Examine from day to day and draw as many stages of the embryo as you can discover with low power or lens, shading your drawings to show the difference between the dark and light regions. Date each drawing.

Does a difference in conditions affect the rapidity of the development?

When the tadpoles appear, watch their growth in the same way, sketching the various stages in their metamorphosis and dating the sketches.

Are they active at first? How supported?

When they begin to move about, do they come to the surface of the water for air?

How do they breathe?

Examine an external gill with the lens and microscope. What is its structure?

How many pairs of gills? When these disappear, can the tadpole leave the water?

It then breathes by internal gills. How does water reach and leave them?

Watch tadpoles feeding. Do they use animal or vegetable food?

What changes take place in head and tail during metamorphosis?

Which pair of limbs develops first?

When the hind legs have appeared, dissect a tadpole and compare mouth and internal organs with those of the adult frog.

When both limbs appear, does the young frog spend all the time in the water? How can you arrange an aquarium to ascertain?

What advantages accrue to the frog from being able to adapt itself to a change of environment?

Advanced Work. Topics suggested for further study and discussion:

(1) Examination of external features of toad, treetoad, salamander, and other Batrachians, and comparison with the frog and with each other.

(2) Identification of the tadpole stage of each, and comparison of their metamorphoses.

(3) Hibernation of Batrachians.

(4) General characteristics of the Class.

THE FISH (PERCH OR ALLIED FORM)

What is the shape of the body? How adapted for motion in the water? Compressed or depressed?

The locomotive organs are **fins**. How many pairs?

Those homologous to the fore limbs are **pectoral**. Locate them.

The other pair are called **ventral** or **pelvic**. Why?

How many unpaired fins? The one on the back is the **dorsal**; the one on the median ventral line, the **anal**.

The tail fin is the **caudal**. Is it bilobed? If so, are the lobes equal (**homocercal**) or unequal (**heterocercal**)?

Study the structure of the fins. They consist of **rays**, some of which are supported by bony spines and some by cartilage. How many layers of skin are between them?

Examine the different fins and determine which rays are bony and which soft.

The Head.

Examine the mouth. In which direction is the opening? Does it resemble frog or crawfish in this respect?

Open the mouth and note the movements of the jaws. How different from those of the frog?

Are teeth present? If so, where and of what character? How do they point?

Examine the tongue. Describe its size, shape, attachment, and surface.

Note the shape and position of the eyes. Are eyelids present?

Compare the eyeball with that of the frog. Of what movements is it capable?

Examine the nostrils. How many? Do they open into the mouth? (Use a blunt probe to determine this.)

What is their only function? What two functions exercised by the frog's nostrils?

Can you find any external ear?

Look on each side of the head for the gill cover, the **operculum**.

Raise this and examine the gills. Find the **bony arch** supporting the **gill fringes**, and the **gill raker** on the anterior of the arch.

Thrust a scalpel in the mouth and depress the tongue. How does this affect the gills? The gill rakers?

Between the gills are **gill clefts** which communicate with the mouth.

How many gills? Arches? Clefts? Rakers?

How does water reach and escape from the gills? How can you determine this in a live fish?

Why does a fish lie with head upstream?

Describe the body covering. How are the **scales** arranged? The skin covering them is the **epidermis.**

Is the **pigment** which gives color to the body covering in the scales or in the epidermis?

Find a **lateral line** running along the side of the body. What forms it?

The Live Fish.

Which fins are most used in swimming? In rising and sinking? This may be determined by binding down first the pectoral and then the ventral fins to see what difference it makes in the movements.

Bind both pairs. Of what use are dorsal and anal fins?

Can a fish swim backward?

Can it remain stationary without moving the fins?

Have fishes any special resting places or positions?

What special senses are developed in the fish? Which are keenest? How can you find out?

Can a fish live out of water? Explain.

Internal Organs.

Examine a fish that has been dissected, to find the **air bladder.** Is this homologous or analogous to the lungs of higher animals? Can you suggest its use?

Compare the other internal organs of a fish with those of a frog.

How many auricles has the heart?

Is the circulation single or double?
The artery leaving the ventricle goes to the gills. Does the heart pump arterial or venous blood?
Are the digestive organs as well developed as in the frog?
Compare the brain with that of the frog.

Advanced Work. Suggestions for further study and discussion:
Examination of dogfish as to shape of body, snout, tail, and fins; structure and position of latter; body covering; mouth parts; and arrangements of the gills.
Food fishes and their economic importance.
Artificial propagation.
General characteristics of the Class.

THE SNAKE

A Reptile

(A small live garter snake preferred)

What shape? Can you distinguish head? Neck? Thorax? Abdomen? Tail?
Are any limbs visible?
How does a snake move? By means of what?
What body covering and how arranged?
What color? Is there any advantage in the coloring?
Is there any difference in size and shape between the scales on dorsal and ventral surfaces? Between the ventral scales on the body proper and those on the tail?
Are the scales closely applied to the body? Are they covered with epidermis?
Locate the eyes. Are there any eyelids? Have the eyes any movement?
Are external ears present? Are nostrils?

Can you see any breathing movements? If so, describe them.
Are the nostrils of use in breathing?
Is the sight keen?
Is hearing? Is smell?
What sort of food does a snake eat? Does it eat often?
Describe the tongue and its use.
Chloroform a snake. Open the mouth.
Are the jaws closely hinged to the skull?
Why can the snake swallow relatively large objects whole?
Are teeth present? If so where are they and how do they point?
Are they adapted for mastication? Of what use?
With forceps draw out the tongue. Describe its arrangement.
Find the glottis and the opening to the esophagus.
The internal organs are more elongated than those of the frog, and only one lung is developed. Can you suggest a reason?
The heart is much like that of the frog. What cavities has it?
Examine a shed snake skin. Has it any color or markings? How is the skin pulled off?
Draw a dorsal view of the snake's head and a part of its body.
Draw a ventral view of the same.

Advanced Work. Topics for reading and discussion:
Venomous snakes.
The cobra.
The boa constrictor.
Reproduction of the snake.

THE LIZARD

A Reptile

In what respects does the lizard resemble the snake? In what general features do they differ?

Compare the limbs with those of the frog in relative length, arrangement of joints, number of toes, and any other features in which they differ.

Examine the scales on dorsal and ventral surfaces and compare with those of the snake.

Locate the eyes. Are eyelids present?

Are there any nictitating membranes? External ears?

If a live lizard is studied, observe and describe the movements of legs and tail.

Are lizards easily captured?

If the tail is lost, does it grow again?

Advanced Work. Topics for further study and discussion:

The horned toad.

The heloderma, a poisonous lizard.

Reproduction of the lizard.

THE TURTLE

A Reptile

(A live animal preferred)

The body covering is what? The upper part is called the **carapace**; the lower, the **plastron**. How united?

Observe the plates marking the shell.

Describe the coloring.

In the box turtle the plastron is divided by a hinge. Of what use?

Are any scales on head and neck?
Examine the head. What kind of jaws? Are teeth present? Is there a tongue?
Examine the eyes. Are eyelids present? Are nictitating membranes?
Is there any external ear?
Is sight keen? Hearing? Smell?
Are there any nostrils? If so, where?
Can you see any breathing movements? What animal does it resemble in this respect?
Study the legs. How many toes on fore and hind feet?
Is there a tail?
Does a turtle walk or crawl?
Compare turtle, snake, and lizard in external features. Why are all three classed together as reptiles? The internal relationships are greater than the external.

Advanced Work. Topics for further study and discussion:
Alligators and crocodiles.
Reproduction of reptiles.

THE BIRD

(A pigeon or game bird and a number of prepared skins of other species)

What are the divisions of a bird's body? Is any neck present?
What limbs are developed?
What body covering?
How is the shape of the trunk adapted for flight?

The Head.

What range of motion has it?
Describe the jaws. The two divisions of the bill, or beak, are the upper and lower **mandibles**.

Open the mouth. Are both mandibles movable?
Pull down the lower. Is it directly attached to the cranium? Is the gape very wide?
Is the beak relatively long or short? Stout or slender? Blunt or sharp?
Is it hooked? Conical? Do the corners of the mouth turn down?
Are there any bristles at the angles?
To what is the build of the beak adapted? Explain.
Are there any teeth? Is a tongue present?
Locate the nostrils. How protected?
Are eyelids present? Nictitating membranes? Of what use are the latter when present?
Look for the ears. Locate and describe. How protected?

The Wings.

Are they attached to dorsal or ventral side of the body? What advantage in this?
Make out three sets of feathers:
a. the **primaries**, or **pinion** feathers, located upon the hand;
b. the **secondaries**, upon the forearm;
c. the wing **coverts**, at the base of primaries and secondaries and covering the bend of the wing.
With what joint in the human arm is the bend of the wing homologous?
Where is the elbow?
Is the humerus free moving?

The Tail.

Does any part of the bony skeleton extend into the tail? How supported?
How are the feathers arranged? Is the tail forked, blunt, or wedge-shaped?

Of what use?

The feathers on the body proper are **contour** feathers. Do they cover every part?

Lift and examine their attachment. To what fastened? How?

Measure the bird from the tip of the beak to the tip of the tail. Next measure the wing from the bend to the tip, and the tail from its attachment to its tip.

Compare these measurements in several specimens. What is the average length of the bird? Of its wing? Of the tail?

Describe the color of the plumage.

The Foot.

How many toes and how arranged?

Compare the length of the hind toe with the longest of the others.

Is the fourth toe capable of being turned so that the arrangement may be 2–2 or 3–1, according to use? If so, this toe is said to be **versatile**. What advantage would this give?

Is the foot adapted for perching, scratching, swimming, climbing, or tearing prey? Explain.

The **tarsus**, or foot, of the bird consists of a single piece, a consolidation of tarsal and metatarsal bones.

Does the bird place the tarsus on the ground?

Where is the heel? Knee?

Is the femur free?

What covers the tarsus? Is the covering a network (**reticulate**), covered with a few overlapping scales (**scutellate**), or without distinct divisions (**booted**)?

Is it rounded behind or terminating in a sharp ridge?

These peculiarities of beak, feet, wings, and tail, of color

and markings, and of length of the body, legs, neck, wings, and tail, serve to distinguish different Orders, Families, Genera, and species of birds.

Pinion Feathers.

Identify **quill**, **shaft**, **barbs**, and **barbules**.

Barbs and barbules together constitute the **vane**.

Examine barbules with l. p. How are the barbs held together? Why?

Compare one of the small, soft feathers, called **down**, with the pinion feather.

Compare a **pin feather** from the breast.

In what respect do they differ?

Of what use are feathers? What purpose do they serve better than do the scales of fish and reptiles?

The Egg.

(Fresh hens' eggs will serve the purpose of this study.)

What general shape? What outside covering?

Place an egg on the table and then in water. Which end is higher in each case?

Place the egg in a pan of water so it cannot roll; mark the highest point, and boil hard.

Break the shell and put a bit in acid. Of what composed? Examine the lining. What is its character?

Does the egg completely fill the shell? Where is the air space?

Break the shell at this place. Is the membrane single or double?

Cut the egg lengthwise, as nearly as possible in halves. What surrounds the yolk? Is it of uniform thickness?

How is the yolk located?

Prop another egg in water with the small end up, and boil

hard. Compare the position of the yolk with that in the first egg.

What is the position of the yolk in an egg in the nest?

Break a raw egg carefully so as to divide the shell into two cups.

Drain off as much of the white as possible without breaking the yolk.

Keeping the yolk in one half of the shell, look for a light, eyelike spot. If not seen at once, turn the yolk into the other half of the shell.

This spot is the **germinal disk**, in which segmentation takes place to form the embryo.

Towards which end of the egg does it lie?

The remainder of the egg is absorbed as nourishment by the developing embryo. What kind of foodstuff is the white?

Test the yolk for fat. Does it contain any?

What conditions are necessary to the hatching of the egg?

What advantage in having the germinal disk near the upper side as the egg lies in the nest?

What advantage in the air space?

Advanced Work. Topics suggested for further study and discussion:

Protection of birds by law { *a.* song birds. *b.* game birds.

Their economic importance.

Migration.

Nesting.

Introduced birds.

Characteristics of birds; characteristics of principal Orders.

A MAMMAL

(The rabbit, squirrel, rat, mouse, cat, or dog, or any other small four-footed animal will do.)

The Body Covering.

Of what does it consist?
Describe the coloring. Is it advantageous? If so, how?
Is all the hair alike? If not, on what parts is it longest?
Describe and locate the different kinds.
Where is the skin bare?

The Head.

Locate the eyes.
Examine the pupil. What shape when relaxed? When contracted?
Describe the eyelids. Is any nictitating membrane present? If so, how well is it developed?
What additional protection has the eye, which is not present in any lower form?
What part of the ear is developed that is not in the lower animals? Can you see the drum membrane?
Locate and describe the nostrils.
Are the lips peculiar? If so, how?
Open the mouth and examine the teeth, consisting of:
a. the **incisors**, or chisel-like teeth;
b. the sharp single-pointed **canines**, used for tearing food;
c. the **premolars** or **bicuspids**, usually with two cutting points;
d. the **molars**, with broad roughened or ridged surfaces for grinding.
Are all sets present in your specimen?
How many of each set?
How are the teeth adapted to the food of the animal?

Of what movements is the lower jaw capable?

Examine the tongue. How and where attached? Of what composed?

What difference between the surface in anterior and posterior regions?

Look on the sides towards the back for an area containing taste buds. Examine with a lens. What is the shape of a bud?

The Limbs.

How many toes on each foot?

Compare the claws on hind and fore foot. For what purposes used?

Are the feet padded?

Compare fore and hind limbs as to length.

Are they better adapted for running or for leaping?

The Tail.

What is its relative length as compared with the body? With the tails of other animals? Of what use?

The Breathing.

What movements are concerned in breathing? Is the air swallowed? If not, how is it drawn in and how expelled?

Compare the rat, deer, cat, bat, and horse as to body covering, development of limbs and feet, mouth and teeth, other defensive organs, and reproduction.

Why should they be classed together as mammals?

Compare the cat, lion, dog, and wolf. Why are they all classed among Carnivora?

Why are the cat and lion in one family, while the dog and wolf are in another?

What characteristics are possessed in common by the fish, frog, snake, lizard, turtle, bird, mammal?

VERTEBRATE SKELETONS

Compare the skeletons of the foregoing animals and man as to the following points :

The Spinal Column.

Number of vertebræ and shape of each ?

Is the centrum concave or convex on its anterior surface ? On the posterior ?

Are neck, dorsal, lumbar, and tail vertebræ all present ? If so, how do they differ from one another ?

Are any of them very peculiar ? If so, how ?

Are any fused together ?

What advantages gained by these adaptations ?

Are any other bones found in the spine ? If so, how many and where ?

How many ribs and how attached dorsally ?

Is there a sternum ? Is it flat or keeled ? Are ribs attached to it ? If so, how many and how ?

The Skull.

Are both jaws movable ?

Is the lower jaw directly attached to the cranium, or is there an extra bone, the **quadrate**, intervening ?

Is any other skull bone movable ?

Examine the cranium. The irregular fixed joints are called **sutures**. Are they apparent ?

Notice the opening through which the spinal cord joins the brain. The bone which surrounds this is the **occipital**.

Prominences on this which rest on the first vertebra are called **condyles**. Do you find one or two ?

What kind of movement will this joint give ?

Notice the shape of the cranium. How is it related to the development of the parts of the brain ?

The Shoulder Girdle.

How many and which bones are developed? How and where attached? What kind of a joint with the humerus?

How do the hip bones differ in different animals? What kind of a joint with the femur?

The Fore Limb.

Are ulna and radius separate bones or are they partly united?

Locate radius and ulna in your own right arm.

Stretch the arm out before you with the palm of the hand up. Grasp the elbow firmly with the left hand and turn your right palm down. How is this accomplished?

Bend the elbow, with the hand first in one position and then in the other.

Repeat these movements with the bones of hand and arm of the human skeleton. Is the fore limb in any other animal that you have studied capable of this variety of movement?

The Hind Limb.

Compare with homologous parts of the human leg.

Can the sole of the foot be turned up or forward? Explain.

Compare with the limbs of other animals.

Explain the advantages in the adaptations in each case.

Hand and Foot.

Compare the homologous bones in the human hand and foot, including wrist and ankle. How do they differ?

What difference in freedom of movement between thumb and great toe?

What animal can you think of whose hind feet are somewhat like the human hand? Of what advantage?

How many carpals, metacarpals, and phalanges, are developed on the fore limb?