OUTLINES OF
GENERAL BIOLOGY

AN INTRODUCTORY LABORATORY MANUAL

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PREFACE TO THE FOURTH EDITION.

In preparing the present edition little change has been made; such errors as have been brought to notice have been corrected, and some changes have been made in the interest of greater clearness or more precise directions.

The ideal underlying the manual is, as it always has been, to stimulate inquiry and develop the scientific habit of work and thought. The order of presentation remains unchanged, for both from practical and pedagogical reasons such an arrangement has justified itself through years of experience. The order of presentation of topics is, however, of secondary importance, and the individual teacher will make such choice of topics and order of study as best meets his needs.

An elementary course in biology must of necessity be limited to relatively few typical organisms, but the aim of the manual is distinctly not the study of types as such. In our own course the laboratory study is planned to illustrate general biological principles such as the following: fundamental plans of animal structure; homology; adaptation; protoplasmic structure and behavior; development of organisms; and other similar principles. In conducting such a course it is necessary to make definite plans ahead of time, and select from the manual those topics which cover the desired ground. It is believed that there is sufficient material included to make possible a considerable choice to meet varied needs and desires.

It is still a pleasure to acknowledge the cordial coöperation among other members of the zoölogical staff in such suggestions as their several experiences and observations have prompted. Should others who use the book feel disposed to offer suggestions touching either the matter or the method of the manual they may be assured of the cordial thanks of the authors.

C. W. H.
G. T. H.

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GENERAL BIOLOGY.

INTRODUCTION

Laboratory and Apparatus

In order to get the best results in a laboratory course there should be cordial coöperation between students and instructors. The laboratory should be orderly and attractive, and its schedule regarded with the same promptness and fidelity as that of the classroom. Certain apparatus is assigned to each student who must be responsible for it during use. Notebooks, dissecting instruments, pencils, and the laboratory manual, are to be furnished by each student. Each is expected to do his work independently, faithfully, and to have his own outfit which should be kept in the best possible condition for effective use.

Ample laboratory material is furnished for the work required, but it should be used with reasonable economy. This relates to reagents as well as specimens. Let there be particular care in the handling of models or museum specimens placed upon the demonstration table. These are not to be removed from this table without express permission. The same applies to demonstration materials and dissections.

At the close of the laboratory period, which may be extended to students desirous of doing extra work, let the tables be cleared up, the instruments, dissecting pans and the like put in the proper places, all solid waste deposited in receptacles for that purpose, and only water or liquid waste thrown into the sinks.

Notes and Drawings

Experience has shown that it is necessary to make accurate drawings and to write a definite and careful description of an animal if one is to secure a satisfactory knowledge of it. The drawings should be made (on one side only) on unruled heavy paper, or cardboard, with a drawing pencil (about 3H); the notes, written on separate sheets, should accompany the drawings.

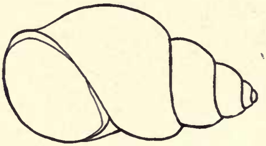

FIG. 1.

Figs. 1 to 3 are from drawings which are correct in form, accurate in structure, and satisfactory from a scientific point of view. The drawings made to accompany the work of this course should be in outline like the figures, since shading tends to obscure rather than clarify the details of structure. The drawings shown in the figures demonstrate the clearness with which details are shown, even when the structure is rather complex. However, it is sometimes desirable to represent the texture of a part and a shaded drawing will occasionally be necessary. Fig. 4 is a drawing of a group of cells characterized by thick walls of rather definite appearance and structure. One side of the drawing is in outline and shows clearly the shape and arrangement of the cells and the thickness of their walls. The

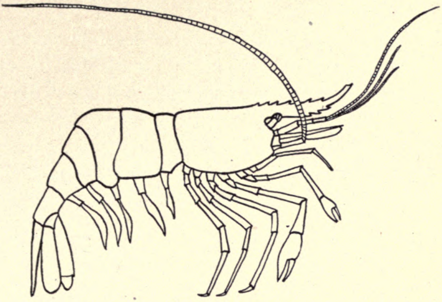

FIG. 2.

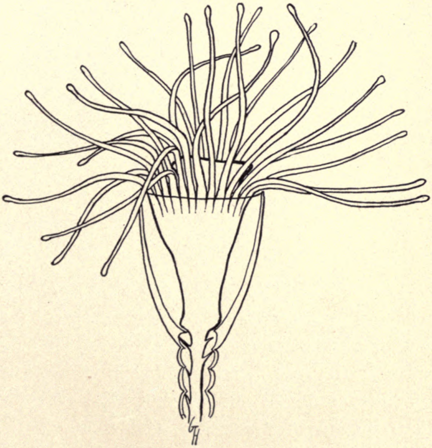

FIG. 3.

shaded portion illustrates the further detail of a certain structure in the walls. Fig. 5, a cell in the process of division, is shaded in a manner which will bring out the details of cellular structure.

The following suggestion may be helpful: Make the drawings large, leave considerable space between them and have them symmetrically arranged on the page. In start-

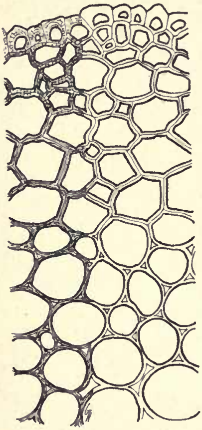

FIG. 4.

FIG. 5.

ing a drawing make all lines very faint, and when the form, proportions and arrangement of parts is satisfactory go over the lines with a smooth continuous stroke, producing a line of the desired strength. The drawing must represent the actual specimen studied, should show the real structure rather than the mere appearance, and should be finished in the laboratory while the specimen is under observation.

Give each preparation careful study before starting a drawing.

The directions for laboratory study are merely suggestions with regard to methods and order of work; the **specimen** is the thing being studied. Do not be afraid to do some things, or to make some drawings not asked for in the outlines, if you can thereby get a clearer idea of the structure or add further to your knowledge of the animal. Most of the questions asked in the outlines can be answered from the specimen if the search is made, but if help is necessary call upon the instructor for aid.

Always give a clear and definite title to each drawing, indicating what aspect of the specimen is shown; also clearly name the parts shown in the drawing. Write labels parallel to the bottom of the page and connect to the part desired by faint continuous lines (these are better than dotted lines). The title of the drawing should be followed by an indication of the scale of the drawing, *e. g.* x $\frac{1}{2}$ means one-half the natural size, x 5 means five times natural size.

Dissection

The object of dissection is to separate the various organs or parts in such a way as to show their form and relation to each other. It consists largely in removing the connective tissue which holds the parts together.

Fix the specimen firmly in a position that will be convenient for work, usually with the head away from you. If pins are used stick them obliquely into the wax of the dissecting pan. Large specimens should be moistened from time to time to keep from drying, and small animals should be dissected under water.

Before starting a dissection study the specimen carefully and note where the cut may be made to expose the part wanted with the least injury to the surrounding parts. Do not grasp nerves or bloodvessels with the forceps, but hold the tissue at one side of them. Do not allow scraps to accumulate on the specimen; with a pipette wash away the dêbris which gathers on the specimen under water, and change the water frequently.

Instruments must be kept clean and sharp to accomplish the best results, therefore do not use scissors or scalpel to cut hard objects and do not allow the instruments to become rusty.

Clean and dry the instruments, after using, and smear them with a little oil or vaseline.

The scissors are used almost exclusively when cutting is to be done. Each blade of the scissors holds the object for the other blade, whereas the scalpel tends to push out of the way the object to be cut, and also often leads to the cutting of underlying tissues that should not be injured. While cutting with one hand, whether with the scissors or scalpel, always use the forceps in the other to steady the object and to hold the edge of the cut.

The Microscope

Since the compound microscope is the instrument most indispensable to the biological student some knowledge of its construction and manipulation should precede its immediate application to the work in which it is used. The following study of its parts and their relations may therefore be made in the order indicated.

1. **Parts.** (*a*) The **base**, a heavy support bearing (*b*) the **column** to which is fastened (*c*) the **stage**, a horizontal support for objects to be examined. In the center of the stage

is an opening for the passage of light by which an object is to be illuminated. It is provided with **clips** for firmly holding the object in position during its study. Situated just under the lower side of the stage is a mechanism, (*d*) the **diaphragm**, for regulating the amount of light admitted to the object. Note that these diaphragms may be of different types, mere disks to be inserted in the stage, or a circular disk to be rotated, or a shutter-like device known as the iris diaphragm. (*e*) Attached to a movable arm under the stage is the **mirror** by which light is reflected through the object and lens to the eye of the observer. Note that it is double, having on one side a plane, and on the other a concave surface; the latter serves to concentrate more light upon the object, and should be used chiefly with the high power lenses.

Above the stage is (*f*) the **tube** supported on the **arm** of the microscope. The tube is a means of attaching the optical parts, *i. e.*, the **lenses**, of which there are several; those at the upper end being called the **oculars** or eye-pieces since they relate directly to the eye of the observer; those attached to the lower end known as the **objectives**, since they relate to the object under observation. The wheel-like parts working on the side of the arm, and a similar smaller one at the top or side, have to do with **focusing** to be explained later.

2. **Adjustments.**—These refer to the matter of so relating the mirror, the object to be studied, the lenses employed, the amount of light admitted, that clear and distinct images are afforded. First in the process is that of light, and practice will be required in order to learn its importance. This will involve testing the effects of both plane and concave mirrors, the use of the diaphragm in regulating the amount of light, and finally that adjustment of the lenses

known as focusing. In the last of these operations will be involved learning the uses of the so-called **coarse** and **fine adjustments,** the former effected by means of the rack motion produced by the large milled heads at the side of the arm, and the second by means of the small milled head at the top or side. Try out all these operations in a general way and finally under the directions of the next section.

3. **Focusing.**—The object to be examined must be thin, since the light must pass through it. The object is placed on a glass slide, with a drop of water or other liquid, and covered with a thin glass cover. Place the slide on the stage with the object directly over the center of the opening. Move the low power objective rather close to the slide and, while looking into the eyepiece, turn the coarse adjustment so as to raise the tube until the object comes into view, now using the fine adjustment focus carefully until the image is perfectly sharp.

The high power, when in focus, is so close to the cover glass that great care must be used in adjusting it or it may be injured. Turn the nose piece slowly to bring this objective into position, taking care to see that it does not touch the cover glass. If it swings into position without striking, a slight movement of the fine adjustment will usually bring the image into sharp focus. If the high power cannot be swung into position the same process of focusing must be used as for the low power. **Always focus upward,** since to do the contrary may result in the lens striking the slide to the injury of both the slide and the lens.

Practice these points patiently and with care until every phase is clearly understood and easily managed. This practice in manipulation will be time well spent, since later work will thereby be done easily and skilfully.

4. **Use and Care of the Microscope.**—Having learned the parts and adjustments of the instrument practice their use until they become familiar. This is especially important in the adjustments relating to light. Test manipulation of mirrors and diaphragms until able to obtain and control just the amount and quality of light essential to the best effects, doing so with eye constantly at the ocular. The best light is that of the open sky (not sunlight direct) or that reflected from bright clouds. Artificial light may be used provided a screen of some sort be interposed, such as a bluish, or ground glass. Begin every study with the low power, nothing is gained by using a higher power than serves the end in view.

To avoid eye fatigue while using the microscope practice looking with both eyes open, which after a little practice is not especially difficult. If not easily acquired, an artificial shade or screen may be used as may be explained by the instructor.

Proper care of the microscope is important if its efficiency is to be at its best. Keep every part clean, do not allow water, or dirt, or chemicals, to remain in contact with any of its parts. This is especially important for the lenses. Do not touch the lenses with the naked finger, and if they should appear dirty cleanse with lens paper furnished by the laboratory. This may be facilitated by breathing on the lens and then gently wiping dry.

Never attempt to take lenses apart.

THE FROG.

Rana Sp.

Frogs may be had at various times of the year, and are easily kept in proper aquaria, so arranged that the animals have range from water to dry or rocky support, provided care is taken to guard against serious contamination of tank or water. They may be secured in late summer or fall, or even in spring, though in New York State there is now a closed season in the spring as for other game animals. In addition to living specimens kept during the year there should also be an ample supply of preserved material for the needs of classes. If specimens are to be injected for study of the blood system this must be done immediately after killing preparatory to preservation.

In the neighborhood of larger cities frogs may often be secured through fish markets, provided attention is given to the subject in ample time, and often at prices much lower than those charged by professional supply departments.

I. External Characters.

What is the shape of the body as a whole? Are dorsal and ventral surfaces well marked? How? Note the division of the animal into head, trunk, and limbs. Is there a neck and tail? What is the character of the skin? In the living animal is the skin moist or dry, warm or cold? Are there scales or other protective structures in the skin?

1. **Head.**—Note its triangular shape. Observe the following parts: **mouth, nostrils, eyes, ear-drum** or **tympanic mem-**

brane. Do the eyes have lids? How many? Which moves in the living frog? Draw the head from the side.

2. **Trunk.**—Note the shape and the differences in the dorsal and ventral sides.

3. **Limbs.**—Note the number and arrangement. In the **hand.** How many **digits** or fingers? The hind limb is fore limbs the following divisions occur: **arm, forearm,** divided into **thigh, leg,** and **foot.** How many digits? How is the leg adapted for swimming? Compare with the fore limb in length and number of digits. Draw both fore and hind leg.

4. **External Apertures.**—Note the position, shape and size of the following: **mouth, anus, nostrils.**

II. Mouth Cavity.

Open the mouth to its full extent, cutting the corners of the jaw if necessary. Are there lips? Is there a **tongue?** What is its shape, size and mode of attachment? Where are the **teeth** found? Teeth on the jaw bones are called **maxillary** teeth, those on the roof of the mouth are **vomerine** teeth. Pass a bristle through the outer nostrils and observe the inner or **posterior nostrils.** Where are they found? Pierce the tympanic membrane and pass a blunt probe into the ear; in the mouth cavity the place where the probe appears is the opening of the **Eustachian tube.**

In the posterior floor of the mouth just at the end of the tongue is a slit, the **glottis,** opening into the **trachea** and **lungs.** Its margin is stiff and cartilaginous, and the opening is closed except when air is passing. The **esophagus** lies dorsal to the glottis. Compare with the latter.

Make a drawing of the mouth cavity, showing all the points referred to.

III. Internal Anatomy.

Fasten the frog in the dissecting pan on its back, and slit the skin the entire length of the body in the median line. Is the skin loosely or closely attached to the body? The spaces that are found beneath the skin are **lymph spaces.** Laying back the skin observe the walls of the abdomen, made up of muscles. Determine the points of attachment of these muscles. In what directions do the fibers of the muscles extend on the ventral wall, and on the side wall? The ventral muscles are the **straight abdominal,** and those of the side walls are the **oblique abdominal muscles.** Also observe the group of **pectoral** or breast muscles in the region of the arm. Is this one muscle or a group of muscles? What is the probable function of these muscles?

Draw the ventral surface of the frog, showing the muscles just studied. If time permits, the muscles of one of the hind legs may be studied and a drawing made.

Cut through the body wall, taking care not to injure the organs lying beneath. Notice that the internal organs lie in a large cavity, the body cavity or **cœlom.** Pin back the flaps and observe the following organs which are exposed:

1. **Heart.**—In the median line beneath the pectoral girdle. It has two thin-walled **auricles** and a thicker-walled **ventricle,** the whole being enclosed in a delicate sac, the **pericardium.** If the heart is beating record the order of the pulsations of the different chambers. From the ventricle a large vessel, the **truncus arteriosus,** extends obliquely forward over the auricles. On the dorsal side of the heart is a thin, triangular sac, the **sinus venosus,** into which the blood comes before entering the heart. Does the sinus communicate with the auricles or the ventricle?

Make drawings of the heart to show these points.

2. **Liver.**—A large, dark red mass, dorsal to the heart. What is its size and shape? Of how many lobes is it composed? Between the lobes is the **bile sac**, or gall bladder. The **cystic ducts** are tubes which lead from the liver to the bile sac and the **bile duct** extends from the bile sac through the **pancreas** to the digestive tube, which it enters about half an inch posterior to the stomach. Turn the liver forward and trace the bile duct to its opening into the intestine.

Make a drawing of this region.

(If the specimen is a female take up, at this point, the study of the reproductive organs. Having shown their position, size and structure in a drawing, remove them and study further the other organs of the body cavity.)

3. **Lungs.**—Two thin-walled sacs dorsal to the liver and at the sides of the esophagus. Note the texture of the walls and the character of the lining. The lungs may be expanded by blowing air into them.

4. **Stomach.**—Note the shape, size and position. How is the stomach held in place? Slit the stomach longitudinally, and determine the character of its walls and its lining.

5. **Intestine.**—Is it straight or coiled? How is it held in position? Compare the walls with those of the stomach. Near the posterior end note an enlargement, the **large intestine.**

6. **Pancreas.**—A pale mass lying in the loop made by stomach and intestine. Show its position in the drawing made of the liver.

7. **Spleen.**—A small round body lying in the posterior part of the body. Does it appear to be joined to, or connected with any other organ?

8. **Bladder.**—A thin walled sac in the extreme posterior part of the body cavity. What is its shape? With what organs does it communicate?

Make a drawing to show the organs so far studied.

9. **Ovaries.**—Found in the female and composed of masses of eggs, their size depending upon the maturity of the animal, and the time of year. If the ovaries are mature they may almost completely fill the body cavity crowding all the other organs that are in the cavity. If the animal is immature the small ovaries will be found near the dorsal part of the body cavity hidden by the digestive organs. Long convoluted tubes along the dorsal wall of the body cavity are the **oviducts.** Anteriorly these are held in place against the esophagus, and open into the cœlom by a funnel-shaped mouth. Near the posterior end each oviduct enlarges to form a sort of bladder, called the **uterus.**

Fastened near the anterior end of the ovaries are slender yellowish **fat bodies.**

10. **Testes.**—These organs, the male reproductive organs, are oval yellowish bodies near the dorsal body wall. Usually connected to them are slender yellowish **fat bodies.** Ducts from the testes pass into the kidneys and communicate with the urinary duct or **ureter.** The ureter, therefore, functions as a common **urino-genital** duct. Rudiments of oviducts may occasionally be present along the sides of the kidneys.

11. **Kidneys.**—To study the kidneys and their ducts, remove the muscle and a portion of the bony **pelvic girdle** which lie ventral to the intestine and cloaca. Place the animal under water and displace the other organs to expose the **kidneys,** a pair of elongated reddish organs situated close to the vertebral column. A small tube, the **ureter,** extends from the posterior end of each kidney to the cloaca. On the ventral side of each kidney is a narrow yellowish line, the **adrenal body,** a gland whose secretion is poured into the blood.

12. **Cloaca.**—The cloaca is a continuation of the large intestine, and opens to the outside on the dorsal side of the animal. Expose the cloaca and note the connection of the bladder, ureters, and oviducts with it.

A diagrammatic drawing made from the side will show the relations of these ducts to each other and to the cloaca; or a drawing on a large scale, from the ventral side will be satisfactory if some parts are slightly displaced.

Observe the **peritoneum**, a pigmented membrane which lines the cœlom. This also covers the organs, and makes up the **mesenteries** which hold the various organs in position.

IV. Circulatory System.

This system must be worked out from specimens whose vessels have been filled with a colored injection mass. Such an injection expands the bloodvessels and causes them to stand out clearly from surrounding tissues and organs. If an injected animal is not used only a few of the larger vessels will be found, and these can be followed for only a short distance

1. **Heart.**—Observe again the shape and position of the heart, and the chambers of which it is composed.

2. **Arteries.**—Leading from the ventricle is a single large artery, the **truncus arteriosus**, which divides into two parts, one passing to the right, and the other to the left. Each of these subdivides into three arteries called the **aortic arches.** The most anterior of these is the **carotid arch,** which supplies blood to the head. Following this is the **systemic arch** which, with its branches, carries blood to the trunk and appendages. The most posterior of the three arches is the **pulmo-cutaneous** which conducts blood from the heart to the lungs and skin.

From each of these large vessels arise a number of smaller arteries; their origin should be determined, and their distribution carefully followed.

A. Carotid Arch. This arch divides into two arteries:

(*a*) **External carotid** or lingual which supplies blood to the tongue and muscles of the lower jaw.

(*b*) **Internal carotid,** which passes around the lower jaw to the roof of the mouth, the orbit of the eye, and the brain.

At the junction of these two arteries is a swelling, the **carotid gland.**

B. Pulmo-cutaneous Arch. This, the posterior of the three arches, divides into two arteries:

(*a*) The **pulmonary** extends to the lungs, in which it divides into several smaller vessels.

(*b*) The **cutaneous** extends anteriorly to the shoulder where it passes dorsally, and, emerging behind the ear, is distributed over the skin of the back and side.

C. The middle arch, the **systemic,** extends dorsally, passes around the esophagus, and the two sides of the arch unite into a single vessel, the **dorsal aorta,** which proceeds posteriorly along the spinal column. From each side of the arch several arteries arise.

(*a*) The **subclavian,** a large artery which goes to the shoulder, will easily be found; it continues into the arm where it is called the **brachial.**

(*b*) The **occipito-vertebral** arises just anterior to the subclavian, passes dorsally through the body wall and divides into two arteries. Branches from this artery may extend into the esophagus.

(*c*) **Laryngeal.**—Along the systemic arch between the occipito-vertebral artery and the heart is a small artery, the **laryngeal,** which goes to the trachea and larynx.

(*d*) **Esophageal.**—This artery arises from the systemic arch posterior to the subclavian, about half way between it and the dorsal aorta. As a rule it comes only from the arch of the left side.

(*e*) **Dorsal Aorta.**—If the stomach is pulled aside this artery will be found along the spinal column; it is formed by the union of the systemic arches of the right and left sides.

Branching from the dorsal aorta are:

(I) **Cœliaco-mesenteric.**—This large artery extending to stomach, intestine, pancreas, liver, and spleen comes from the dorsal aorta just posterior to the union of the two sides of the systemic arch; but the blood is derived almost entirely from the left side of the arch. The **cœliac** artery supplies the stomach, the **mesenteric** the intestine, the **splenic** the spleen.

(II) **Urino-genital** and **lumbar** arteries arise from the ventral side of the dorsal aorta in pairs, and extend to the kidneys, reproductive organs, fat bodies, and dorsal body wall.

(III) Near the extreme posterior end of the dorsal aorta a small **posterior mesenteric** artery passes into the rectum.

(*f*) **Common iliac** arteries are formed by the division of the dorsal aorta; they supply blood to the hind legs.

(I) A short distance from its origin each common iliac gives off, on the outer side, one or more **epigastric** arteries which extend to the ventral abdominal wall.

(II) Slightly posterior to the epigastric a small artery, the **recto-vesical,** comes out on the inner side of the iliac and supplies blood to the bladder, cloaca, and pelvic muscles.

(*g*) The **sciatic** artery is the continuation of the iliac artery in the leg. Soon after entering the leg the sciatic gives off a large branch, the **femoral** artery, which supplies blood to the thigh muscles. At the knee the sciatic divides into two chief branches, the **tibial** extending along the front of the leg into the foot, and the **peroneal** which passes along the back of the leg into the calf muscles.

Make a large drawing of the heart and arterial system, carefully showing the origin and distribution of the vessels studied.

3. **Veins.**—While the arteries have been under investigation it will have been noticed that there were other vessels, not injected, running parallel with the arteries. These were some of the larger veins of the body. The veins make up a system for the return of the blood to the heart, but their further study will not be attempted here.

Before leaving the study of the circulatory system one should see the circulation of blood in a living frog. This may easily be done by examining with a microscope the thin web in the foot of an anesthetized animal.

V. Nervous System.

The nervous system consists of three general divisions; the central, composed of the brain and spinal cord; the peripheral, which includes the nerves connecting the central system with sense organs and muscles; the sympathetic, a series of nerves extending to the internal organs.

1. **The Central System.**—Place the frog dorsal side uppermost and slit the skin along the median line from the snout to the anus. Lift up the cut edges and notice the pairs of delicate thread-like nerves which run through the muscles

of the body wall to the skin. Next remove the skin of the body, the roof of the cranial cavity, the muscles of the back, and with sharp pointed scissors cut away the arches of the vertebræ. This will expose the **brain** and **spinal cord** which will be found to be covered with a delicate blackish membrane, the **pia mater.** In addition to this inner covering there is an outer one, the **dura mater,** which lies close to the skull and vertebræ, and has been removed with the bone.

The following parts may now be identified, beginning with the anterior end:

(*a*) **Olfactory Lobes.**—These are at the extreme anterior end of the brain. They are not distinct lobes but are separated by a shallow groove from the rest of the brain. Are the two lobes separate or fused? **Olfactory nerves** pass forward from these lobes to the nostrils.

(*b*) **Cerebral Hemispheres.**—Two large ovoid bodies immediately posterior to the olfactory lobes.

(*c*) **Thalamencephalon,** a narrow, cylindrical portion connecting the cerebral hemispheres with the optic lobes. Upon it, occupying a median position, is a small body, the **pineal gland.**

(*d*) **Optic Lobes,** posterior to the thalamencephalon. What is the size and shape of these parts as compared with the cerebral hemispheres?

(*e*) **The Cerebellum** is a small transverse fold posterior to the optic lobes.

(*f*) **Medulla Oblongata,** following the cerebellum. In it is a triangular cavity, the **fourth ventricle.**

(*g*) **Spinal Cord.**—The medulla tapers gradually into the cord without any sharp demarcation. Is the cord as long as the body? Is it of equal width throughout its length? If not, in what regions is it widest?

A swelling in the region of the arm would constitute a **brachial enlargement**, and one near the legs a **sacral** or **lumbar enlargement**. How does the cord terminate?

Make a large drawing of the brain and spinal cord from the dorsal side. Use care in getting the dimensions and proportions accurate, measuring the parts with a rule if necessary.

Carefully remove the brain and cord from the body, place in a watch glass of water, and construct an accurate drawing of the ventral side of the brain. In addition to the parts already observed the following should be identified:

(*h*) **Optic Chiasma.**—Formed by the crossing of the optic nerves as they leave the optic lobes.

(*i*) **Infundibulum.**—A small shield-shaped body posterior to the optic chiasma.

(*j*) **Pituitary Body.**—This lies in a little pocket of bone in the floor of the skull. It is usually torn from its attachment to the infundibulum when the brain is removed from the cranial cavity.

2. **The Sympathetic System.**—This is best seen by placing the animal ventral side up, moving the viscera to one side and looking for a very delicate thread-like nerve, the **sympathetic nerve**, which runs along one side of the dorsal aorta; a similar nerve is present in the same position on the other side. When these are found the organs of the body and the lower jaw should be removed, but the dorsal aorta left in place. Place the animal under water and lift the dorsal aorta to find the **sympathetic nerves**, their **ganglia** and connections with the spinal nerves. Observe carefully the relation of sympathetic and spinal nerves, the position and number of sympathetic ganglia, and the delicate nerves connecting spinal and sympathetic nerves.

A single drawing should be made to show the sympathetic and peripheral systems.

3. **The Peripheral System.**—This is composed of the nerves which come from the brain and spinal cord; the former are called **cranial nerves,** the later **spinal nerves.** There are ten pairs of cranial nerves, but on account of their close relation to the bone of the skull their origin and distribution will not be worked out. If possible examine a demonstration preparation showing these nerves.

The spinal nerves come out in pairs, and each single nerve arises from the cord by a **dorsal** and a **ventral root.** Since these roots pass through the bone of the vertebral column their origin is difficult to determine, but the spinal nerves themselves may easily be found along the dorsal wall of the body cavity. Determine how many of these nerves there are, and trace their course and distribution. Give especial attention to networks or fusions of nerves called **plexuses:**

(*a*) The **brachial,** in the region of the fore limb. Of how many nerves is the plexus composed? Is the fusion of these nerves complete? Trace a large nerve, the **brachial,** into the arm.

(*b*) The **sciatic** or **lumbar** plexus, is in the posterior part of the body anterior to the place where the legs are attached. Of how many nerves is the plexus composed? What is the nature and the extent of the union? Trace a large nerve, the **sciatic,** into the leg. Follow it in its course through the leg and foot.

Construct a large drawing showing the spinal nerves, and the sympathetic system so far as it has been studied.

VI. Sections of the Body.

Having studied the organs and the parts of the body thoroughly, we should have a good idea of the relations of one part to another. Make a drawing of an ideal cross-section of the body of the frog showing all the organs and parts in their proper relation and proportion.

VII. Microscopic Anatomy. (Histology.)

This involves the study of the tissues and cells of which the various organs are composed. It will be found that there are only a few kinds of fundamental tissues and these are repeated over and over again in the various organs. The relations of shape and position may differ somewhat in different places, but the tissues have the same general appearance and function wherever they are found.

1. **Tissues.**

(*a*) **Blood.**—Mount a drop of the blood of a frog on a slide, and cover with a cover glass. Observe the colorless fluid or **plasma** in which are floating the **corpuscles** or blood cells. How many kinds of cells do you find? Observe their shape, color, relative size, and comparative numbers. Are the cells nucleated? If the slide is placed on a warm stage it may be possible to demonstrate the movement of the white corpuscles. Draw.

(*b*) **Epithelium.**—Epithelial tissues are those which cover the free surfaces of the body or line cavities. The outer skin and the lining of the digestive tube are examples. Epithelium is of different kinds according to the shape, structure and arrangement of the cells.

(I) **Squamous** or **Scaly.**—Examine the epidermis of the frog. What is the form of the cells? Are nuclei present? Do the cells form a layer? Do they overlap at the edges? If possible examine sections made vertically through the entire skin. In these sections only the outer layers of cells make up the epithelium. Draw.

(II) **Columnar.**—Examine prepared slides which show sections through the intestine of the frog. What is the form of the cells lining the cavity? How are they placed? What is the position of the nuclei in the cells? **Goblet cells,** which contain secretions of **mucus**, are often found in the epithelium. Draw.

(III) **Ciliated.**—Examine the cells scraped from the roof of the mouth of a freshly killed frog. Compare the cells with those of squamous and columnar epithelium in all points. In what are they alike? In what different? Can you see the movement of the cilia? Where on the cells are the cilia located? Draw.

(*c*) **Cartilage.**—Examine prepared slides of cartilage, or make a slide of fresh cartilage from the frog. Get a very thin piece and observe the transparent matrix in which are embedded the cartilage cells. Note the shape and the size of the cells and the manner in which they are grouped together. How does the cartilage differ in appearance from the other tissues? Are the cells nucleated? Do you find cells with more than one nucleus? Explain. To what does the matrix correspond in the other tissues? Draw.

(*d*) **Muscle.**

(I) **Striated.**—The striated (voluntary) muscles are those that are under the control of the will. Examine the muscle of the leg of the frog, by teasing it in salt solution. The **fibers** should be well pulled apart. What is the shape of the fibers? Do they tend to separate into smaller **fibrillæ**? Is there anything that suggests the name "striated" muscle? If nuclei are present where in the fiber are they located? Draw.

(II) Smooth or **unstriated muscles.**—These are muscles which are automatic in action, or at least not under conscious control. The muscles of the intestines, the bladder, etc., are examples. A piece of muscle from the stomach when teased should show the fibers. Observe the shape, arrangement, and nuclei of the fibers. Draw.

(*e*) **Nerve Tissue.**

(I) **Fibers.**—Tease the sciatic, or other large nerve, in salt solution. In a single fiber look for a place where it is torn or crushed and identify the delicate sheath on the outside. Inside this is the thicker **medullary sheath.** Making up the center is the axis cylinder, **axone,** or nerve proper. Draw.

(II) **Cells.**—Remove one of the spinal ganglia and tease in a drop of salt solution containing some stain, or study prepared slides showing the nerve cells. Look for large cells and note the relation of the cells to the fibers. Is there a nucleus in the cell? Draw.

2. **Organs.**—Having studied several of the fundamental tissues one should be able to recognize them in organs. In the following study observe what tissues are present and how they are arranged:

(*a*) **Spinal Cord.**—In prepared slides of sections of the spinal cord note the following points: shape, size, surrounding membrane (pia mater), **nerve roots, dorsal fissure, ventral fissure, central canal,** position of the white matter, shape and position of the gray matter. In the **white matter** will be found nerve fibers, connective tissue, bloodvessels and corpuscles. In the **gray matter** the nerve cells will be rather prominent.

Make an outline drawing four inches in diameter showing the relative position and proportion of these parts. Arrange the drawing with the dorsal side of the cord toward the top of the page. Fill in with care some of the details of structure observed.

(*b*) **Stomach.**—With the low power observe the four layers of the wall, as follows, from without inward:

(I) **Serosa** or **Peritoneum.**—(This is very delicate and may be lacking.)

(II) **Muscular coat**, consisting of

(1) an outer **longitudinal** layer. Note the shape of the cells. Do all contain nuclei? How do you account for this?

(2) an inner **circular** layer. What is the shape of the cells? Are nuclei present? What is the relative thickness of the two layers?

(III) **Submucosa.**—Made up chiefly of connective tissue and bloodvessels. Note the general character of the tissue and the staining properties.

(IV) **Mucosa** or **Mucous Membrane.**—This is marked off from the submucosa by a narrow band of muscle cells (the **muscularis mucosæ**). The surface is covered with **columnar epithelium** which dips down to form numerous pits into which the **gastric glands** empty. The glands are surrounded by connective tissue.

Make a drawing three inches in diameter of a segment of the stomach wall as seen under low power.

Under high power study a portion of the mucosa and note the following points: shape of the gastric glands; general character of the epithelium lining the pits, the shape of the cells and the position of the nuclei.

Make a drawing of a gastric pit and of the glands emptying into it, as seen with the high power.

VIII. Embryology.

It will be found necessary to have a complete series of eggs and tadpoles preserved in formalin, especially in large classes. It is also desirable to have the living material at hand when undertaking this study.

1. **The Egg.**—Examine the eggs in a mass, also compare the masses of the toad and other amphibia. How thick is the surrounding jelly? Distinguish in it three layers, with concentric layers in them. What is the color of the egg? The darker side of the egg is the **animal** or **protoplasmic pole,** the side opposite is the **yolk** or **vegetative pole.**

Make a drawing of the egg and its envelopes, also draw each of the following stages as studied.

2. **Early Cleavage Stages.**—What evidence do you find that the egg differs from the ones previously studied? Find one with a single groove surrounding it. In what direction does the groove extend? Are the resulting parts equal? Find an egg with a second groove at right angles to the first. The first one gives the **two-cell** stage, the second one the **four-cell** stage. Are the cells equal in size? The third groove passes in a horizontal or equatorial direction. How many cells result? What is their relative size?

3. **Later Cleavage Stages.**—Study eggs in the **sixteen-cell,** and **thirty two-cell** stages. How are these stages produced from the earlier stages? Are the cells equal in size? Examine both poles of the eggs and explain the differences found. Does the relative size of the pigmented and unpigmented areas remain unchanged in later cleavage stages? How is this to be explained?

4. **Blastopore.**—The pigmented cells divide more rapidly than the white cells and come to grow over the latter; at the same time the pigmented cells become infolded and grow into the egg itself. This continues until but a small mass of white cells can be seen. The term **blastopore** is applied to the opening, and the mass of white cells is spoken of as the **yolk plug**. Later the blastopore closes and the yolk plug is forced inside the egg.

5. **Neural Groove.**—On what is to become the dorsal side of the body will be found an open groove with slightly elevated margins. How far does it extend? Is it open throughout its length? Examine several specimens. What distinguishes the part which is to form the brain from that which will produce the spinal cord? The margins grow together to form a tube and this subsequently develops into the brain and spinal cord. How does the shape of the embryo compare with the earlier stages? In eggs which have elongated, is there any marked difference between dorsal and ventral, anterior and posterior?

6. **Gill Stage.**—In a tadpole just hatched observe the beginning of the formation of **head, body** and **tail.** There is no mouth yet present, but on the ventral side of the head are **suckers** by which the tadpole adheres temporarily to some support. **Nostrils** and **eyes** are beginning to form, and **gill buds** indicate the position of future gills. In a somewhat later stage finger-like **gills** are produced upon the sides of the head. At such a period mouth, eyes, nostrils and tail are well formed, and the internal organs are undergoing their development.

7. **Tadpole.**—Distinguish head, body and tail regions. What has become of the external gills? The fold of skin covering the internal gills is the **operculum** and the opening to the gill chamber is the **spiracle.** On which side is the

spiracle found? At this stage the **eye, mouth, nostrils** and **teeth** are well developed. Also on the ventral surface the **heart, internal gills,** and coiled **intestine** will show through the body wall.

8. **Metamorphosis.**—The tadpole or fish-like stage continues for some time (it may be a year or two in frogs) before a metamorphosis into the adult form begins. This metamorphosis is first shown by the formation of the hind legs. Carefully study a tadpole with the hind legs present and determine the character of sense organs and other external features. The forelegs start their formation within the gill chamber and are not apparent externally until they become rather large, when they break through the skin covering the gills. In a specimen with both fore and hind legs observe the changes in form of the body and head. As the legs increase in size what becomes of the tail?

Dissect the ventral body wall from a large tadpole without legs, and also from one with both pairs of legs present. Determine what changes are taking place in the internal organs during this time. When the tail is finally absorbed and the toad or frog leaves the water, the animals are like adults except for the reproductive organs, which require a considerable time for their perfect development.

ORGANS, TISSUES AND CELLS.

THE term **organism**, as used in biology, designates in general an individual animal or plant, and implies that they are composed of **organs**. For example, the ears, eyes, legs feet, of a dog are familiarly known as organs; and the same is true of such internal structures as stomach and liver. It is perhaps not so well known that organs are likewise complex structures made up of simpler components, and as in general these are composed of a network of similar elements they are usually spoken of as **tissues**. To demonstrate the organic structure of a frog it is only necessary to critically observe its external features, or perhaps dissect and lay open its interior. To demonstrate that **organs** are composed of **tissues** will require the use of the microscope, and in most cases some means of dissecting and preparing them for study. This phase of biology is known as **microscopic anatomy**, or **histology**. Finally, such a study will reveal the fact that a given tissue is composed of still more elemental structures which are called **cells**. The following outline of laboratory study will afford a direct introduction to these phases of our subject.

1. Mount in water a small fragment of frog epidermis, and examine with the high power. Make a careful drawing of a group of cells, showing cell walls, and nuclei.

2. Strip the epidermis from the upper surface of the leaf of Tradescantia, mount in water and examine. Compare the shape, size, and general appearance of the cells with those of the animal epidermis. Make a drawing of a group of cells.

3. With a razor cut very thin transverse and longitudinal

sections of the stem of Tradescantia, of geranium, begonia, or other plants, mount these in water and examine. In the cells near the center of the stem note the shape, arrangement, and cell contents. Look especially for crystals in these cells. The presence of crystals in the cells indicates the presence of what kind of material?

4. Cut very thin sections of a potato tuber just beneath the skin. Mount in water, study and make drawings of the cells and their contents. Remove the cover glass, add a drop of dilute iodine solution and allow it to remain for a few minutes. Wash off the iodine, replace the cover glass and examine the section again. Since the iodine solution has the property of turning starch blue what do you conclude as to the cell contents in this case?

5. Stems of other plants may be sectioned and treated in the same manner, and an idea obtained as to the abundance of starch and its position in the plant. What is the use of this starch? What explanation can you give as to the differing amounts of starch and of the different places of storing it in the plants examined?

6. Examine cartilage from a frog or other animal and make drawings showing the cells and the intercellular substance. Mount a drop of blood from the frog and examine with the high power, draw the various kinds of cells found therein. If possible place this latter slide on a warm stage and note the effect on the white corpuscles. In what ways do these cartilage and blood cells differ from the other cells already studied, and in what ways are they similar? Try especially to determine what represents the cell walls in the cartilage.

7. From the data obtained in the above studies write a careful description of the cell as you understand it. Tell particularly what you have found concerning the cell contents, and their functions.

PROTOPLASM OR LIVING MATTER.

In the preceding study it was found that the cells were of various sizes, shapes, and uses. In some were found such storage stuffs as starch, fats, and mineral substances, in others, and indeed most, might have been noted a more or less homogeneous or granular substance which has come to be known as **protoplasm,** a substance which Professor Huxley aptly called "**the physical basis of life,**" since life is only known to us in association with this physical material. While a great deal of investigation has been devoted to the study of protoplasm, its chemical nature and its physical structure, and while much has been learned along these lines, still that which is as yet unknown is much greater. An elementary course would not be the place to undertake a study of these properties of protoplasm, yet it is not beyond the scope of even such a course to endeavor to observe some of its more obvious **characteristics,** and some of the things which it **does.** It will be interesting to study something of its actual activities, its movements, its behavior under varying conditions of cold or warmth, and to note perhaps certain aspects of its structure. Since such study can only be made with the high power of the microscope it will be necessary to select living things whose structure is such as to render them favorable for observation, *i. e.*, those which are sufficiently transparent to enable one to see through them and note all that takes place within. Certain plant cells are especially favorable subjects, as are also some of the transparent animal organisms, like the common amœba.

The following types, among others also available, afford good material for such study.

I. Protoplasmic Movement.

1. Mount some of the healthy, younger leaves of Elodea in water and with the high power examine their structure. In the cells look for rather large green bodies, the **chlorophyll bodies.** What is their form and how are they arranged in the cells? These bodies float in a liquid, the **protoplasm,** which is so transparent it is exceedingly difficult to see.

Having noticed these features of structure look closely for any signs of movement in the cell contents. The movement is not rapid nor it is continuous, but you should observe it in some of the cells of the young leaves. Make a drawing of several cells, showing the chlorophyll bodies, and by arrows indicate the direction of movement of the protoplasm.

2. Mount a cluster of leaves from the tip of the stem of the stonewort, Chara or Nitella. The younger, more transparent cells in this cluster should show the **circulation of the protoplasm** very clearly. It will be necessary to focus through the outer layer of the protoplasm which contains the chlorophyll bodies, the latter being stationary in this form. Note the direction in which the protoplasm moves, and whether all the cell contents are involved. Make a drawing of the cell as seen with the high power, and indicate by arrows in what direction the protoplasm is moving. It may be possible to see the **nucleus** which is carried along by the currents.

3. In the cultivated spiderwort (Tradescantia) the **streaming of protoplasm** is beautifully shown. If the flower of this plant is available take some of the hairs which are

present around the stamens, mount in water and with the high power observe the protoplasmic movements. Record your observations in a drawing.

4. If amœba is at hand observations should be made on the streaming or flowing movements of the protoplasm.

II. Ciliary Movement.

In certain cells, particularly of animals, the protoplasm is extended beyond the free ends of the cells into very delicate vibratile filaments called **cilia.** Mount a small fragment of the gill of a clam, or the cells scraped from the roof of the frog's mouth, and look for these moving cilia. Possibly the only sign will be in the currents of water caused by the movement of the cilia, the latter moving so rapidly they can scarcely be seen. In a place where the movement is not so rapid observe the direction in which the cilia move and whether they change the direction of movement. Make a drawing.

THE CELL.

Cytology.

The unfertilized egg of the starfish is a good example of a typical cell or egg. Other eggs as those of Cerebratulus, the large jellyfish Aurelia, or tissue cells, if large, may serve equally well.

1. **Form.**—Are the cells alike in shape and size? The shape of a cell, if unconfined, is usually spherical, but in tissues this form is modified by the pressure of adjacent cells, or as a result of adaptations for some particular function.

2. **Structure.**—The essential elements of every cell are cell protoplasm or **cytoplasm,** and **nucleus.** Is there a membrane about the cell? Note the general appearance of the cytoplasm. Is it **granular, fibrillar,** or **alveolar?** Is the cytoplasm alike in all parts? In some eggs spheres or granules of yolk are scattered through the cytoplasm. In what portion of the cell is the nucleus located? Is this position constant? Is there a membrane about the nucleus? What is the character of the contents of the nucleus? If the cell is stained note the granules, or flakes, within the nucleus which stain more densely. These are spoken of as the **chromatin,** the faintly stained, or unstained, material is **achromatin.** Is the chromatin arranged in any definite way as though on a framework? Within the nucleus is often a rather large, deeply, staining spot, the **nucleolus.** Is it in any constant place in the nucleus?

3. **Cell Division.**—This fundamental feature of living things presents two rather distinct and definite aspects, namely,

mitotic, or indirect division, and **amitotic**, or direct. The latter, while apparently simpler, involving the direct division of nucleus and cytoplasm by a simple pinching into two parts, is yet less common than the former, and no attempt will be made to study the process in this connection.

Mitosis.—In sections of the root tip of the onion, or of the testis of the grasshopper, study the cells which are in the process of division. Find a stage in which the chromatin of the nucleus is forming a long tangled thread, or else a series of densely staining bodies. These bodies produced from the chromatin of the nucleus are called **chromosomes.** Find a cell in which the nuclear membrane is disappearing. What is the position of the chromosomes? Do you find a **spindle** made up of delicate fibers to which the chromosomes are attached? In the cells of some organisms there is a tiny spot, the **centrosome,** at the end of the spindle and from this centrosome starlike rays, the **aster,** radiate into the cytoplasm.

Next examine a stage where the chromosomes are grouped into a mass, or plate, at the center of the spindle. At about this stage each chromosome splits into two parts, and the halves separate and are drawn toward the poles of the spindle. In this position the chromosomes lose their distinctness, form a new nucleus with a membrane, the body of the cell divides into two parts and we have the division of the cell completed.

The stage of the formation of the chromosomes and their arrangement in the spindle is called the **prophase** of division; the splitting of the chromosomes makes up the **metaphase**; the separation and the pulling apart of the chromosomes comprises the **anaphase**; the formation of a new nucleus and the division of the cell body is the end or **telophase.**

Make a drawing of a cell in each phase of division.

It should be clearly understood that the nuclear changes described above constitute an uninterrupted process. The separation of the process into distinct phases or stages is made for convenience in description and analysis. The preparations on the slides which show the distinct phases, therefore, represent cells which were killed in the midst of the process, and which were permanently fixed in this condition.

4. **Cleavage and Development.**—In order that an egg may develop and grow into a new organism several preparatory processes are essential. First a ripening or **maturation** process is necessary for both the female reproductive cells (**ova** or **eggs**) and the male reproductive cells (**spermatozoa**). After maturation **fertilization** must occur, and this consists in the union of an ovum and a spermatozoön. The fertilized egg is now capable of further development which is initiated by a division into cells, a process called **cleavage** or segmentation.

In dividing starfish eggs look for stages of **2-, 4-, 8- cells.** Are these cells enclosed within a membrane? Are they of equal size? Each cell continues to divide until a large number are present, and these are arranged in the form of a hollow sphere, the **blastula.** Are all the cells of the blastula of the same size? Look for other stages in which one side of the blastula is flattened or pushed into the hollow of the sphere. Such a stage is spoken of as the **gastrula** and is really a double-walled sac or embryo, the outer wall making up the **ectoderm** and the inner the **entoderm.** Later a middle layer or **mesoderm,** is formed between the ectoderm and the entoderm. These three layers are the **germ layers** of the embryo from which are differentiated the organs of the developing organism.

Study and draw several stages of cleavage, of the blastula and gastrula formation.

In the development of any animal it may be stated that, from the outer germ layer, or ectoderm are formed the covering of the body with its protective structures such as scales, feathers and the like, the nervous system and the sense organs. The entoderm or inner germ layer gives rise to the lining of the digestive tube, the gland cells of liver, pancreas and stomach, the lining of lungs and trachea. From the mesoderm are derived the muscle, bone, connective tissue, blood, heart and bloodvessels, the kidney, reproductive organs and their ducts.

AMŒBA

The Proteus Animalcule.

Amœbæ are among the simplest of living things, they look like tiny drops of clear jelly usually somewhat granular within. The amœba will be almost constantly moving and changing its shape, whence it gets the name of **"proteus" animalcule.** This habit of changing the shape is one of the surest methods of identifying the animal.

Mount on a slide some of the sediment from the dish supposed to contain amœbæ, cover with a cover glass and search for an amœba with the low power. If one is not found wait several minutes and examine again; in this time the amœba may have crawled out from the sediment. When an amœba is found examine with the high power. Be careful not to move the slide enough to lose the animal.

I. Morphology.

1. **Form.**—Note the changing shape, and the root-like prolongations of the body called **pseudopodia.** Are these pseudopodia alike? How many are there? Is the number constant? Can you discover their function? Make a series of 10 outline drawings (each about an inch long) at intervals of two or three minutes. By means of arrows indicate the direction of movement of the protoplasm.

2. **Structure.**—The protoplasm which makes up the substance of the animal is composed of an inner part called the **entoplasm,** and an outer **ectoplasm.** How are they distinguished? May these distinctions be traced into the

pseudopodia? Is the boundary between the two parts a sharp one? Which layer is the more fluid? Is there a definite membrane about the animal?

Within the entoplasm may be seen **food vacuoles** which are usually rather small and spherical, though they may be quite large and of irregular shape, depending upon the kind of food which has been eaten. Do you find what might be considered as lifeless material such as crystals, oil drops, and the like? In the entoplasm may also be found the **contractile vacuole**, a transparent, spherical body which disappears and reappears at intervals. Its function appears to be **excretory.**

Sometimes the **nucleus** can be seen. This is a circular or oval, denser body, usually granular in appearance. Does it occupy a definite and constant position in the amœba? If it cannot be seen in the living animal examine one of the stained and mounted specimens.

Make a drawing about two inches in diameter, fill in, and label all the details mentioned above.

II. Physiology.

1. **Movements.**—Is motion continuous? Regular? How is it produced? Is there any definiteness of direction? Watch the formation of a pseudopodium and describe what part the ectoplasm and entoplasm play in the process. Are the currents in the entoplasm at all constant? Where are they the swiftest, where slowest? Trace on paper the path that an amœba has taken in the time under observation.

2. **Nutrition.**—If opportunity offers determine how an amœba eats, and how it gets rid of waste matter. From an examination of the food vacuoles determine, if possible, what the animal eats. Look especially for **diatoms** and **desmids** and for small **protozoa.** Is there a definite course

of food particles in the body? Where is the food digested? How is it distributed?

3. **Sensation.**—Does the amœba ever appear to **feel** an object against which it presses? Does it avoid obstacles? Tap the cover with a needle, are there indications that the animal has the sense of **touch**? If the slide is placed upon a warm stage it may be possible to determine whether the animal responds to temperature. If heated to 40° C. the amœba will be killed.

4. **Reproduction.**—Occasionally one meets some of the stages that the animal undergoes in its life history, such as **encysted** specimens and specimens undergoing **division.** If any of these stages are found examine them with care and make drawings of them.

Various kinds, or species, of amœbæ may be found which may differ in number, shape and position of the pseudopodia; in size and abundance of granules in the entoplasm; and in the presence of a shell about the animal.

PARAMECIUM.

THE SLIPPER ANIMALCULE.

PARAMECIUM is found in water containing decaying organic matter, *i. e.*, in infusions of organic matter hence the name **infusoria**, the class to which the animal belongs. In nature Paramecium will be found in almost any ditch or pond which contains much organic matter. In a jar containing an infusion of hay the paramecia are usually found near the surface and often in a ring around the edge of the dish. Mount a drop of water from this region of the dish, first placing a thin layer of cotton on the slide to trap the animals, or a solution of gum to lessen the activity. Examine with the low power.

I. Morphology.

1. **Form.**—Are there individual differences in size? Can the animals be seen with the naked eye? In outline the animal is elliptical or oval, often rather slipper-shaped, whence comes the name **"slipper animalcule."** Is the shape constant under all conditions? Watch one while it is passing through a narrow space. Is the body **rigid** or **flexible?** Are there definite **anterior** and **posterior** ends? If so, how are they distinguished?

With a piece of clay make a model of the paramecium. Be careful to get the right proportions and shape.

2. **Structure.**—Along one side of the animal is a groove which leads to a mouth opening. The most satisfactory

way to observe this groove, the **buccal groove**, is to watch the animal as it rotates on the long axis (use the low power). In the clay model already constructed indicate the position and shape of this groove.

Examine with the high power. If the movements are not sufficiently restricted to allow the examination of specimens with the high power, place them in a rather thick gelatin solution, which will retard their movements. Or one may try the following scheme: on a slide without cotton place a drop of the water containing the animals and cover with the cover glass. With a piece of filter paper applied to the edge of the cover glass slowly draw some of the water from under the cover. Continue until the cover begins to touch the animals and to flatten them **slightly**. At this point it will be found that the paramecia do not have room to move about and, being flattened somewhat, the internal structure is more evident. The success depends upon the remov a of just the right amount of water. Remember the shape of the animals under these conditions is considerably distorted, and some of the structures are not normal.

Can you distinguish an **ectoplasm** and an **entoplasm?** In what ways are these like, or unlike, the same parts of amœba? In a quiet specimen observe the ectoplasm carefully and look for a delicate outer layer, the **cuticle**, which serves as a cell wall. Fine, hair-like, protoplasmic processes, the **cilia**, project from the surface of the body. Are these cilia present on all parts of the body? Are they of uniform length? In the deeper part of the ectoplasm are minute oval sacs called **trichocysts**, arranged perpendicular to the surface. Very often they look like short stiff rods rather than sacs. The contents of these sacs may be forced out beyond the cilia, or even entirely out of the body, and appear as rather thick threads in the water. The tangle of threads so produced seems to serve as something of a protection to Paramecium.

Within the entoplasm are **food vacuoles,** masses of food forming little spheres or globules and surrounded by a little liquid. Are these of the same size? Where in the body are they most abundant? Do they resemble the food vacuoles of amœba? Do you find **contractile vacuoles?** How many? Where situated? Is the contraction or the expansion more rapid? Just after the disappearance of the vacuole look closely for **radiating canals** in the same region. If more than one vacuole is present observe whether they contract and expand together. What is the nature of the contents of the contractile vacuoles? What function might they serve?

The **nucleus** can rarely be seen in the living animal. In order to render it visible place a drop of methyl green near the cover glass and draw it underneath by the use of filter paper. When the excess of stain is replaced by clean water, the nucleus should be visible as a green spot. In what part of the body is the nucleus? This nucleus is called the **macronucleus** and is rather large; by its side is a smaller nucleus, the **micronucleus,** which is difficult to demonstrate except by special means of preparation.

A drawing about four inches long should be made and in it should be represented all the details of structure mentioned above. Also make a drawing of an ideal cross section of the animal through the middle region of the body.

II. Physiology.

1. **Movements.**—In what directions may the animal move? What are the means of locomotion? Run some powdered carmine under the cover glass and observe the currents

produced by the action of the cilia. What is the general direction over the surface of the body? In the mouth groove?

2. **Defense.**—Run some dilute picric acid under the cover and observe the trichocysts which are thrown out. In a drawing show the **trichocysts** and the **cilia.**

3. **Nutrition.**—(*a*) **Ingestion of food.**—Place some paramecia on a slide with a small amount of powdered carmine in water and watch the formation of a food ball in the gullet, and the way in which it is taken into the body. When it gets into the body it becomes a food vacuole.

(*b*) **Nature of the Food.**—Study the contents of the food vacuoles found naturally in the body and determine, if possible, what the Paramecium feeds upon, especially whether it is plant or animal food.

(*c*) **Digestion.**—Observe the changes in form, size and amount which take place in the food as it passes through the body. Are there changes in the food vacuole? What do they mean?

4. **Circulation of the Protoplasm.**—Watch the food vacuoles, especially after having added the carmine, and see whether they change their position in the body. If there is any movement make an outline drawing and show by arrows the course of the circulation.

5. **Irritability.**—What reasons are there for believing that Paramecium is sensitive to external influences? Do they avoid objects? Do they collide with each other in motion? Do they tend to collect in masses? Where? Why? Are they as active at the end of the hour as at the beginning? Why? Is the animal sensitive to touch or pressure?

6. **Reproduction.**—(*a*) **Fission.**—This is the usual method of reproduction and consists in the division of the animal into two parts. At what part of the body and in what direction

is the line of division? Can one speak of "parent" and "offspring"? Stain the dividing animals with methyl green and note what changes are taking place in the nucleus.

(*b*) **Conjugation.**—This is of less common occurrence and depends in part upon the physiological condition of the animals. Look for pairs of individuals which are joined together by the **buccal groove.** This contact of the animals is only temporary for they later separate; in the meantime, however, portions of the nuclei have been exchanged. If slides with stained specimens showing conjugation are at hand examine them for the nuclear changes involved. Is there any distinction of sex in these conjugating individuals?

VORTICELLA.

THE BELL ANIMALCULE.

MOUNT some of the scum from the top of the water in a jar containing Vorticella, and look for tiny bell shaped organisms borne on a stalk. They are much smaller than Paramecium and are usually in groups or colonies. Be sure that there is plenty of water and that the cover does not press on the animals and distort them. It will not be necessary to have a layer of cotton on the slide, since the animals are fastened to a stalk and will not swim away.

I. Morphology.

1. **The Stalk.**—What is its shape? Its length as compared with its width? Its shape when it is contracted and when expanded? In the stalk there is present **cuticle** and **ectoplasm** but no entoplasm. The central axis (ectoplasm) is usually easily seen. Does it run through the exact center of the stalk? With your highest power study the structure of this stalk and make a drawing of it, very much magnified, showing how it is constructed and how it connects with the body of the animal. Can you give any explanation for the coiling of the stalk when it contracts?

2. **The Body.**—What is the shape when seen from above? from the side? When the animal is contracted? when it is fully expanded? In a fully expanded individual note the **peristome** or rounded edge of the bell. Does it extend completely around the bell? The top of the animal is

raised in the form of a dome or plate, forming the **disk.** Between the peristome and the disk is a gutter-like depression leading into a deep pit, the **vestibule.** Is there anything in Paramecium which corresponds to this vestibule? From the vestibule the **esophagus** extends downward. Trace its direction and determine its shape. In Vorticella where are the cilia located and how are they arranged?

In the body look for a transparent covering, the cuticle. Is there ectoplasm and entoplasm as in Amœba and Paramecium? Is the differentiation of these layers as marked as in the other protozoa studied? Are **food vacuoles** present? Are there **contractile vacuoles**? How many? Where located? The **nucleus** is an elongated horse shoe or "C" shaped mass in the entoplasm. It may be more easily found if the animals are stained with methyl green. A micronucleus is present, but is so small as to be found only with great difficulty.

II. Physiology.

1. **General Movements.**—Observe the manner in which the stalk contracts. What changes take place in the body during this contraction? May the body contract without a contraction of the stalk? Note the rapidity of the movements in the contraction and in the expansion. How does the animal assume the expanded condition? Which is the part to first assume the expanded condition? Note that in some cases there is no stalk attached to the animals. How do they behave when this is the case? Vorticella may separate from its stalk and become free-swimming for a time. During this period a second row of cilia develops about the base of the bell, to aid in locomotion. (In some cases this separation from the stalk is not normal, but is due to pressure from the cover glass or to some other unusual condition; in

such instances the cilia are like those in the normal stalked form.)

2. **Ciliary Movements.**—Add powdered carmine to the water and observe the directions of the currents produced and also the method of feeding. Watch the formation of a food vacuole. If there is a movement of these in the body indicate by arrows in a drawing the course taken.

3. **Irritability.**—Notice what happens when the slide or cover is tapped, and when the animal is touched by something. Is Vorticella more or less sensitive than Paramecium? Does it always contract when it touches something? Explain.

4. **Reproduction.**—(*a*) **Fission.** Look for individuals undergoing fission. Where does the division begin? In what direction does the division take place? After the division is completed one of the two new animals separates from the stalk, swims away and later settles down, forming a new stalk.

(*b*) **Conjugation.**—Individuals may rarely be found undergoing conjugation. In Vorticella this involves the permanent union and fusion of a small individual with one of the normal stalked forms.

Questions on the Protozoa in General.

Tell something of the shape of protozoa, of their size. Is the body symmetrical? Is the shape constant? Is there any distinction of the animals into regions? What sorts of motions have the animals? How are these movements produced? Do all the protozoa examined have the same motor apparatus? Does the body contain blood and is a heart present? Is there anything corresponding to stomach, lungs, or gills? Do the animals eat, digest food, breathe, see, feel? Do they have nerves or brain? If the organs needed for performing these functions in other animals are absent in the protozoa, how can you account for the fact that they do perform these functions?

Is the protoplasm protected in any way? What means of defense have they? How can one account for their wide distribution and abundance?

In what ways do these single celled animals differ from the single cells of plants and of higher animals? In what ways do they resemble each other? Could single cells from the many-celled animals exist alone as do the Protozoa?

Write a brief paper answering the questions above and discuss the points suggested.

PLEUROCOCCUS.

Pleurococcus is a unicellular plant, growing on damp stones or ground, and is very common upon the trunks of trees.

I. Morphology.

1. **General Structure.**—Note the appearance of Pleurococcus in its natural growth on a piece of bark or damp wood. Is it evenly distributed over the surface? Compare several specimens of bark on this point. What is the color? Does it vary in different specimens? Compare pieces of dry bark, and those which have been in a moist place for several days.

2. **Minute Structure.**—Scrape bits of the plant from the bark and mount on a slide with water. Examine first with the low power, and then with the high power of the microscope. Note the form of the cells, and whether they are single or associated in definite groups. Make drawings of any different appearances found.

Is there a **cell wall**? What is its color? Can the **protoplasm** be seen? The green color of the plant is due to the presence of **chlorophyll**; usually this is distributed throughout the protoplasm, though it may be in several distinct **chloroplasts** or chlorophyll bodies. Is there any **nucleus** which can be seen in the living cells?

II. Reproduction.

Look for cells which are in the process of division to form groups of two, three, four or more cells. This is the ordinary mode of propagation by Pleurococcus. Is there any regular order in the number of cells produced?

In some unicellular plants similar to Pleurococcus another sort of reproduction occurs, viz., by a division within the cell there are formed a number of motile cells called **zoöspores.** These may be of two sizes, the larger ones called **macrozoöspores,** and the smaller ones **microzoöspores.** Locomotion of these spores is by means of flagella. Can you suggest any advantage in having a zoöspore stage? A conjugation of macrozoöspores and microzoöspores may occur.

COLONIAL PROTOZOA.

AMONG protozoa are to be found various species which, instead of becoming independent and separating from their fellows at once after division, remain for some time, or permanently, associated in **colonies.** The formation of groups or companies was noted in Vorticella. Other vorticella-like animals (**Carchesium, Epistylis**) may be grouped into permanent, branching, tree-like masses. **Gonium, Pandorina, Volvox,** are well-known examples of free-swimming colonies. Such forms are especially interesting for they show the beginning of differentiation and complexity in a phylum comprising the simplest organisms. They are further interesting, (*a*) in suggesting a possible origin of **multicellular** organisms; (*b*) in that their **animal** or **plant affinities** are still open to question.

As a type of these colonial forms **Volvox** is suggested for study. It may often be collected in the spring or fall from small lakes or ponds containing Riccia, duck-weed and other plants. By stocking jars from the water of ponds where the organisms are found, and maintaining conditions as nearly normal as possible, they may be kept in the laboratory for several weeks.

I. Morphology.

1. **Form of Colony.**—What is the general shape? Color? If living, note the movements of the colony and determine how it is produced. Of how many kinds of cells is the

colony composed? How do they differ in size, position, and shape?

2. **Structure.**—Note the size, shape, and large number of cells which make up the body of the organism. How are the cells connected with each other? Under high power make out the flagella of the cells. How many has each cell? With what part of the cell are they connected?

Make a careful drawing of a group of cells, their structure, and connection to other cells.

II. Physiology.

1. **Reproduction.**—(*a*) **Asexual.** Certain cells, **parthenogonidia,** migrate from the outer wall into the interior of the sphere and there, without fertilization, give rise to small colonies by repeated divisions.

(*b*) **Sexual.**—Other cells which move into the interior of the sphere are specialized reproductive cells. The egg (**macrogamete**) is large, the spermatozoids (**microgametes**) are small. These two kinds of cells fuse or conjugate and the fertilized egg develops into a new colony.

Make drawings of different stages of reproduction, both sexual and asexual.

Would you regard Volvox as a unicellular colony or as a very simple multicellular organism? Give reasons for your conclusion.

SPIROGYRA.

Pond Scum.

Spirogyra is a filamentous alga common in ponds, ditches, or sluggish streams during the summer months, usually floating on the surface or adhering lightly to some support. It is often called **"pond scum," "frog-spittle," "brook-silk."** The scientific name comes from the spiral arrangement of the chlorophyll in the cells. The alga may be collected late in the fall and kept in aquaria all winter, usually in good condition.

I. Morphology.

1. **General Characters.**—Note the color, texture, slippery feeling. Do different masses show variations in these respects? To what extent?

2. **Microscopic Characters.**—Mount a few filaments in water and examine with low, and with high powers.

(*a*) **Shape of Filament.**—Is it simple or branched? Is it of uniform size? Are there signs of roots? Is there a root end or a tip to the filament?

(*b*) **Structure.**—Is the filament composed of cells? If so are they of uniform size? Note any variations. How are the cells united? Is a cell wall clearly distinguishable? Is it of uniform thickness over all portions of the cell? Stain the filament by running a drop of iodine under the cover glass and note effects on all parts of the cell. Are there indications of starch?

Mount fresh filaments and study the chlorophyll bands, or **chloroplasts.** What is their general form? How many in a cell? How many spirals of the chloroplast in a single cell? Note the form of the margin of the band. What relation has this to certain round bodies, the **pyrenoids,** situated at regular intervals along the bands? Test for starch in the pyrenoids and surrounding granules.

(*c*) **Nucleus.**—Examine the cells in both fresh and stained condition for the nucleus. Does it occupy the same position in all cells? What is its shape?

Make drawings to show the points observed.

II. Physiology.

1. **Plasmolysis.**—In fresh specimens look for a very delicate film of protoplasm lining the cell wall. If it cannot be found in fresh specimens try the following experiment of **plasmolyzing** the cell: Run a few drops of a 10 per cent solution of salt or sugar under the cover glass, and note what happens to the protoplasm. Is there any change in the **cell wall**? In the **chloroplast**? During the experiment, and probably before, vacuoles will have been noted in the cells. What effect had plasmolysis upon these? Explain.

2. **Photosynthesis.**—Study the effects of light on starch making by examining specimens which have been kept in the dark for twenty-four hours and testing for starch. Compare with specimens which have been freely exposed to light. What conclusions may be drawn?

3. **Reproduction.**—Occasionally during the summer or fall Spirogyra may be found in the process of **conjugation.** This consists in the union of cells of two parallel filaments lying close together by outgrowths of tubular processes from each cell, and their final fusion with those of the adjacent

cell. In this way there is a fusion of the protoplasm of the two cells.

If filaments are found in this condition note any differences in color and size of the filaments and cells, as compared with the ordinary condition. Are all the cells of the filaments undergoing conjugation in the same stages of conjugation? Does the **chloroplast** take part in the process?

The result of this conjugation is the formation of a **zygospore.** What is its shape? Color? Size? Are zygospores found in cells of both the conjugating filaments? Is there any indication of sexual distinction in the two filaments? In what condition are the old cells after conjugation is complete?

SPONGE.

Grantia Sp.

A few sponges are found in fresh water, but most are marine; the latter are found in all parts of the world under a great variety of conditions. Grantia is a solitary form, not producing colonies as do many others, though buds at its base may temporarily make a small colony. It is permanently attached to rocks, piles and sea-weed below low-water mark.

I. External Anatomy.

Place a specimen in a watch glass in water or alcohol. Observe the form of the animal, and its mode of attachment. At the free end note the opening, the **osculum,** partly covered and protected by a cluster of **spicules.** This opening is not a mouth, but an **excurrent opening** for the discharge of water from the animal. In the sides of the animal are many minute openings, the **incurrent pores** or **ostia.** Are these covered or protected by spicules like the osculum?

Make a drawing of a specimen.

II. Internal Anatomy.

With a razor cut a dry specimen longitudinally and examine the section with a lens. Observe the **central cavity** and the small pores, the **apopyles,** which pierce its wall. In the walls find a series of canals arranged in radial fashion.

These are of two sorts, **incurrent canals** open to the outside, and **radial canals** or **flagellated chambers** which open into the central cavity.

Draw the sectioned specimen.

III. Microscopic Sections.

Study stained sections made transversely through a decalcified specimen. Make a careful study of the arrangements of the parallel tubes in the walls, and their relation to the central cavity. Are the tubes open at both ends? Is it possible to distinguish the **incurrent** and the **radial** canals? What structural features make this distinction possible? Are there any openings, the **prosopyles,** between the incurrent and radial canals?

With the highest power examine the cells. The central cavity is lined by flat or **pavement epithelium**; the radial canals are lined by peculiar cells, the **gastral epithelium,** or **choanocytes,** which are elongated cells bearing flagella; the incurrent canals and the outer surface of the body are covered with flattened cells, the **dermal epithelium.** Scattered through the sections may be found germ cells, **sperms** or eggs or segmenting eggs. Observe especially their location with regard to the cellular layers.

Make a careful drawing of a portion of a transverse section.

IV. Skeleton.

If a specimen is boiled in caustic potash the fleshy matter will be destroyed, leaving only the **skeleton.** The latter is made up of a series of **spicules** embedded in the flesh. Mount some of these loose spicules in water and examine with the microscope. Draw the different kinds found.

HYDRA.

HYDRA is found in ponds and lakes which contain pond weeds such as, **Elodea, Sagittaria, water-lilies, duck weed,** and the like, usually being attached to these plants. Specimens secured from such localities and placed in aquaria with aquatic plants will live indefinitely, if supplied with food in the form of small crustacea or "water-fleas."

From the aquaria in the laboratory remove hydra with a clean pipette and place in a watch glass with water from the aquarium. Place this dish on the stage of the dissecting microscope and examine the specimens.

I. Morphology.

1. **Form.**—Describe the shape and color of the animal. Is the body differentiated into regions as head and base? Is it attached or free? Do the length and breadth remain constant? At the free end of the body is a row of **tentacles,** how many are there? Is the number the same in all specimens? Compare notes with other students to determine this. If both the **green** and the **brown hydra** are available compare them in number of tentacles. Are the tentacles smooth and even in contour? Compare the length and the shape of the tentacles when expanded and when contracted. Within the circle of tentacles is a small opening, the **mouth,** often difficult to see in living animals.

On the larger, mature, animals will often be found processes resembling the hydra. These are **young hydras,** or buds, and this budding is the common method of reproduction. What become of the buds? Are **colonies** formed by budding? Why?

Make an outline drawing of the animal in the expanded condition, and one of the contracted animal.

2. **Minute Structure.**—Place the dish containing the hydra on the stage of the compound microscope and examine with the low power; or place the hydra on a slide and cover with a cover glass, supporting the latter to prevent crushing the animal. Is there a cavity (the **enteron** or digestive cavity) in the animal? Does the cavity extend into the tentacles? Sometimes small particles may be seen floating in the cavity of the body or tentacles, or even passing from the enteron into the tentacles. From this fact what inference may be drawn as to the structure of the tentacles and their mode of nutrition?

Observe that the body is composed of layers (tissues), an outer **ectoderm** and an inner **entoderm**. Which of these layers is thicker? Are the layers made up of cells? In which layer is the coloring matter located? Is the color evenly diffused or is it segregated into distinct bodies?

Draw a portion of the body enlarged to show the layers; also show the cells if it is possible to determine their outlines.

With the high power observe an extended tentacle. Do you find ectoderm and entoderm? Are cells present? Note the knobs on the tentacles, composed of oval, transparent, bladder-like bodies or cells. These are the stinging cells (**nematocysts** or **thread cells**) which represent modified ectoderm cells. Where are the nematocysts most abundant? Is there any definite arrangement of these cells? From the outer end of each of these cells projects a stiff hair-like process, the trigger or **cnidocil**. Within the capsule of the cell is a coiled thread which may sometimes be made out with the high power. The nematocysts may be discharged from the body and the thread thrown out, this serving to secure prey or to protect the animal. The capsule of the cell contains a fluid which escapes through the thread, and kills or paralyzes small animals. By gently tapping on the cover glass above the animal, or by introducing beneath the cover some irritating fluid as dilute acetic acid or iodine, one may cause a discharge of the nematocysts. Study such discharged cells and observe the **capsule,** the **thread** and the **barbs.**

Drawings should be made to show the structures worked out.

II. Physiology.

1. **Irritability.**—Touch various regions of the body with a needle and note results. Is hydra sensitive? Are the several parts equally sensitive? Jar the table or the slide. What does the hydra do?

2. **Contractility.**—Does the body of the animal show spontaneous movements? Do the tentacles show the same properties? Does the contraction of the tentacles and body, or of all the tentacles, take place at the same time, or is there independent movement and contraction? What effects on the shape of the body do the various movements produce? Do the movements seem to be definitely coordinated or purposeful?

3. **Locomotion.**—Does the animal remain fastened in one place in the aquarium or does it move about? On the outside of the aquarium make a mark to locate the position of an individual. Make several observations after some hours or days and determine whether the specimen has moved.

4. **Heliotropism,** or movements in response to light. Examine hydra in the aquarium. Are specimens arranged

or distributed in any special relation to light? Note where the specimens are most abundant, rotate the jar 90 to 180 degrees and observe again after several days. Have the hydras retained the old position or are they in a new part of the jar? Are they in the same position, relative to the source of light, that they were before the jar was moved?

5. **Food Taking.**—It is possible to artificially feed specimens by suspending bits of raw beef within reach of the tentacles, or by placing it in watch glasses with hydra. The method of capturing prey may often be observed by placing water-fleas in a jar or watch glass containing hydra.

6. **Reproduction.**—(*a*) **Asexual.** The presence of buds has already been noted. How does the process take place? In what ways does it differ from the process of fission in the protozoa? What becomes of the bud? What parts of the body are involved in the formation of the bud? Draw.

(*b*) **Sexual.**—The same individual usually produces both male and female reproductive products. The **spermaries** (**testes** or male organs) will be found, if present, as small conical elevations on the body just below the tentacles. If these are mature the microscope may show active movements on the inside; this is caused by the swimming of the **spermatozoa** within the testis. If the testis is ruptured the spermatozoa may be seen swimming about in the water. Is there more than a single testis on one animal?

The **ovaries** (egg-producing or female organs) usually develop later than the testes and will therefore not be found on the same animal that shows the male organs. The ovaries are larger than the testes, more spherical, and occur near the base of the animal. Within the ovary may sometimes be seen the single large egg or ovum. Is there more than a single ovary on one animal?

Which of the layers of the body is involved in the formation of the reproductive organs? Make drawings.

III. Sections of the Body.

On the slides are thin sections of the body cut transversely, that is at right angles to the long axis of the body. These sections have been colored to render them more distinct. Distinguish the ectoderm and entoderm. How are they separated? How does the supporting layer which separates them differ from the ectoderm and entoderm? Is the ectoderm of uniform thickness? Note shape, size and contents of the cells. At the inner ends of the cells may sometimes be found muscular prolongations of the ectoderm cells. Between the bases of the ectoderm cells are smaller cells not extending to the surface. These are **interstitial** cells and from them arise the nematocysts and the reproductive cells.

Compare the cells of the entoderm with those of the ectoderm in shape, size and contents. Look for **gland cells** in the entoderm. These will appear as more deeply staining cells between the ends of the cells which border on the enteron; they secrete digestive enzymes.

Draw a portion of the section much enlarged showing, especially, the cell structure.

HYDROID.

PENNARIA TIARELLA.

PENNARIA is a colonial, marine animal growing on seaweed, on the piles of docks, and in similar places. It is a relative of the fresh water polyp, which has already been studied.

1. **The Colony.**—Examine a portion of the colony with a lens, and note that it consists of a stem with branches, each terminated by a flask-shaped body. This body is called the **hydranth** or **zoöid,** and represents a single individual of the colony comparable to an entire hydra. Are all hydranths alike in form and size? What is the general form and character of the colony? Is there any definite order to the branching? How is the colony attached? This basal portion, the **hydrorhiza,** is really a creeping portion of the stem. Do young stems arise from it? In the stem the central axis, which is the fleshy part of the animal, is called the **cœnosarc,** and it is surrounded by a horny, dark colored, protective sheath, the **perisarc.** Does the perisarc cover all parts of the colony?

Make a drawing of the colony about twice natural size, showing its habit of growth.

2. **Hydranth.**—Place a portion of a colony in a watch glass or on a slide and with the low power of the compound microscope make out the form and shape of a single hydranth. Are tentacles present? How many? How arranged? Are the tentacles alike? If more than one kind is found note

the points of difference. A mouth is present at the tip of the hydranth, but, unless open, will not readily be found. Is there a cavity present as there was in hydra? Does it extend into the stem and the tentacles?

Make an enlarged drawing of a single hydranth with a portion of the adjacent stem.

With the high power examine the different tentacles of a hydranth with care and make out the **ectoderm** and the **entoderm**, and the boundaries of the cells. Are the tentacles alike in the arrangement and relative size of the layers and of the cells? Are they hollow as in Hydra? Look for bladder-like, oval, transparent cells in the tentacles (the **nematocysts** or **stinging** cells). Note their size and arrangement.

Make drawings of portions of the different tentacles as seen under the high power.

3. **Reproduction.**—Reproduction in Pennaria, and in the hydroids generally, is of two kinds, **asexual and sexual.**

(*a*) **Asexual.**—The entire colony is produced by budding. Look for buds on the sides of the stem, just below the hydranths. These buds produce new hydranths, and thereby increase the size of the colony. Other buds are formed on the sides of the hydranths, these are called **medusæ** and when they are full grown they separate from the hydranth and float freely in the water. They have the power of locomotion and swim about as distinct individuals. If possible make out the structure of the larger ones.

(*b*) **Sexual.**—The medusæ formed by budding from the sides of the hydranths are sexual individuals, and they produce either eggs or spermatozoa. The eggs and the spermatozoa are ripe when the medusæ are liberated, and are cast into the water where fertilization occurs. The fertilized egg develops into a free swimming **larva** which after a time settles down, fastens itself to some body and grows into a polyp or hydranth, which by budding produces a new hydroid colony.

The life cycle of this animal is, therefore, somewhat complicated and involves an **alternation** of **generations.** A hydroid, we have seen, by asexual budding produces a medusa, and this through sex cells gives rise to a hydroid colony. There is, therefore, an alternation of the asexual and the sexual methods of reproduction.

HYDROID.

OBELIA OR CAMPANULARIA.

THIS hydroid has about the same mode of life and lives in the same places as Pennaria.

With a lens examine a colony making out the stem, branches hydrorhiza, and hydranths. Compare with Pennaria on these points. Make a drawing of the colony showing its habit of growth.

With the compound microscope examine the colony more carefully and discover whether there is a **perisarc** as in Pennaria. Does it differ from that in the other hydroid? In these hydroids the perisarc at the end of each branch widens out to form a funnel-shaped enlargement (the **hydrotheca**) which may entirely enclose the hydranth. Why are some hydranths entirely enclosed within hydrothecæ, while others extend beyond this? The perisarc around the stem, and around the hydranth as well, is of a horny consistency and has been secreted by the ectoderm cells of the cœnosarc. When this was taking place the ectoderm was in contact with the perisarc. Examine the colony closely and find different stages in the formation of a hydrotheca.

Compare the hydranth with that of Pennaria in size, shape and structure. How many tentacles are there? How are they arranged? Are they alike? Note the mouth, which is at the end of an enlargement, the **proboscis** or **hypostome**. How is the hydranth supported in the hydrotheca?

Make an enlarged drawing of an expanded and another of a contracted hydranth.

Examine a tentacle with the high power and find the **ectoderm** and the **entoderm** layers, and the outlines of the cells of these layers. How does the tentacle differ from that of hydra, and from that of Pennaria? Are **nematocysts** present? Where are they located? Make a drawing of the basal portion of a tentacle showing the cell outlines.

Look for branches which have an elongate, rather club-shaped, enlargement of the perisarc. The cœnosarc within will show no tentacles and no mouth. This is the **gonangium,** or receptacle containing reproductive buds. The cœnosarc forms a central core the **blastostyle,** which is a modified hydranth body; from the sides of this are budded off small **medusæ.** These medusæ become free, escape from the gonangium and swim away. Unlike Pennaria the medusæ of Obelia are not sexually mature at the time of escape, but the eggs or spermatozoa are formed only after several weeks of active life. The eggs develop into new hydroids as in Pennaria, the same **alternation** of **generations** being shown. Draw a gonangium.

Campanularia differs from Obelia chiefly in its reproductive process. In Campanularia no medusæ are formed, but within the gonangium eggs or sperms are produced. Fertilization occurs within the gonangium and the egg develops into a free swimming larva (**planula**) which escapes from the gonangium. The planula fixes itself and transforms directly into a polyp, which buds and produces a colony.

THE MEDUSA.

GONIONEMUS MURBACHII.

THE medusæ formed by the hydroids studied, Pennaria and Obelia, are so small that their structure can be made out only with some difficulty. Therefore, a larger medusa is taken as a type for study. Although Gonionemus does not belong to the same order as the hydroids described, and the hydroid stage is greatly reduced, it has about the same structure as the medusæ which are formed from these hydroids.

Place specimens in a watch glass with water and examine with a lens. The **umbrella** or **bell** shape is rather characteristic of all medusæ. The external convex part is called the **exumbrella** or **aboral,** and the concave part is the **subumbrella** or **oral** side. The under part of the medusa is partly closed by a membrane called the **velum,** or veil. Where are the tentacles? Are they alike. How many are there? Are they regularly arranged? Are nematocysts present? If so note their arrangement. Near the tip of the tentacle is an adhesive or **muscular pad** used by the medusa for holding against some object.

Within the subumbrellar space note the central hanging sac, the **manubrium** or stomach. Is a **mouth** present? A **gastric** cavity? How does the mouth differ from that of the hydroids? Note the **radial canals,** delicate tubes which extend outward from the center of the bell. How many canals are there? Is the number the same in all specimens?

Are they symmetrically arranged? Do they join the gastric cavity? The canals extend to the periphery of the bell and open into a **marginal** canal which extends completely around the medusa and communicates with the hollow tentacles. Why is there such a system of canals in the medusa and not in the polyp?

Hanging from the under surface of the canals are large, convoluted, ribbon-like organs, brownish in color. These are the **reproductive organs.** The medusæ are males or females, but the reproductive organs look alike.

Draw the entire medusa from the side; also from the oral aspect. Draw a portion of a tentacle showing the arrangement of the nematocysts, and the adhesive organ.

EARTHWORM.

Lumbricus Sp.

Place the worm in the dissecting pan with enough water to cover it. What is the form of the body? Does it vary in any part? What is the color? Does it vary? Has the body any protective covering? Are there appendages such as legs? Are there gills or other respiratory structures? Are there organs of hearing or sight?

I. External Anatomy.

1. **General Features.**—Notice the regular segmentation of the body into a series of rings, **somites** or **metameres.** How many? Compare with the number found on other specimens and indicate whether it is constant. Are the somites of the same size and form throughout? Notice the **prostomium** projecting from the first somite, and the **clitellum** or **girdle** about one-third of the way back from the anterior end. Which segments make up the clitellum? In what way does this part of the body differ from the rest? The clitellum is composed of glands in the skin which secrete a substance to form the cocoon or case in which the eggs are deposited.

2. **Regions of the Body.**—Distinguish an anterior or head end, and a posterior or tail end. Is there a definite head? How are the dorsal and ventral sides differentiated? Are

these distinctions equally marked in all parts of the body? Are the two sides of the animal alike? If so, it is said to be bilaterally symmetrical.

3. **Setæ** are short, horny spines embedded in the body wall but projecting a little. They aid in locomotion. They may be felt by rubbing the finger over the ventral surface of the body. If this region is examined with a lens the setæ will be seen as tiny brown spots. How many are there on each somite? How are they arranged?

4. **Openings of the Body.**—The **mouth** will be found on the ventral side of the body at the first somite. What is the position of the mouth relative to the prostomium? At the end of the last segment of the body is the **anus**, the posterior end of the digestive tube. On the ventral side of the fifteenth somite are the openings of the testes, called the **sperm ducts**, one on either side surrounded by swollen lips. The ovaries open through the **oviducts** on the ventral side of the fourteenth somite, but they are not surrounded by swollen lips. The openings to the **sperm receptacles,** of which there are two pairs, are situated in the grooves between the ninth and tenth and the tenth and eleventh somites, and are on the sides of the animal in the same line as the lateral rows of setæ.

The openings of the **excretory organs** are found in each segment on the ventral surface a little anterior to the outer seta of the ventral row. They are not very plain, but with a lens will usually show well on some somites. The **dorsal pores,** which communicate with the cœlomic cavity, are in the middorsal line and open in the grooves between the somites.

Draw the anterior and the posterior parts of the body to show all that you have observed.

II. Internal Anatomy.

With the scissors cut through the body wall in the mid-dorsal line from about the middle of the body to the third somite, taking care not to cut the viscera lying beneath. Carefully cut the membranous partitions, the **septa**, at the points where they join the body wall and pin back the flaps of the latter. Notice that the body wall forms a tube in whose cavity, the body cavity or **cœlom**, lies another tube, the **alimentary** or **digestive tube**: also that the septa divide the body cavity into smaller chambers. What relation is there between the septa and the external segmentation? Observe first the alimentary canal which extends through the animal; also several pairs of conspicuous white bodies near the anterior end. The latter are the **sperm sacs.**

1. **Circulatory System.**—This system is a series of closed tubes consisting of several longitudinal vessels and many circular vessels connecting them. The largest of the longitudinal vessels, the **dorsal vessel,** is in the middorsal line against the alimentary canal. Beneath the intestine is the **ventral vessel** which will be seen later when the alimentary canal is removed, and ventral to the nerve cord is a third longitudinal vessel, the **subneural vessel.** The **circular vessels** extend between the dorsal and the ventral vessels and occur in pairs. Five pairs of these circular vessels in the anterior region (somites seven to eleven) are very large, and being contractile are called **hearts**; the dorsal vessel is also contractile. Carefully dissect away the septa and expose the hearts.

2. **Reproductive System.**—The earthworm is a hermaphrodite animal containing both the male and the female organs in a single individual.

(*a*) **The Male Organs.**—The sperm sacs, or **seminal vesicles,** lying in somites ten to fourteen are large white organs, composed of several lobes. In these the spermatozoa undergo a portion of their development. There are two pairs of **spermaries** or **testes** enclosed within the seminal vesicles, but they are so minute as to render their dissection very difficult.

(*b*) **The Female Organs.**—The **sperm receptacles** are two pairs of spherical, whitish or yellowish sacs beneath the sperm sacs, in the ninth and tenth somites. In these receptacles the spermatozoa received from another worm are stored, and from them the sperms are passed into the egg case in which the eggs are laid. The **ovaries** (one pair), are small organs near the median line, attached to the anterior septum of the thirteenth somite. They will be rather hard to find. Posterior to them are funnel-shaped openings which lead into the **oviducts,** and these in turn open to the exterior at the fourteenth somite.

Earthworms meet and pair at night in May and June, and the sperm receptacles of each are filled with spermatozoa from the other worm. They separate and later the girdle secretes a fluid which hardens and forms a tough cylindrical membrane or cocoon about the body. The cocoon is moved forward and as it passes the fourteenth somite eggs pass into it, and at somites ten and eleven spermatozoa enter and the fertilization of the eggs takes place. The cocoon passes over the anterior end of the animal and drops to the ground, the ends close and within this free capsule the development of the young worms takes place.

3. **Digestive System.**—Carefully remove the sperm sacs and the septa in the anterior portion of the body, exposing the tube-like esophagus. Find the following parts: **pharynx** (somites two to five), **esophagus** (six to thirteen), **crop** (four-

teen to sixteen), **gizzard** (seventeen to ninteen), **stomach-intestine** extending to the posterior end of the body. In the walls of the esophagus in somites ten to twelve are three pairs of small sacs or pouches, the **calciferous glands,** which open into the esophagus.

Compare the several organs in size, color, thickness of walls, the lining of each. In the stomach-intestine note the dorsal infolding, the **typhlosole.** Note also the delicate muscle fibers which extend from the body wall to the pharynx. What possible function might these serve?

4. **Excretory System.**—This consists of paired segmental organs, the **kidneys** or **nephridia,** which are made up of coiled tubes held closely together and suspended close to the ventral and lateral body wall. Remove one of the nephridia, place on a slide, and examine with the compound microscope.

Make a large drawing and in it show all the internal structures that you have observed.

5. **Nervous System.**—Dissect and remove the anterior end of the alimentary canal except the pharynx. This will expose the white **nerve cord,** lying in the median ventral side of the body cavity. Immediately over this is the ventral bloodvessel, one of the main longitudinal trunks of the circulatory system.

Examine with the lens and notice that there are small swellings, the **ganglia.** How many in each somite? Are there nerves coming out from the cord? How many in each somite? Do they come from the ganglia, or from between the ganglia? Carefully expose the cord anteriorly, pushing the pharynx to one side, and on the dorsal side of the pharynx will be found the **cerebral ganglia** or brain. How is this connected with the ventral cord? Make a large drawing of the brain and several of the ganglia and their nerves.

III. Microscopic Anatomy. (Histology.)

On the slides furnished are sections across the body in the region of the stomach-intestine, and these are stained in order that the various tissues may be more plainly seen.

1. Study the entire section and identify the following structures: (*a*) **body wall** and its layers; (*b*) **cœlom;** (*c*) **intestine**; (*d*) **dorsal** and **ventral bloodvessels**; (*e*) **nerve cord.** Other organs likely to be found are setæ, excretory organs, septa.

Make a drawing of the entire section showing all the parts mentioned, but not attempting to indicate the cells which make up the tissues.

2. **Body Wall.**—With the high power study the body wall and make out the **cuticle, epidermis, circular muscles, longitudinal muscles,** and a delicate layer of cells lining the cœlomic cavity, the **peritoneum.** Make out the cellular character of the various layers and make a drawing of a small segment of the body wall showing the layers and the cells which compose them.

3. **Intestine.**—Are the walls of the same thickness throughout? The dorsal infolding of the intestinal wall is called the **typhlosole.** How much of the cavity of the intestine does it occupy? Make a careful study of the tissues and cells of the intestinal wall; from without inward these are as follows: **Chlorogogue**, pear-shaped cells rather loosely arranged; between the bases of the chlorogogue cells are small scattered fibers, the **longitudinal muscle**; a definite and clearly marked **circular muscle** layer; inside of this there may be spaces, the **bloodvessels** of the intestine; lining the intestine is a thick layer of ciliated, columnar **epithelium.**

Draw a portion of the wall as seen with the high power, showing the cells of each layer.

4. **Nerve Cord.**—What is the shape of the cord as seen in section? If nerves are present notice the place and the manner in which they emerge from the cord. The cord is enclosed within a connective tissue **sheath**, scattered through which are many **muscle fibers**. Are these circular or longitudinal muscles? Also within this sheath are located three longitudinal bloodvessels, ventrally the **subneural**, at the sides the **lateral-neural vessels**. The pear-shaped cells in the cord are the **nerve cells**, and the delicate fibers that seem to be prolongations of the cells are the **nerves**. Are nuclei present in the nerve cells? Are the nerve cells abundant? Where are they located? At the dorsal side of the cord are three areas that are called **giant fibers**. Filling up the bulk of the cord are connective tissue fibers.

Draw an enlarged section of the entire cord, showing the points observed.

IV. Physiology.

Make the following study of the living worm.

1. **Movements.**—Place the worm on a damp, rough surface, as filter paper, and observe the kinds of movements and the way they are produced. By what means does the worm move from place to place? Can it climb over obstructions? Place the worm on a moist, perfectly clean glass. Explain the behavior observed.

2. **Sensitiveness.**—With a bristle or a blunt instrument, touch the worm in different places. What regions are the most sensitive? How is this indicated? Try the effect of stimuli such as warmth of the breath, sunlight, vapor of ammonia or chloroform, dilute acetic acid. Record the results obtained.

3. **Circulation.**—If the body wall is not too thick, nor too heavily pigmented, the pulsations of the dorsal bloodvessel

may be seen through the wall. In what direction is the blood flowing? Further observations on circulation may be made upon a worm, anesthetized with chloroform, which has been opened to expose the bloodvessels. Observe the contraction of the dorsal vessel and the hearts, also note the delicate bloodvessels upon the various organs.

SAND WORM.

NEREIS VIRENS.

THESE animals are found on the seashore in burrows of sand and mud near low water mark.

I. External Anatomy.

1. **General Features.**—Is there a differentiation into dorsal and ventral? Anterior and posterior? How are these regions distinguished? Compare with the earthworm. How many somites? Is the number as variable as in the earthworm? Are the somites alike in size and form? Is the body divided into regions?

2. **Head.**—In the head there are the following parts: A triangular **prostomium** which bears on its anterior margin a pair of short **tentacles.** On each side there is a fleshy **palp.** The four **eyes** are on the dorsal surface of the prostomium, and are sometimes hard to find. The **peristomium** is the ring around the mouth. Compare it with the first body somite. It bears four lateral or **peristomial tentacles** on either side. Note the large **jaws** which may be partly extended from the pharynx.

Make a drawing showing the head and several of the body somites.

3. **Appendages.**—On each side of most of the somites there is an appendage called a **parapodium.** In each parapodium there are the following parts: A dorsal blade, the **gill,** which bears a short **cirrus;** and a ventral blade consist-

ing of two fleshy lobes. There is also a **ventral cirrus.** From each blade a number of **setæ** arise in bundles. In each blade there is embedded a short stiff rod, the **aciculum,** which serves to support the appendage. Examine the last body somite and note any differences from the other somites.

Make an enlarged drawing of a single parapodium.

II. Internal Anatomy.

Open the worm in the same manner as the earthworm. Note the **body wall,** the **cœlom,** the **septa,** and observe any differences from the conditions present in the other worm.

The digestive system has a large muscular **pharynx,** in which are the large **jaws** noted above, and also some small **teeth** covering the walls. Can you account for the differences in the pharynx of this worm and the earthworm? The pharynx opens into a large **crop,** into which also empty **digestive glands.** Was there anything corresponding to the digestive glands in the earthworm? The rest of the digestive tube is composed of the straight **stomach-intestine.**

The **pharynx** is protrusible and there are **protractor** and **retractor muscles** to operate the proboscis and the jaws.

The circulatory and excretory systems are much like those of the earthworm, though they are not so large nor so easily worked out.

In the sand worm the sexes are separate and the reproductive organs are present only at the breeding season. A portion of the tissue lining the cœlom produces sperms or eggs at this time. When the reproductive products are ripe the body wall is ruptured and the germ cells escape into the water where the fertilization takes place. Unless the worms were obtained during the breeding season the reproductive organs will not be found.

The digestive tube should be removed to expose the **nerve cord**, which is present on the ventral body wall as in the earthworm. Compare the cord with that of the earthworm. Are **ganglia** present? Describe the arrangement and distribution of ganglia and nerves. Is there a **commissure** about the pharynx and a brain or **cerebral ganglia** on the dorsal side?

On account of the numerous sense organs on the head the brain is larger and there are more nerves coming from it than in the earthworm. The brain lies very close to the surface and is difficult to expose without injury.

Make drawings to represent the various internal systems.

THE FERN.

PTERIS AQUILINA.

THE common brake is widely distributed, growing in nearly all damp, shady places. If the structure of the entire plant is to be studied, they should be collected and used fresh or else preserved in formalin. Early summer is the best time for the collection, though the plants will be in fairly good condition in the early fall. For the histological study the rhizome must be sectioned in the usual way. The sections may be stained, but some of the tissues will show well without stain.

This organism is composed of organs which are partly underground and partly above ground, the former composed of the underground stem, or **rhizome**, and **roots** which serve to absorb water and salts from the soil. From the rhizome **leaves, or fronds**, extend into the air as the chlorophyll bearing parts, with supporting and nutritive organs.

The leaf consists of a main stem or **stalk** divided into leaflets, or **pinnæ** and **pinnules**. It is in the leaf that the food is elaborated from simple compounds and elements through the activity of the chlorophyll bodies, or **chloroplasts,** which are but modified masses of protoplasm. Here are also found organs of reproduction.

The main object in the study here outlined is an insight into the fundamental structure of a plant, its parts, their relations and functions. A further aim is, by rough comparison, to discover any similarities of structure and organization, between plants and animals, as well as to demonstrate the contrasts of structure and their relations to the markedly different functions to be performed.

I. Leaf or Frond.

1. **The stalk or stipe** bears the expanded, foliaceous part with its numerous lobes, **pinnæ,** which are further subdivided into ultimate leaflets, **pinnules.** Note whether there are, on any part of the frond, hair-like elements, **trichomes.**

2. **Midrib and veins** are special structures forming a sort of framework of the leaf. Are midrib and veins derived from the stalk and connected with it? Do they sustain any relation to the lobings of the leaf? Not only do these form a structural framework, they are also paths for the movements of liquids.

3. **Histology of the Leaf.**—From portions of the leaf remove bits of the epidermis and examine with both low and high power and study the structure. Are cells present? Observe the shape, structure, contents. Compare the epidermis from both sides of a leaflet and note likenesses and differences. Look for minute pores, **stomata,** and note upon which side of the leaflet they occur. They are the so-called breathing pores, and relate to the functions of transpiration and respiration. Sketch cells of the epidermis.

II. Rhizome.

Study sections of the rhizome and note the varied aspects of different regions, which indicate the several tissues, or tissue systems, of the rhizome. On the outside is the **cortex,** made of an outer layer of **epidermis,** lifeless and protective, and beneath this a **subepidermis** whose cell walls are hard and woody, but which contain living protoplasm.

Make a careful drawing of some of the cells of this region.

Within the cortex, and making up the greater part of the rhizome, is the living tissue, called **parenchyma** or pith. What is the shape of the cells? How are they joined together? Is there protoplasm within these cells? Are there any bodies within the protoplasm which might be dead substances as food? If fresh sections are available treat with iodine solution and determine whether starch is present.

Make drawings of the parenchyma cells.

Scattered through the parenchyma are two large masses and several smaller masses of brownish cells, the **sclerenchyma.** Is there any definite arrangement to these masses? Compare the shape and the grouping of the cells with that of the parenchyma. Is it similar to the parenchyma? Is the cell wall like that of the parenchyma cells? Is protoplasm present? Do these cells resemble more the parenchyma or the cortex? These cells are developed from the parenchyma cells by the formation of **lignin** or **wood,** and they serve to form a framework for rigidity and support. Is the structure apparently adapted for this? Why would the parenchyma not serve this purpose.

Make a drawing of the cells of this tissue.

Oval or circular patches are scattered through the rhizome and are known as **fibro-vascular bundles.** These bundles anastomose and form a sort of network through the rhizome and frond, through which liquids are conducted from place to place. Study one of the bundles carefully and make out the following:

1. **Bundle sheath,** around the bundle.
2. **Phloëm sheath,** parenchyma like cells containing protoplasm and starch.
3. **Bast Fibers.** Small cells with protoplasm.
4. **Sieve Tubes.** Large thin walled cells.

5. **Tracheids.** Very large thick walled, empty cells or tubes.

6. **Spiral Vessels.** Smaller empty cells.

The functions of the different portions of the bundles must be determined by reference to text-books.

Make drawings showing the different cells of the bundles.

If possible examine longitudinal sections and identify the tissues observed in the transverse sections.

In a very general way compare the organization and structure of the fern with that of the earthworm or other animal. Are there similar functions in the two, if so what are they, and what organs perform them? What organ system has the animal that is lacking in the plant and vice versa? In what are the tissues alike, in what different? In what respects are the cells of these tissues alike, in what different?

III. Reproduction.

Ferns present conspicuous sexual and asexual cycles, or **alternation of generations.** Of these the ordinary fern plant is the **asexual generation** or **sporophyte,** producing within certain organs of the leaf numerous, non-sexual spores. These germinating give rise to inconspicuous, sexual plants forming the **sexual generation** or **gametophyte,** which form the sex cells.

1. **Sporophytic Organs.**—Examine mature leaves for the spore-producing structures, **sporangia,** which are borne along the margins of the leaflets. Observe the membrane, **indusium,** which encloses and protects the sporangia. With needles carefully dissect off the coverings and observe the sporangia. Describe the shape, color and size of these capsules. Can you find any variations? If so, how do you account for such?

Examine some of the sporangia, and work out the following parts, using the high power where necessary:

(*a*) **The Stalk or Pedicle.**—What is its shape and structure?

(*b*) The **Capsule** which contains the spores. What is its shape and structure? Note especially the **annulus**, or crescent of thickened marginal cells forming a crest or ridge. Is it continuous about the entire capsule? Where is it most developed? Is the capsule more fragile at one point than another? Examine several capsules in demonstrating this point. Observe the size, shape and arrangement of the lateral or parietal cells of the capsule.

(*c*) **The Spores.**—Rupture sporangia by pressure of the cover glass and examine the **spores**. What is their color and shape?

Make drawings which illustrate the various structures studied above.

2. **The Prothallium (Gametophyte).**—Study prothallia in their normal growing condition if possible. What is their general appearance, color and shape? Carefully isolate a single specimen as directed by the instructor and proceed to work out its distinctive morphological features. Is it differentiated into an upper and a lower surface? If so, what are the distinguishing characteristics? Has the plant rootlike organs or **rhizoids**? Where are they located and what is their probable function?

Carefully examine the lower surface of the prothallium for the presence of the following organs:

(*a*) **Antheridia.**—These are small somewhat spherical bodies usually located among the bases of the rhizoids. They correspond to the male sexual organs and may contain small coiled **antherozoids**, the male sex cells.

(*b*) **Archegonia.**—The archegonia, or female sex organs, are small, finger-like projections in the region of the sinus, or notch, of the prothallium. Compare carefully their shape and structure with that of the antheridia. When the archegonia are mature each one contains a single **egg** cell.

Make drawings showing the location of the sex organs on the prothallium, and also showing the character of these organs as seen with higher power.

3. **Development.**—After fertilization, which takes place within the archegonium, the fertilized egg cell undergoes a cleavage and gradually develops into a young fern. It soon develops its own roots and leaves and becomes a perfectly independent plant. The plant produced in this way is the sporophyte generation.

YEAST.

Dissolve a small piece of compressed yeast in water, mount a drop on a slide and examine with the compound microscope. Or better mount a drop of Pasteur's solution in which yeast is growing vigorously.

I. Morphology.

1. **Form.**—What is the form of the yeast cells? Are all cells of the same shape? Are they single or in groups? Are the cells arranged similarly in different groups? Are they uniform in size? Make drawings to show the points observed.

2. **Structure.**—Is a **cell wall** present? Note its color and thickness. Is **protoplasm** present within the cell? Does it show any color? Look for **vacuoles** within the cell. Is more than one present? Is the size of all vacuoles the same? Is there any difference in size or number of vacuoles in single cells and in groups of cells? Is there any difference in size and number of vacuoles in growing yeast and yeast from a compressed cake. How can this be accounted for? Small glistening oil drops are often present near the vacuoles. A **nucleus** is present in each cell but it can be demonstrated only by special methods.

II. Physiology.

1. **Reproduction.**—Examine cells from actively growing yeast and from compressed yeast and note any differences

in form, number and size of cells in a group. Explain the differences.

The chief method of reproduction in yeast is by asexual **budding** or gemmation. How does this method differ from fission in protozoa?

2. **Growth.**—In the following experiments the amount and rate of growth may be roughly estimated by the increase in the turbidity of the liquids; fermentation may be indicated by the rate and the amount of gas produced.

(*a*) **Food Supply and Growth.**—Fill four test tubes (if fermentation tubes are at hand better results will be obtained by their use) half full of the following fluids, and into each place the same amount of yeast from the same culture. Keep all the tubes under the same conditions.

(I) Distilled water.
II) 10 per cent sugar solution.
(III) Pasteur's solution without sugar.
(IV) Pasteur's solution with sugar.

After several hours or a day observe the tubes and determine in which the growth and fermentation have been most rapid and greatest.

(*b*) **Other Conditions and Growth.**—Prepare several tubes with Pasteur's solution containing sugar, and to each add the same amount of yeast. Place some of the tubes in a warm place (about 35° C); some in a cold place (on ice if possible); boil some and place with the first ones; to some add a few drops of a poison like mercuric chloride or formalin; place some tubes in the sunlight and others in darkness. Into a similar tube place some yeast filtrate. After several hours, or on the next day observe the tubes and note all the differences. Draw what conclusions you can as to the effect of the different conditions upon the growth of yeast, and upon its power to cause fermentation.

(*c*) **Fermentation.**—Conduct some of the gas being formed in a culture of vigorously growing yeast through lime-water or baryta-water. What is the effect on the lime-water? A milky appearance or a white precipitate indicates the presence of carbon dioxide. Is this the gas which is being produced by the yeast?

Permit yeast to grow in a large flask of Pasteur's solution until growth has ceased, *i. e.*, until gas is no longer evolved. Distill the contents of the flask at a low temperature (about 80° C) and test the distillate for alcohol by odor, taste, and inflammability. (The test will be more certain if a second distillation is made.) What conclusions can you draw from the experiment?

From the experiments upon the life and activities of yeast write a report clearly showing the nature of the experiments, the results, and the conclusions which may logically be drawn from them. Give a summary of the conditions which are favorable and those which are unfavorable for growth and ferment action of yeast.

BACTERIA.

Bacteria flourish only in the presence of moisture, but are found in soil and air; indeed hardly any condition where life is possible is devoid of bacteria. Some are among the most useful and important of organisms, and others are among the most dreaded and dangerous of all living things. Many of the most virulent of diseases which afflict mankind have been traced directly to bacteria. Some study of their peculiarities, conditions of activity, method of protection from them may be of interest and importance economically and biologically.

I. Morphology.

Mount a drop of water from a hay or other infusion of organic matter, or from slime in aquaria, and examine under the highest power of the microscope. Note the numbers of very minute, almost transparent bodies present, some in motion and others quiescent.

The forms of bacteria are very simple and comprise only three principal types: the sphere (**coccus**), the rod (**bacillus**), and the spiral (**spirillum**). How many of these kinds are distinguishable in your preparation? Is the size variable? Which type is generally largest, and which smallest? Is the movement which is taking place a locomotion or merely a vibration or oscillation?

Make drawings to show the shape and relative size of the types of bacteria found.

II. Reproduction.

Bacteria reproduce chiefly by fission, hence the scientific name of the order, Schizomycetes (Fission fungi). One indication of this fission which may easily be observed is the presence of chains or groups of bacteria. In what way is this an evidence of division?

III. Physiology.

Bacteria are plants but are not able to manufacture their food as the green plants do. In order to grow they must be in a medium which contains available food, and the culture media used for their growth are so prepared as to furnish the conditions necessary for their growth and activity.

1. **Distribution of Bacteria.**—Methods of preparing the nutritive media can be found in any of the manuals on bacteriology. With tubes or Petri dishes containing sterilized gelatin make the following experiments:

(*a*) Keep some carefully closed and labeled "not exposed."

(*b*) Expose some to the air of the laboratory for three minutes, and label accordingly.

(*c*) Expose some to the dust from laboratory tables or floor, or dust from the outside.

(*d*) Let a drop of water from the laboratory tap flow over another.

(*e*) Capture a fly and let it walk over the gelatin.

Set these aside in a warm place and examine after a day or two, noting what differences there are in the several dishes. The small spots or patches probably present are colonies of bacteria. Do they differ in form and color? Examine the series still later. Have the colonies grown?

How is this indicated? Do any of the colonies have any effect on the gelatin?

2. **Surrounding Conditions and Growth.**—Into tubes of bouillon introduce several drops of fluid from some culture of bacteria and treat the tubes as follows:

(*a*) Close the tube with a plug of cotton.

(*b*) Close the tube with cotton and boil for five minutes.

(*c*) To a third tube add a small portion of a poisonous substance, such as corrosive sublimate or formalin.

(*d*) Place some tubes in the bright sun and others in the dark; place some on ice and others in a warm place.

Label all the tubes and set away for a day or more. Observe and note changes, if any, as indicated by the odor and cloudy appearance of the culture fluid. Explain the differences.

THE CRAYFISH.

CAMBARUS SP.

I. External Anatomy.

COMPARE with the earthworm with regard to regional differences such as anterior and posterior ends, dorsal and ventral sides, head and tail. Are these regions more or less sharply marked? Is there perfect bilateral symmetry?

Distinguish an anterior region, the **cephalothorax**, and a posterior, the **abdomen**. In what ways are they alike? In what different? Is there a definite head? Note the **exoskeleton**, is it present everywhere? Where is it thickest and hardest, where thinnest? What explanation can you give for these differences?

1. **Abdomen.**—Is it segmented? If so, how many segments? The last segment is called the **telson**. Does it differ from other segments? Is free movement of the segments possible? Is it equal in all directions? How are the segments joined together? Are appendages present? Are they present on all segments? Are they alike?

2. **Cephalothorax.**—Is the form like that of the abdomen? Are segments present? Is there any thing to suggest segmentation? The shell-like exoskeleton in this region is called the **carapace**. Are the edges of the carapace free or fixed? To what extent? Are the appendages of this region similar in form?

3. **Sexes.**—Distinguish the following characters:

(*a*) **Male.**—The first abdominal appendages are modified into tube-like or spine-like organs; the abdomen is narrower than the thorax; the genital openings are on the bases of the hindmost legs.

(*b*) **Female.**—The abdomen is slightly broader than the cephalothorax; the genital ducts open on the bases of the third pair of legs. What is the character of the first abdominal appendages?

4. **External Openings.**—(*a*) **auditory,** on the dorsal side of the basal joint of the antennules; (*b*) **excretory,** at the base of the antennæ on the ventral side; (*c*) **mouth,** on the ventral side between the jaws; (*d*) **genital ducts** already noted; (*e*) **anus,** on the ventral side of the last segment of the body.

Draw the entire animal from the side, $\times$ 2.

II. Appendages.

1. **Abdominal.**—Carefully dissect the appendages from one side of the abdomen and arrange them in order on a piece of paper. Using the third appendage as a type notice its biramous character; there is a basal portion, the **protopodite,** and two distal portions, the **exopodite** and the **endopodite.** Compare the other appendages with this one and determine whether they have the same structure. Are there any variations from this structure? What are they? Which appendages show the greatest modification? In what way? Can you explain it? Draw the first, the third and the last appendage.

2. **Cephalothoracic.**—In a similar manner dissect off the walking appendages from the same side of the animal and arrange them in order as before. Explain such differences in structure as appear. Do these appendages bear any

resemblance to the third abdominal? Are protopodite, exopodite and endopodite present?

Draw the first, the third and the last walking appendages. The first pair are called **chelæ.**

Remove the mouth parts on the same side, and arrange them in order. From the outside inward they are called: 3d pair of **maxillipeds,** 2d pair of **maxillipeds,** 1st pair of **maxillipeds,** 2d pair of **maxillæ,** 1st pair of **maxillæ, mandibles.** Compare each one of these with the third abdominal appendage and with the walking appendages. Are they biramous, are the protopodite, the exopodite, and the endopodite present? Are the appendages of this group alike? Might they be considered as modifications of a common structure? Do they have the same number of joints as the walking appendages? In the 2d maxilla note the **gill bailer** which lies in the gill chamber and whose movement creates a current of water which passes over the gills.

Draw the 3d maxilliped, the 2d maxilla, and the mandible.

Remove the **antenna** and the **antennule** from the same side of the body. Compare with the other appendages, what are the likenesses and the differences? Draw.

Considering all the appendages, indicate whether there is a common plan in their structure, and if so what it is. Also indicate what the departures from this plan have been, and suggest advantages of these variations. Parts having the same fundamental structure are said to be **homologous;** and in this animal there is represented a **serial homology.**

III. Internal Anatomy.

1. **Respiratory System.**—Carefully cut away the carapace from the side of the body and expose the gill chamber and the **gills** contained therein. What is the form of the gills?

Of what advantage is this form? To what are the gills fastened? How does the water get to the gills? Why are they under the carapace?

2. **Circulatory System.**—Carefully remove the carapace from the dorsal side of the body. The **heart** will be found in the posterior portion of the cephalothorax, as a delicate shield-shaped body. Notice any vessels which extend out from the heart and examine an injected specimen, if one is available. Note the small openings in the heart, these are **valves.** In what direction do they permit the blood to flow? Trace all the bloodvessels which can be found.

3. **Reproductive System.**—The **ovaries** are granular bodies of considerable size located in the dorsal part of the thorax and abdomen. Note the shape and extent of the organ and trace the ducts to the openings already noted. The **testes** are in a similar position but are smaller and are of a whitish color; the sperm ducts are somewhat coiled and longer than the oviducts.

4. **Digestive System.**—Remove the gills from one side of the body and cut away the body wall of the same side. This will expose the greenish liver and the other digestive organs. Remove the lobe of liver on this side and expose the stomach and intestine.

In the extreme anterior part of the body cavity will be found the large **stomach** composed of two parts, from which the **intestine** leads backward to the anus. Between the mouth and the stomach there is a short **esophagus.** Trace the digestive tube from the mouth to the anus, observing the shape and the size of the parts and their exact position. Do the large digestive glands, or **livers,** open into the intestine or the stomach?

Draw the animal from the side as opened and show all the organs that are exposed or that can be seen by dissection.

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Open the stomach and observe the character of the lining. Of what use are the **teeth** that are present in the walls? How do they operate? If food is present in the stomach try to determine its character.

5. **Excretory System.**—The openings have been noted as being on the basal joint of the antennæ. The excretory organs themselves, the kidneys or **green glands,** lie just dorsal to the bases of these antennæ and therefore in the extreme anterior part of the body cavity.

6. **Nervous System.**—Dissect the muscle and other tissues from the abdomen and expose the **nerve cord.** Be careful not to break any of the nerves in cleaning away the muscle. Expose the cord to the extreme posterior part of the abdomen, then trace it forward into the thorax, dissecting as much as is necessary to expose it. In the anterior part of the body the cord will be found to divide into two parts, forming a **commissure** which passes around the esophagus to the dorsal side. Here the two cords unite again to form the **cerebral ganglia** or **brain.**

Notice the number, position, arrangement of the **ganglia,** their size, the distribution of the nerves which come from them, and the termination of the nerves of the brain in the **sense organs** of the head. Compare this nervous system with that of the earthworm.

Make an enlarged drawing of the entire system.

IV. Physiology.

1. **Locomotion.**—In working on the living animals do not excite or irritate them. Place the crayfish in a pan with sufficient water to cover it and observe it while walking or crawling. What appendages are used? Can it walk backward as well as forward? Are the legs used in any

definite order? Place the animal on the table, does it walk equally well out of water? While the animal is in the water frighten it by thrusting a pencil at it; notice how it swims, what parts are used and how? What advantage comes from swimming in this direction?

2. **Defense.**—With a pencil make motions at an animal to see how it defends itself. Allow it to grasp the pencil to show the strength of the grasp.

3. **Respiration.**—While the animal is at rest in the water place a little colored liquid near the bases of the legs. Where is this liquid drawn into the animal and where does it reappear? Try dropping the colored liquid at various places along the edge of the carapace. What causes the movement of the liquid? What purpose do the currents serve? How is it that a crayfish, while breathing by gills, can live for some time out of water?

4. **Sensitiveness.**—Note the range of motion of the eyes. Could an enemy approach the animal from any direction without being seen? What are the advantages and what the disadvantages of having the eyes on movable stalks? In what ways are the eyes protected? Touch one of the eyes and see what happens.

Test the sense of touch at various places on the body; where is it most sensitive? Are all parts of the appendages equally sensitive? Touch some of the hairs at different places on the body; are they sensitive?

5. **Feeding.**—Small pieces of meat may be placed near the animal to determine how it reacts, and also to show in what way the food is grasped and how it is passed to the mouth. If possible note the action of the different mouth parts. If this sort of a test is made you should also determine whether the animal prefers fresh or decaying meat.

THE GRASSHOPPER.

THE following outline will apply to any of the common grasshoppers, though the larger ones are, of course, preferable for the study of the structure.

I. External Anatomy.

1. **General Characters.**—The body of the grasshopper is made up of **head, thorax** and **abdomen.** Are these divisions well marked? Are they as well differentiated as in the crayfish and earthworm? Are **somites** present? Are they found in all regions of the body? Is an **exoskeleton** present? Compare with the crayfish in regard to exoskeleton. In what ways do they differ? Are **appendages** present? Are they found in all regions of the body?

2. **The Head.**—What is its shape? How is it attached to the thorax? Study the position and structure of the **antennæ.** Observe the large **compound eyes.** With a lens determine why these are called compound eyes. In addition to these eyes there are three **simple eyes** or **ocelli.** One in the center of the head, below the antennæ, and the others near the dorsal, anterior border of the compound eyes.

About the mouth are several appendages: (*a*) **labrum,** or upper lip; (*b*) **mandibles,** or jaws; (*c*) **maxillæ**; (*d*) **labium** or lower lip. Observe the position each occupies and the direction of movement. Remove the appendages, note the structure of each one and make a drawing showing this structure.

3. **Thorax.**—Distinguish the following divisions: (*a*) **prothorax,** (*b*) **mesothorax,** (*c*) **metathorax.** These three parts of the thorax represent somites. Are they sharply separated from each other? Do they move? In what respects do they correspond to typical segments of the crayfish? Observe the several plates of which each is composed. What appendages are borne by each somite?

4. **Appendages of the Thorax.**—(*a*) **Legs.** How many? Distinguish the following joints: **coxa,** a short segment next to the body; **trochanter,** the second segment, which may be fused with the first in the jumping legs; **femur,** the middle segment; **tibia**; **tarsus** or foot. Is the tarsus a single piece? Compare the several parts of each of the legs with corresponding portions of the others. In what are they alike? In what different?

(*b*) **Wings.**—How many? On which somites are they borne? Note their size, color, and texture. What is their relative position in repose? In flight? Spread the wings and study the arrangement of the veins.

Make drawings of the first and third legs, and of both pairs of wings.

5. **Abdomen.**—Of how many somites is it composed? Compare the male and female specimens carefully in shape, size, number and relations of the somites. In what particulars do they differ? Compare the first somite with those following and note any differences. In this somite there is a membranous **tympanum** or ear drum.

Study the structure of a somite and observe a dorsal portion, the **tergum** and a ventral **sternum.** Are these parts well marked? Are they present in each somite? Are the terga and sterna capable of movement?

In the side walls of the somites are small openings or pores called **spiracles.** These are the external openings of the respiratory system, which is made up of a series of branching tubes inside the body for carrying air to the various organs and tissues. There are eight pairs of spiracles in the abdomen, and two in the thorax; determine the exact location of these.

At the end of the abdomen the somites are considerably modified, to form spines, plates and the like. The hard spines in the female comprise the **ovipositor**, or egg-laying organ. Determine the number of spines and the relation of these to the somites adjoining. In the male there are smaller spines which function as genital organs during mating. In both males and females the anal opening is dorsal, beneath a chitinous plate, and the reproductive opening is toward the ventral side.

Make a drawing of the entire animal from the side.

II. Internal Anatomy.

Remove the wings and cut along each side of the median dorsal line. Remove the entire dorsal part of the body wall and expose the internal organs.

1. **Respiratory System.**—**Tracheæ** or air-tubes will be seen as fine white tubes, much branched and extending to all organs and tissues of the body. The tracheæ open to the outside through the spiracles. Demonstrate this connection.

2. **Digestive System.**—Distinguish the following parts: (*a*) **esophagus**, leading from the mouth to the crop; (*b*) **crop**, a large organ located in the prothorax; (*c*) **gastric cæca**, a series of pouches surrounding the posterior end of the crop; how many are there? Do they connect with the cavity of the crop? (*d*) The **stomach** is an enlarged part behind the cæca; (*e*) **intestine** the posterior portion

of the digestive tube ending at the anus. The intestine is made up of three parts.

3. **Excretory System.**—This comprises a number of delicate capillary tubes, the **Malpighian tubules**, which are twisted together and may partly fill the body cavity. They connect with the digestive canal at the point where the stomach and intestine join.

4. **Reproductive System.**—The reproductive organs, **testes** or **ovaries**, are present in the abdomen, dorsal to the digestive tube. These organs are made up of tubules closely packed together. They open to the exterior through the sperm ducts or oviducts, whose openings are ventral to the anal opening. The ovary in mature animals may be a mass of eggs completely filling the body cavity.

Make a large drawing to show all the organs and systems worked out.

5. **Nervous System.**—Remove the alimentary canal and the reproductive organs. The **nerve cord** should now appear along the median ventral line, covered over with a thin sheet of fat tissue. Are **ganglia** present? How many in the abdomen? In the thorax? Is there a ganglion to each somite? Where are the ganglia largest? Trace the general direction of the nerves which leave the ganglia. In the head is a ventral **infra-esophageal** ganglion, and a dorsal **supra-esophageal** ganglion or brain. These two large ganglia are connected by **circum-esophageal commissures.** From the brain nerves go to the ocelli, compound eyes, and antennæ.

Make a large drawing showing the nervous system.

Compare the crayfish, the grasshopper and the earthworm in regard to: (*a*) The plan upon which the body is constructed; (*b*) the organization of somites into well defined regions; (*c*) the arrangement and structure of the appendages; (*d*) the number, position and structure of the sense organs; (*e*) the structure of the circulatory, digestive and nervous systems. Which of these animals is the more highly specialized? Is one better adapted to its modes of life than the others? Give reasons for your conclusions.

III. Physiology.

From a study in the field and in the laboratory work out the following activities of the grasshopper.

1. **Movements.**—Describe the kinds and methods of locomotion. What structural features of the legs are adaptations for leaping? How many times the length of the body may the grasshopper leap? What is the purpose of the hooks on the legs? Are both pairs of wings used for flight?

2. **Sensitiveness.**—With a bristle touch various parts of the body, including the antennæ. Which is the most sensitive part? Does the grasshopper see? What evidence is there of this? Is there any evidence that it hears?

3. **Protection.**—Has the grasshopper any means of defense? Is it protected by color? How does it escape its enemies?

4. **Respiration.**—Observe the respiratory movements of the abdomen. Knowing the structure of the respiratory system, which is characteristic of all insects, explain why non-poisonous powders may often kill insects.

5. **Nutrition.**—Place animals in a cage with leaves of grass and other plants. If possible observe the method of using the different mouth parts. By using different kinds of plants it may be possible to determine whether there is any choice of food.

HONEY BEE.

Apis Mellifica.

The honey bee belongs to the class Insecta and, therefore, has certain characteristics in common with the grasshopper and other insects. For example, there is the same division into head, thorax and abdomen; a subdivision of thorax and abdomen into segments; and a similar number and disposition of antennæ, eyes, legs and wings. The grasshopper, however, is a relatively simple insect, while the bee is one of the most complex. The bee is of interest from its habit of community or social life, with different castes or classes in the community. It is also of interest in its highly specialized and adapted organs, as compared with the more simple ones of the grasshopper.

External Anatomy.

1. **General Characters.**—Notice the division of the body into regions, and compare with the grasshopper. Especially note the covering of **hairs** over the body, is this present in all parts or is it limited in distribution? Remove some of the hairs, place on a slide and examine with the compound microscope. The longer hairs of the body differ in what way from the shorter hairs of the appendages?

2. **Head.**—Is the head freely movable? Is it more or less so than in the grasshopper? The **compound eyes** are quite similar to those of the grasshopper, but observe the short spine-like hairs on their surface. Compare the com-

pound eyes of a worker and of a drone bee; in what respects do they differ? What explanation can you give for this difference? The eyes of the queen are like those of the workers. Three **ocelli** are present as in the grasshopper. Observe the position and the structure of the **antennæ.**

3. **Mouth Parts.**—The mouth parts of the bee are the same in number as those of the grasshopper, but greatly modified and adapted to different functions.

(*a*) **Labrum.**—This is a flap of skin forming an upper lip.

(*b*) **Mandible.**—There is a pair of mandibles or jaws behind the labrum. Both the mandible and the labrum are quite similar to those of the grasshopper, but somewhat reduced in size. The mandibles of the worker differ slightly from those of the queen and the drone.

The remaining mouth parts, the maxillæ and labium, are much modified and together form a proboscis for sucking liquid food.

(*c*) **Maxilla.**—The palp of the maxilla is reduced in size to a mere rudiment. The remainder of the appendage forms the hollow outer portion of the proboscis.

(*d*) **Labium.**—Of this appendage there are three chief parts, the base, the **labial palps,** and the **glossa** or "**tongue.**" The glossa forms the center of the proboscis, is covered with long hairs, and ends in a spoon-like lobe called the **labellum.**

To study the mouth parts straighten them out, away from the head, cut off the entire tip of the head and mount this on a slide in glycerin. It may be necessary to separate these parts somewhat with needles.

Make a drawing of the mouth parts.

4. **Thoracic Appendages.**—(*a*) **Wings.**—Remove the wings from the body and mount on a slide. Study the arrangement of the **veins** in each wing. With the compound microscope observe the **hooks** on the anterior border of the hind wings which attach this to the fore wing. What is there on the fore wing to hold these hooks?

Make a drawing of the wings.

(*b*) **Legs.**—The legs are composed of five segments as those of the grasshopper, but the basal joint of the tarsus or foot is much enlarged and is sometimes called the **metatarsus.** The legs of the bee serve not only for locomotion, but also as tools for other complex functions.

1. **Prothoracic Leg.**—Between the tibia and the first tarsal segment is the **antenna cleaner;** on the outer end of the tibia is a **pollen brush,** composed of stiff hairs.
2. **Mesothoracic Leg.**—At the end of the tibia is a long spine, the **pollen spur.**
3. **Metathoracic Leg.**—How do the tibia and first tarsal joint compare in size with similar parts of the other legs? The outer surface of the tibia is hollowed out to form the **pollen basket;** the inner surface of the first tarsal joint is covered with rows of stiff spines, the **pollen combs.** Between the tibia and the first tarsal joint are the so-called **wax shears,** which, however, are used in gathering pollen and have nothing to do with wax manipulation.

Compare these adaptive specializations of the legs of the worker with the legs of the drone, and note what differences occur. Is it possible to explain these differences?

Remove each of the legs from the body, study with a lens or low power, and make drawings to show the points observed.

5. **The Sting.**—The sting is located in a cavity in the end of the abdomen, which is formed by an infolding of some of the posterior abdominal segments. The sting is homologous with the ovipositor of other insects.

Remove the dorsal wall of the end of the abdomen and dissect out the sting apparatus. Mount this on a slide in glycerin and study with low power. There is a shaft composed of a dorsal **sheath** and two barbed **lancets** or **darts.** The sheath and lancets form a hollow tube through which the poison flows. At the sides is a pair of **sting palps,** soft whitish projections, which serve as sense organs by which the bee can tell when she is in contact with the object which is to be stung. When the sting apparatus is removed one or both of the **poison glands** will usually be present. Other parts of the complicated apparatus will also be found. Determine the character of the sting proper and the palps, and make a drawing to show the structures observed.

As a portion of this study the different classes of the community, **drones** (males), **queens** (females), and **workers** (neuters or imperfect females), should be compared. Especially should this comparison be made to determine the differences in structure which are correlated with the specializations of parts for particular functions.

Field studies should be made, if possible, to observe the habits of the bees, especially that of gathering nectar and pollen. An interesting study of the activities within the hive can be made if an observation hive of glass is available.

THE CLAM.

Unio Sp.

The common fresh-water mussels or clams, of almost any genus, are excellent for study. Those of some size are best. The marine clam (Venus) while not so large nor so satisfactory, is quite similar in most of its structural features. Clams live partly buried in the sand or mud, with the posterior end of the body protruding. They may be collected by digging. It is possible to keep them alive for some time if placed in tanks of running water.

I. External Anatomy.

1. **Shell.**—Note the general form and relations of the shell. Are the **valves** (the two parts of the shell) similar in size and form? The dense horny hinge is the dorsal part, and the knob or elevation on the shell (**umbo**) is nearer the anterior end. Has the animal a right and a left side? Observe the parallel, concentric lines extending from the umboes to the margins of the valves; they indicate **lines of growth**, though their number gives no evidence of the age of the clam. Each line was at one time the edge of the shell. Study the action of the **ligament** or **hinge** in a recently opened shell; what function does it serve? The ligament is an uncalcified portion of the shell.

Make a drawing of the shell from the side, and one from the anterior aspect.

2. **Interior Surface of the Shell.**—Wedge the shell open and then cut the muscles which are attached to the valves. When this is done what happens to the valves? What causes this? What is the function of the muscles? (If the animal is preserved and the valves are already open, cut the muscles and determine the functions of muscle and ligament.) Cut the ligament and remove the left valve, being careful not to remove any of the body within the shell; a fold of skin which sticks to the shell must be carefully separated.

Compare the color and markings of the interior of the shell with those on the outside. Are lines of growth present? Are there any scars on the inside of the shell? What has been the cause of these? Find the marks made by the **adductor, retractor,** and **protractor** muscles. (In Venus there is no protractor muscle.) How many of these muscles are there? What is their function? When the clam was smaller than it is now where were the muscles attached? How do you know? Is there any evidence of growth over any part of the muscle scars that now show? At the dorsal side of the valve notice several teeth (not present in all clams), the **hinge teeth.** What is their function?

Draw the interior of the shell.

3. **Structure of the Shell.**—Break the valve that has been removed and examine the broken surface. Notice the thickness of the shell in different regions. Look for layers in the shell, an outer very thin layer, the **periostracum,** greenish or brownish in color. (This layer is not always seen since it may have been worn off.) Next comes the **prismatic** layer, and inside the **nacreous** or mother-of-pearl layer. The periostracum and the prismatic layers are formed by the thickened edge of the mantle. Once formed they cannot be added to except at the edge of the shell.

The nacreous layer is secreted by the surfaces of the body and of the mantle in contact with the shell. It may continue to form throughout life. Is there any proof that this has happened?

4. **Body.**—While working on the following external features of the body remember that while the shell is properly a part of the body, an **exoskeleton**, yet the fleshy part exposed by the removal of the shell is still the external portion of the body of the animal.

(*a*) **Mantle.**—This is the thin membrane lining the shell and covering the rest of the body. How many lobes are there? Are they attached to the shell? If so, where, and to what extent? Are they joined to each other at any point? In the posterior part of the body observe that the margins of the mantle are hollowed out to form two oval openings, a ventral **incurrent**, and a dorsal **excurrent** opening or **siphon** (in Venus the mantle is fused to form two tubes). Determine the cavities into which the openings lead. All the water that comes into the shell enters through the incurrent and all leaves by the excurrent opening. The cavity between the mantle lobes is the mantle cavity and in it are several organs.

(*b*) **Gills.**—Remove or turn back the mantle from one side and expose the gills, which are thin membranes hanging freely in the mantle cavity. How many on each side of the body? Are they of similar size and form? How and where are they attached to the body? In the female the gill acts as a brood pouch during the breeding season and is then greatly distended by the contained embryos. A study of sections of the gill may be made to show the layers of which the gill is composed, the water tubes, and the bloodvessels.

(*c*) **Foot.**—This is the large dense median part of the body; it forms a muscular wedge or keel by means of which the animal moves. Above the foot is the softer visceral mass of the body.

(*d*) **Muscles.**—The **adductor** muscles, already noted, close and hold the shell shut. There are **protractor** muscles for pulling the foot and body ventrally, and extending it from the shell. The **retractor** muscles draw these same parts back into the shell. Note their position and the manner in which they work. (In Venus there is no protractor muscle.)

(*e*) **Labial Palps.**—Small, thin, leaf-like organs behind the anterior adductor muscle. They aid in passing the food to the mouth.

(*f*) **Mouth.**—Between the palps and below the anterior adductor muscle.

(*g*) **Anus.**—Opens into the excurrent or cloacal chamber it will be found against the posterior border of the posterior adductor muscle.

Make a drawing with the mantle removed.

II. Internal Anatomy.

1. **Circulatory System.**—The heart lies dorsally between the ligament and the bases of the gills in an oval sac, the **pericardial cavity.** Dissect the pericardium from the dorsal side and expose the cavity and the heart. The latter is made up of a central muscular portion, the **ventricle,** and two triangular lateral portions, the **auricles.** Compare the auricles and ventricles in thickness of walls. If a live clam is at hand observe the pulsations of the heart. The ventricle surrounds the posterior portion of the intestine. There are two arteries leaving the ventricle, the **anterior aorta** and

the **posterior aorta,** which carry blood to different regions. **Veins** return the blood to kidneys, gills, and auricles.

2. **Excretory System.**—The **kidney** is a dark greenish gland on either side of, and ventral to, the pericardial sac. Each kidney is a wide thin-walled tube, doubled on itself so that the two ends are close to each other. These ends are anterior and about opposite, and ventral to, the anterior end of the pericardium, while the loop is posterior and lies against the posterior adductor muscle. One end of the kidney opens into the pericardium, the other into the cavity of the inner gill.

3. **Nervous System.**—This system is composed of three pairs of **ganglia** connected by nerves. First locate the **visceral ganglion** just under the posterior adductor muscle. It will appear as a yellowish mass under the skin which covers the muscle. How many nerves arise from this center? To what regions or organs do they go? A small nerve on either side extends forward from this mass to the brain. The brain or **cerebral ganglia** will be found just under the palps above the mouth, one on either side. From this nerves extend to the adductor muscle, mantle and palps. Also a nerve, the cerebral connective, connects the two ganglia.

The **pedal ganglia** are a fused pair in the foot and are joined to the cerebral ganglia by connectives. These ganglia will be found while working on the digestive system.

4. **Digestive System.**—With a razor split the foot and the visceral mass vertically in the median line. Identify the following parts: The **mouth** is immediately behind the anterior adductor muscle. From this a short **esophagus** leads to the **stomach,** which is in the dorsal part of the body. Note the greenish digestive gland, or **liver,** surrounding the stomach. The **intestine** extends from the ventral side of the stomach to the ventral part of the foot, then poste-

riorly through the foot. Here it turns on itself and extends anteriorly again, then dorsally, passes through the ventricle of the heart, goes dorsal to the posterior adductor muscle, and ends at the anus in the cloacal chamber.

5. **The Reproductive Organs.**—The **ovaries,** or **testes,** are present in the visceral mass of the body. They are usually light brown in color and entirely fill the spaces between the folds of the intestine. The ducts empty near those of the kidney in the supra-branchial chamber.

Make a large drawing to show all the organs studied.

6. **Sections of the Body.**—In order to show the relations of the various organs of the body in a manner as clear as possible a study of sections of the body is desirable. These are sections across the entire body at different regions. Make drawings of the sections and show the position and arrangement of the organs that are in the section. Show the plan of the organs by making the drawings rather diagrammatic.

(*a*) Section through the stomach, shows the **stomach, mantle, palps, liver, reproductive** organs, anterior **aorta, foot.**

(*b*) Section through the heart. **Mantle folds, gills, supra-branchial chamber, intestine** (cut across several times), **pericardial cavity, ventricle, auricles, vena cava** (a large vein in the center of the body below the pericardial cavity), **kidney, ureters, reproductive organs.**

(*c*) Section through the posterior adductor muscle. **Adductor muscle, intestine, gills, supra-branchial cavities, mantle, visceral ganglia** of the nervous system.

III. Physiology.

1. **Sensitiveness.**—Place a clam in a dish of water and allow it to remain until the shell opens and the foot and

edges of the mantle are extended. Use a bristle or a delicate glass rod to test the sensitiveness of the various parts exposed. Determine whether foot or mantle, and which portions of the mantle, are most sensitive; test especially the edges of the siphons. What response is made to delicate tactile stimuli? To stronger stimuli?

Sensitiveness to chemical substances may be tested by directing gentle currents from a pipette against various portions of the body.

Place a specimen in a very dim light, and when the shell opens direct a beam of light against the body. Is there a response to this stimulus? Place the animal in sunlight or bright light from some artificial source, and interpose a screen between the light and the animal, thus casting a shadow upon the body. Note the character of such responses as occur.

2. **Circulation of Water.**—Introduce a few drops of a colored fluid into the water near the posterior end of a clam whose shell is open. If the water is drawn into the shell observe the place where it enters. Does the colored fluid pass out of the shell again? Where is the point of exit? What service to the clam would there be in such incurrent and excurrent movements of the water? Further light on this advantage will be gained by observing a clam partly buried in the sand in the normal manner.

3. **Feeding.**—Carefully insert a knife between the valves of a living clam and cut the two adductor muscles where they are attached to the shell. Loosen the mantle and remove one valve entirely, thus exposing the body. Lay back the mantle, or cut it loose, to expose gills and palps. Drop some powdered carmine, chalk, or other small solid particles upon the surface of the gills and note any movement of these particles. In what direction is the movement?

Are any of the particles carried far enough forward to reach the mouth? In the clam it is by ciliary movements that small organic particles are carried to the mouth, and the entire food is composed of these particles.

4. **Heart Beat.**—In a specimen with one shell removed observe carefully the region of the body dorsal to the gills and in front of the posterior adductor muscle. This is the position of the heart and its pulsations may be seen through the delicate walls of the mantle. If care is used one may remove the mantle and pericardial walls and expose the heart itself. When the heart is exposed the pulsations of auricle and ventricle may be easily observed.

SNAIL.

Helix Pomatia.

For this study the French snail is suggested, but the common pond snails, Physa, Planorbis, Limnæa can be used.

1. **The Living Animal.**—How does the snail move? What is the shape of the foot? What is the relation of the foot to the rest of the body? What is its relation to the shell? The anterior part of the foot is called the **propodium,** the posterior portion the **metapodium,** and between these two is the **mesopodium.** Are these regions sharply marked off?

2. **Head.**—At the anterior end note the position and form of the mouth. **Tentacles** are present in this region. How many? Size and form? Touch one with a needle. What happens? On the tentacles are small, pigmented, glistening spots, the **eyes.** Note their position and number.

Locate the **anal opening** on the right side of the head. In the air-breathing snails the **respiratory opening** is near the anal opening.

3. **Shell.**—Is there a division into valves? How many turns does the shell make? Do the shells vary in size? Do the coils turn to the right, or to the left? Is the coiling loose or close, flat or conical? The **apex** of the shell is the oldest part, the opening of the shell is the newest part of the shell. In some species one side of the mouth of the shell is drawn out into a spout-like process. For what purpose is this? In some snails there is an oval plate which closes

the opening of the shell when the animal withdraws into it. Is there such a plate, or **operculum**, in the form you are studying?

The lines that run parallel to the mouth of the shell are lines of growth. Are these uniformly spaced? Can you explain any variations? The whorls or turns of the shell run around a central axis, the **columella**. Observe the columella and the spirals of the shell in a broken shell. Describe the relations of the columella to the other parts of the shell.

Make a drawing of the snail from the side, showing the foot, head, shell.

THE FISH.

Perch, Sucker, Cunner, or other Bony Fish.

While the following directions have been made with reference to the perch, the others named, or indeed almost any species at hand may be employed. It will be especially valuable to have a few living specimens, minnows or gold-fish, in a laboratory aquarium for actual observations of movements.

For dissection preserved specimens are quite as good as those freshly killed or obtained from the market; the last are likely to have been kept in storage for some time and the internal organs are often worthless for study.

I. General Features.

Note the shape of the body and its special differential features—head, tail, body proper, fins. Are the body features sharply marked? How do they compare with those of the frog? Is the shape adapted to the life and habits of the fish? Note the scales, their shape and arrangement. Are they found on all parts of the body? How are they attached to the body? What is their relation to the skin? Examine a few quite critically and decide whether they are entirely naked and whether the margin is smooth or toothed. A scale with a smooth, rounded outline is called **cycloid**, one with a toothed margin is called **ctenoid**; to which of these does your specimen belong?

II. External Anatomy.

1. **Fins.**—How many are there? Where are they located? Are they alike? Fins are said to be **paired** or **single.** The paired are called **pectoral,** occupying a position similar to the fore legs of the frog, and **ventral,** situated back of the pectorals and on the ventral side of the body. How many unpaired fins? The one just behind the vent is known as the **anal,** one occupying the median dorsal position is the **dorsal.** What others are present and how characterized? Study especially the structure of the paired fins and compare with the others. In what alike, in what different? Study also the ray-like structure of the supporting rods of the fins, are they alike in all?

2. **Mouth.**—Note its shape and size. Open and close the lower jaw and observe the movements of the several parts. Are there lips? Identify the following bones of the upper jaw: **premaxillary,** forming the anterior and lateral portion and extending backward to unite with the **maxillary.** Do both bear **teeth**? What is the shape of the teeth? The lower jaw is composed of the **dentary** bones. Do they bear teeth? Compare with those of the upper jaw. Within the mouth cavity note the shape, size and position of the **tongue.**

3. **The Eyes.**—Observe their location, size and shape. Test the range of motion by pressing them with the forceps or finger. Are there **eyelids**?

4. **Nostrils.**—How many openings? What is their shape and position? Do the nostrils communicate with the mouth as in the frog? Are they of use in breathing? How do they operate in smelling?

5. **Gill Openings.**—Observe that these openings are on the side of the head and are covered by flaps, the **opercles.**

Can you identify the **subopercle, preopercle, interopercle?** Under the opercles on the ventral side is the **branchiostegal membrane** and the **branchiostegal rays** which support the membrane. How many are there? Raise the operculum and examine the **gills,** their number and arrangement and method of support. On the anterior margin of the **gill arches** are teeth called **gill rakers.** What function can you suggest for them? Press down the tongue and observe the effect upon gills and gill rakers. How does the fish breathe? What motions are involved? Watch a fish in the aquarium to find an answer to these questions.

6. **Lateral Line.**—A series of raised, dot-like markings along the sides of the body. Examine one of the scales which has on it one of the dots and see what it is like. The lateral line has a sensory function.

7. **Openings.**—Just in front of the anal fin look for openings of the **anus** and **genital organs.**

Make a drawing of the fish as seen from the side.

III. Internal Anatomy.

Make a median incision just in front of the anus and carry it forward to the hinder border of the gills, being careful not to injure the underlying organs. Make cuts at right angles so that the flaps may be pressed to one side. Place the fish on its side and work out the internal organs. Compare the body cavity with that of the frog. Is there a **thoracic** cavity distinct from an **abdominal?**

1. **Liver.**—This is a reddish organ of considerable size. How is it held in place? Is there more than a single lobe in it? Is a **gall-bladder** present as in the frog?

2. **Stomach.**—Raise the liver and push it to one side to expose the **stomach.** From the stomach the **esophagus**

leads to the mouth, and extending posteriorly to the anus is the **intestine**. What is the shape and size of the stomach? Are there **pyloric cœca** present? (These are small finger-shaped filaments, not present in all fish.) Note the **mesentery** which supports the stomach and intestine.

3. **Spleen.**—Observe its shape, color and position in the mesentery.

4. **Reproductive Organs.**—The size of these organs will depend upon the season, *i. e.*, whether it be before or after the breeding period. At this season they are large and may fill up most of the body cavity. The **testes** are usually whitish organs occupying a position similar to that in the frog. The **ovaries** may vary in color and are often bright yellow or orange. Determine the openings of these organs in the posterior part of the body cavity.

5. **Kidney.**—Along the dorsal wall of the body cavity is the large **air bladder** and just above are the two kidneys. The **kidneys** open into the **urinary bladder** in the posterior part of the body, and this opens to the outside just back of the anus.

6. **Heart.**—The heart is in the extreme anterior part of the body. Is it in the same cavity as the other organs? What is the shape, and of how many chambers is it composed? If it is desired to trace the bloodvessels they should be injected as in the frog.

Make a drawing in side view to show the internal organs.

7. **Nervous System.**—This system in the fish has much in common with that of the frog. The brain and cord can be more easily dissected in a specimen preserved in formalin.

8. **Brain.**—Dissect off the skin and muscle and finally the bony skull thus exposing the brain, and note: (*a*) the **cerebral hemispheres**; (*b*) **olfactory lobes**; (*c*) **optic lobes**; (*d*) **thalamencephalon,** between (*a*) and (*c*), upon which

note the **pineal body**; (*e*) **cerebellum**; (*f*) **medulla oblongata,** from which continues the **cord.**

9. **Nerves.**—The ten pairs of **cranial** nerves are very similar to those of the frog and have the same names. The **spinal** nerves may be exposed and their distribution studied as may be directed by the instructor.

Make drawings to show the nervous system.

CLASSIFICATION OF LIVING THINGS.

Both as a convenience in the study of organisms, and as in some degree indicative of their genetic relationships, various efforts have been made to arrange them under such a systematic classification as would serve these ends. The work involved in the foregoing laboratory course, while dealing with a few typical organisms, and devoted chiefly to their morphology and physiology, has also revealed unmistakable relationships of structure and function, which in turn have afforded evidence of the larger relationships of descent. That a given kind or species of animals has descended from a common line of ancestry is of course universally recognized. That differing, but closely similar, species have likewise descended from a common ancestor slightly more remote is also generally recognized as a fact. Out of the study of large series of such facts has come the conception of evolution, long known to students of biology, but first brought into prominence by Lamarck and Darwin. All modern systems of classification have been attempts to express the facts of such relationships of descent or evolution. The following partial and abbreviated tabulation of the animal kingdom may illustrate, in a general way, the main features of the subject.

PHYLUM PROTOZOA.—Unicellular, microscopic animals, or colonies of independent cells.

Class 1. Rhizopoda.—Protozoa possessing the power of thrusting out pseudopodia. A shell is often present. Amœba, Arcella, Heliozoa.

Class 2. Mastigophora.—Protozoa, generally of small size, provided with one or more flagella. Euglena, Peranema, Pandorina, Volvox.

Class 3. Infusoria.—Protozoa bearing cilia, with mouth and contractile vacuole always present. Paramecium, Vorticella, Stentor, Colpoda.

Class 4. Sporozoa.—Parasitic protozoa without motile organs in the adult; reproduce by spore formation. Plasmodium.

PHYLUM PORIFERA.—Radially symmetrical animals, the body wall containing many pores for the entrance of water, and usually supported by a skeleton of spicules.

PHLYUM CŒLENTERATA.—Radially symmetrical animals with mouth and gastro-vascular cavity, but without cœlom. Stinging cells present.

Class 1. Hydrozoa.—Cœlenterates with solitary or colonial polyps, and with an alternation of generations. The medusæ have a velum. Hydra, Pennaria, Obelia, Gonionemus.

Class 2. Scyphozoa.—Cœlenterates of considerable size, the medusa prominent but the polyps much reduced or absent. The edge of the bell is lobed and a velum is not present. Aurelia, Cyanea.

Class 3. Actinozoa.—Polyps solitary or colonial, with esophageal tube and mesenteric folds. A medusa generation is entirely lacking. Sea anemones and corals.

PHYLUM ECHINODERMATA.—Radially symmetrical animals usually with a pentamerous arrangement. Mouth and anus present, cœlom well developed, a water vascular system. The body wall contains calcareous plates and usually bears spines.

Class 1. Asteroidea.—Star-shaped forms, the arms not sharply marked off from disc but with an ambulacral groove from which tube-feet project. Starfish.

Class 2. Ophiuroidea.—Star-shaped forms, the arms sharply marked off from disc and without ambulacral groove. Brittle stars, serpent stars.

Class 3. Echinoidea.—Spheroidal or discoidal forms with a shell of closely fitting plates and with movable spines. Tube feet project from five rows of pores on the shell. Sea urchins.

Class 4. Holothuroidea.—Elongated worm-like echinoderms with muscular body wall containing scattered plates. Contractile tentacles about the mouth, and tube feet in the form of papillæ. Sea cucumbers.

PHYLUM PLATYHELMINTHES.—Flattened, bilaterally symmetrical, worm-like animals with an excretory system of branched canals containing flame cells. Anus is not present, and cœlom not developed.

Class 1. Turbellaria.—Free living Platyhelminthes with a ciliated ectoderm and a centrally located muscular, protrusible proboscis. Planaria.

Class 2. Trematoda.—Parasitic forms with unsegmented, flattened body. Anteriorly placed mouth and one or more ventral suckers. Liver fluke.

Class 3. Cestoda.—Elongated, and usually segmented, Platyhelminthes without mouth or digestive tube. Suckers or hooks at one end, and a complete reproductive system in each mature segment. Tape worms.

PHYLUM NEMATHELMINTHES.—Elongated, cylindrical or thread-like worms with unsegmented body. Terminal mouth and anus, cœlom present, appendages wanting. Body covered with a heavy cuticle. Free living or parasitic. Pork worm (Trichinella), vinegar eel, thread worms.

PHYLUM ANNELIDA.—Segmented worms, usually with a well marked cœlom. Internal organs segmentally arranged. As a rule chitinous setæ are embedded in the skin.

Class 1. Chætopoda.—Annelida with conspicuous setæ. The well marked cœlom divided by septa. Earthworm, Nereis.

Class 2. Hirudinea.—Elongated, flattened annelida with anterior and posterior suckers, without setæ and with median genital openings. Cœlom much reduced. Leeches.

Class 3. Gephyræa. Unsegmented worm-like animals with a spacious cœlom not divided by septa, an anterior anus and a single pair of nephridia. Setæ absent.

PHYLUM MOLLUSCA.—Bilaterally symmetrical, unsegmented animals, with a ventral foot, a mantle fold, and usually a univalve or bivalve shell. The central nervous system consists of a circum-esophageal ring.

Class 1. Lamellibranchiata.—Symmetrical mollusca without head; with bilobed mantle, bivalve shell, and usually with lamellate gills. Clams, mussels, oysters.

Class 2. Gastropoda.—Asymmetrical mollusca with a distinct head usually bearing tentacles, a muscular creeping foot, a continuous mantle fold and usually a coiled shell of one piece. Snails.

Class 3. Cephalopoda.—Mollusca with a well marked head, a circle of arms bearing suckers around the mouth, and well developed eyes. There is a heavy muscular mantle fold; the nervous system is concentrated in the head. Squid, octopus.

PHYLUM ARTHROPODA.—Segmented animals with a firm external skeleton and jointed appendages.

Class 1. Crustacea.—Aquatic arthropods breathing by means of gills, with two pairs of antennæ and numerous pairs of biramous appendages on thorax and abdomen. Crayfish, lobster, crab, water flea, barnacles.

Class 2. Myriapoda.—Worm-like arthropods with numerous similar segments bearing similar appendages. One pair of antennæ, breathe by means of tracheæ. Millipeds, centipedes.

Class 3. Insecta.—Arthropoda with the adults usually bearing three pairs of legs and two pairs of wings; body divided into head, thorax and abdomen; single pair of antennæ; breathe by tracheæ. A metamorphosis is common in the life history. Fly, mosquito, beetle, grasshopper, bee.

Class 4. Arachnida.—Arthropoda without antennæ, with four pairs of legs and two pairs of mouth parts. Body divided into cephalothorax and abdomen. Breathe by means of tracheæ and book lungs. Spiders, mites, scorpions.

PHYLUM VERTEBRATA.—Animals with dorsal brain and cord, enclosed in an unsegmented skull and a segmented vertebral column. Red blood; usually with two pairs of appendages.

Class 1. Pisces.—Aquatic vertebrates breathing by means of gills; typically with two paired and other unpaired fins. Fishes.

Class 2. **Amphibia.**—Cold blooded vertebrates with naked scaleless skin. Breathe by lungs in adult life commonly, the larvæ breathe by gills. Heart with two auricles and a single ventricle. Frogs, toads, salamanders.

Class 3. **Reptilia.**—Cold blooded scaly vertebrates. Breathe by lungs; heart with auricles and two imperfectly separated ventricles. Snakes, turtles, alligators, lizards.

Class 4. **Aves.**—Warm blooded, oviparous, bipedal vertebrates covered with feathers. The chambers of the heart are completely separated. The anterior appendages have the form of wings. Birds.

Class 5. **Mammalia.**—Warm blooded, hairy vertebrates. Viviparous; mammary glands with which they suckle the young. Red blood corpuscles non-nucleated. Mammals.

10

APPENDIX.

Collection and Preparation of Material.

Amœba.—While amœba has a wide distribution, in no place is it very abundant, nor are culture methods as successful as with other protozoa. By putting Elodea, Ceratophyllum, or other water plants, into a shallow dish with a small amount of water and allowing the plants to decay, amœbæ may often be found in some abundance in the slimy sediment. The slime on lily pads often contains amœbæ. Occasionally amœbæ will be extremely abundant in the scum on a freshly started hay infusion, especially when pond weeds have been present in the infusion.

Paramecium.—Into a hay infusion twenty-four hours old (that made from dry timothy hay is best), place some water and organic matter from almost any pond or swamp. After about a week Paramecium will be found in abundance. Or fill a jar half full of Elodea or other pond weeds, cover with water and allow the plants to decay. Do not place the jars in the direct sunlight.

To keep a culture in vigorous condition remove some of the old hay and about one-third of the water, and add fresh hay and water, every two or three days. If several cultures are running and are changed on different days one may have vigorous cultures of Paramecium constantly.

Conjugating paramecia are often obtained a few days or a week after a fresh culture is started, if the culture has been started by bringing in Paramecium from outside.

Paramecium probably never encysts and a hay infusion made as sometimes directed, but not inoculated from some source containing the animals, will not give rise to paramecia. The culture **must be inoculated** from an old culture, or the animals must be introduced from outside sources.

To kill Paramecium hot Worcester's fluid is probably the best. A round bottomed vial is filled one-third full from a good culture, with as many of the animals and as little fluid as possible. Fill the vial to the top with hot Worcester's fluid and allow to stand fifteen minutes, during which time the animals will settle to the bottom. With a pipette draw off as much of the killing fluid as possible and add water to wash, using several changes and stirring up the mass of paramecia as little as possible. Stain in hematoxylin rather heavily, destain with weak acid, or acid alcohol, until the color is very faint except in the nucleus. Wash in water, dehydrate, clear and mount on a slide in balsam. Support the cover glass to prevent crushing the animals.

Vorticella.—If sticks, leaves, and pond weeds are placed in a jar and allowed to stand a day or two a scum will form on the water, and in this scum Vorticella will often be abundant. In such fresh cultures large specimens are usually found. The methods used for continuing Paramecium cultures will be fairly successful for Vorticella. Similar methods of killing and staining may be used but are not very successful, on account of the contraction which usually takes place in Vorticella.

Hydra.—In ponds, swamps, and slow moving streams covered with "duck-weed" (Lemna) green hydra will often be abundant in spring and summer. Brown hydra is more often found in larger ponds and lakes on Sagittaria and pond-lily leaves. Place the plants, in both cases, in jars and set in a bright place, but not in the direct sunlight. Within a few days hydra, if present, will be found on the side of the jar toward the light. In the autumn secure leaves from the bottom of the pond and some of the surface mud.

Hydra will flourish if the jar is kept supplied with an abundance of "water-fleas," Daphnia, Cyclops, Cypris, etc., and budding will be abundant on the hydras. If the food supply is allowed to diminish reproductive organs will often begin to appear.

To kill hydra expanded remove a single specimen from the aquarium with a pipette and place in a perfectly clean watch glass with only a small amount of water. When the animal in the watch glass is well expanded dash hot Worcester's fluid, or hot Bouin's fluid, over it and allow to stand ten minutes. The animal may then be washed and treated for further use by staining or embedding for sections. Handle very carefully since the killing fluid makes them rather brittle. If whole mounts are desired a light stain with hematoxylin is good. When mounting support the cover glass to prevent crushing.

Hydroids, Jelly-fish.—If these are collected the jelly-fish should be preserved in formalin. Obelia should be narcotized with magnesium sulphate before killing, to get the hydranths expanded. It is well to have the hydroids killed in some killing fluid and preserved in alcohol, though for general external study preservation in formalin is satisfactory. To make whole mounts of the hydroids proceed as for hydra.

Earthworm.—In the spring and early summer after a soaking rain large earthworms can easily be obtained at night. With a light examine the ground, preferably in a garden or where there is little grass. Place the worms in a can with a little soil until morning.

To preserve put the worms in a dish or pan with enough water to just cover them and add a few drops of alcohol every few minutes. After several hours they will be found to be motionless and should not respond to tactile stimuli. They should now be laid out straight and flat in a disk of weak alcohol and allowed to remain for not more than four hours. They are then to be placed in 80 per cent alcohol, or better a mixture of alcohol and 10 per cent formalin for preservation. The worms should be kept straight in the preservative since they are much easier to study when in this condition.

A somewhat clearer demonstration of setæ and of external openings can be made on worms killed (after narcotizing) in 1 per cent chromic acid. After twenty-four hours in the chromic acid, wash overnight in water and preserve in alcohol. These are not so good for internal study.

For sectioning place worms in a dish with moist filter paper and leave for several days until they void clean filter paper instead of dirt. The digestive tract is now in condition for sectioning. Narcotize with alcohol (or chloral hydrate, or chloretone) and when motionless cut into small pieces and fix in Bouin's fluid.

It is very easy to keep earthworms alive all winter with little or no trouble. In a wooden box filled with moist loamy soil place a number of worms and keep the box in a cool place. Every few days leaves, pieces of apple, etc., should be spread on the surface for the worms to feed upon. Cover the box with a heavy cloth (burlap) which is kept moist and the soil will need very little attention. If the soil should appear dry it must be sprinkled enough to thoroughly moisten it.

Grasshopper.—The larger grasshoppers are best for study on account of their size, and are necessary if much internal study is to be made. But for the study of external features the small red-legged locust (*Melanoplus femur-rubrum*) will be satisfactory. Some of these should be alive in the laboratory for study of the habits of living specimens. Preserve insects in alcohol, rather than formalin.

Crayfish.—Crayfish may be purchased alive from dealers, or collected. If they are collected in the autumn and placed in a tank (or tub) with water and kept in a cool, rather dark place, they will live for a long time. If running water is not available the water in the tank should be changed occasionally, especially if a scum appears on it.

For demonstrating water currents over the gills use powdered carmine, India-ink, methylene blue, etc., and drop along the edge of the carapace. A piece of the carapace at the side of the mouth parts may be removed in the living animal, if carefully done, and the movement of the gill bailer demonstrated.

The heart and larger bloodvessels are easily injected with a thin starch mass. Either remove a piece of the carapace and with syringe gently inject the mass into the heart, or if the position of the heart is determined the carapace and heart may be pierced with the cannula of the syringe.

For preservation cut away a small piece of the carapace on the dorsal side to permit the entrance of the preservative. Alcohol is a better preservative than formalin since the acid in the latter dissolves out some of the mineral matter of the shell, and leaves an undesirable scum on the liquid and about the animals.

Clam.—The fresh water clam is much easier and better for study than the salt water forms. Use the larger forms. If the valves are forced open and a wedge of wood, or a pebble, is placed between to prevent closing, the animals may be thrown directly into formalin for preservation. They may be kept alive for some time in a cool place with running water.

To harden for making macroscopic sections across the body, wedge the valves open, place in 1 per cent chromic acid for a day or so. Wash in water and preserve in alcohol. When ready for sectioning remove the valves carefully, place the body of the clam on a piece of cork or wax and with a razor or brain knife make sections from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick.

Snail.—If the edible snail (French or Roman snail) is used it must be purchased from dealers.

Frog.—Any of the common frogs will do, though they should be as large as possible. For the study of living specimens in the winter, material must be obtained from dealers unless it has been collected earlier and kept alive in a tank. If the animals are placed in a tank and kept in a cool place in running water, or the water frequently changed, and there is a platform or float on which they may rest, it is possible to keep them alive all winter. During cold weather food is not needed. To preserve, anesthetize with ether or chloroform and place in 5 per cent formalin. Alcohol is not so good as a preservative for these forms.

For demonstration of circulation in the web, narcotize the frog with chloretone, place on a plate of glass and cover body with damp cloth. Hold the toes spread apart with bent pins held in place against the glass with masses of putty or wax.

To inject the bloodvessels for the study of the arterial system proceed as follows: Anesthetize the frogs with chloroform or ether (the latter leaves them in somewhat better condition), remove a piece of the pectoral girdle from over the heart, and remove the pericardium. With the scissors cut a slit in the ventricle, insert the cannula through the ventricle into the truncus arteriosus, and with a steady, gentle pressure fill the arteries with the injection mass (formula for injection mass on page 159). No ligature will be needed since the valves of the truncus prevent the backward flow of the mass. During the injection of the arteries the blood has been forced into the veins, and because of this it is possible to follow the veins fairly well without injecting them. After the injection is complete, the blood and excess injection mass should be washed off, and the frogs preserved in formalin.

For the study of the histology of the frog examine fresh tissues in normal salt solution. For sections of the spinal cord fix in 10 per cent formalin, embed in paraffin and make rather thick sections. Borax carmine or hematoxylin are good stains to show the general form and something of the cells. For a sharp distinction of the white and gray substances Weigert's hematoxylin method for medullated nerves gives beautiful results. (See directions in books on technic. The mordant of copper acetate may be used after the sections are on the slide.) For sections of the stomach cut the organ into two parts, rinse in salt solution and fix twenty-four hours in Zenker's fluid. Hematoxylin and Congo-red are good stains to differentiate the tissues.

In the spring get spawn from ponds and place small masses in jars for the study of the development. Water plants in the jars will help to aërate the water. If the water at any time appears turbid, change. The tadpoles may be kept for some time after hatching if the aquaria are kept supplied with algæ or other water plants.

Preparation and Mounting of Slides.

To get the best results in mounting small objects or sections, the animal or tissue must be properly prepared. It must be killed quickly so that the constituents of the cells are fixed in a normal condition. Usually some hardening of the tissue takes place during the fixation, but if not the alcohol used for preservation will also accomplish this purpose.

Killing and **fixing** reagents are numerous; some are good for a special purpose only and others have a wider use. Those mentioned among the reagents are good, easily used, and satisfactory for any of the work demanded in a beginning course.

After fixation the tissue must be washed to remove the excess of the reagent, and then preserved in 80 per cent alcohol until wanted for use. Since this procedure has a bleaching effect on the tissues, dyes are used to stain the object to make it more easily seen. If sections are desired it is necessary to embed the tissue or organ in paraffin or other medium to support the softer mass while the sections are being made. Directions for this must be had from books on histological technic.

For examination of living tissues normal salt solution is the medium used; for fresh water animals, if alive, water is used; preserved animals are examined in the solution in which they are preserved. Glycerin is used if it is desired to render the objects somewhat transparent. They may be placed in the glycerin from water, alcohol, or formalin directly.

If a permanent mount is desired the object is usually first stained, then dehydrated by placing for about an hour in alcohol of various grades (35 per cent, 50 per cent, 70 per cent, 80 per cent, 95 per cent). If absolute alcohol is at hand they should be placed in this for an hour to complete the dehydration. To remove the alcohol some fluid, usually an oil, is used which will mix with the alcohol and also with the balsam which is used to complete the mounting.

Cedar-wood oil, clove oil, creosote, xylol and benzol are some of the common fluids used for this purpose. Not only do they remove the alcohol but they also render the object transparent and are therefore called clearing agents. Cedar-wood oil and xylol are the most commonly used of the oils mentioned. When the object has become transparent it is placed on a slide, the excess of oil allowed to run off, or removed with filter paper, then a drop of Canada balsam placed on the object and this is covered with a thin cover glass which is allowed to gently settle on the object. When the balsam has hardened the object is permanently fixed.

If absolute alcohol is not at hand for the final dehydration, place the object from 95 per cent alcohol directly into a mixture of one-third beechwood creosote and two-thirds xylol, or into the same proportions of xylol and melted carbolic acid crystals. Cedar oil and oil of cloves will also clear directly from 95 per cent alcohol. After the object has been cleared proceed as directed in the previous paragraph. Before a slide is laid away it should be labeled as to the animal, or part, or tissue; how fixed; how stained; date and name of person making the preparation.

Reagents.

Acetic Acid.—A solution of 0.2 per cent to 1 per cent applied to fresh tissues will render the nuclei visible.

Alcohol.—This is the most used reagent in the laboratory and should be kept on hand in abundance, made up in various strengths. Alcohol is rather expensive if bought in small amounts from a druggist or ordinary dealer, but it can be purchased, for scientific purposes, with the revenue tax remitted. The collector of internal revenue of the district, or the Federal Treasury Department can give directions for its purchase. Denatured alcohol may be used and is cheaper, and about as satisfactory, as the regular alcohol. Grain or ethyl, and not wood or methyl alcohol, should be used; the latter is poisonous.

Commercial alcohol is ordinarily about 95 per cent in strength. To make various grades from the commercial product, fill a graduate with 95 per cent to the mark which indicates the desired strength, and then add water up to 95 cc (*e. g.*, to make 70 per cent from 95 per cent take 70 cc of alcohol and add water up to 95 cc). It is well to have alcohol of the following grades prepared: 35 per cent, 50 per cent, 70 per cent, 80 per cent, 95 per cent. These will be used in the preparation of slides. For preservation 70 per cent or 80 per cent is used.

Acid Alcohol.—Of 70 per cent alcohol take 99 cc and of concentrated hydrochloric acid 1cc. Used chiefly for destaining tissues.

Anilin Dyes.—For staining, these may be dissolved in water, or in alcohol of any grade. They are most commonly used in aqueous solutions. It is better to stain for some time with a weak solution, than for a brief period with a strong mixture. Some of the stains will be removed by alcohol, and experience, or reference to some book on technic, must show the best methods of use. The common dyes used for the staining of the cytoplasm are: eosin, congo-red, acid fuchsin, light green, orange G.

Benedict's Solution.—Used in the same way as Fehling's solution for demonstrating the presence of grape sugar. This solution is said not to deteriorate on long standing.

Sodium citrate	173 g.
Sodium carbonate	100 g.

Dissolve in 600 cc water, using heat. Filter and make up to 850 cc with water. Dissolve 17.3 g. of copper sulphate in 100 cc water and make up to 150 cc with water. Add the cupric sulphate solution to the carbonate-citrate solution slowly, stirring. The mixed solution is ready for use.

Borax Carmine.—Dissolve 4 g. borax in 100 cc water. Add 1 g. carmine and dissolve it with heat. Cool and add to the solution 100 cc of 70 per cent alcohol. Filter after twenty-four hours. A good stain for large objects and for tissues in bulk. Use the stain twenty-four hours, and differentiate with acid alcohol.

Bouin's Fluid.

Saturated aqueous picric acid	75 cc
Commercial formalin	25 "
Glacial acetic acid	5 "

It is best to add the acetic acid just before using. Kill the tissue four to twenty-four hours, wash in 50 per cent alcohol, preserve in 80 per cent alcohol. This is one of the best of the killing fluids for general use.

Chloretone.—Make a saturated solution in water. Used for narcotizing animals. In some cases it may be sprayed on top of the water which contains the animals. For narcotizing frogs for demonstrating the circulation of the blood in the web the following method has proved satisfactory: With a pipette inject about 2 cc into the stomach through the esophagus. If after twenty minutes the animal is not quiet repeat the dose. The animal will remain quiet for hours, but will be recovered within twenty-four hours.

Chloriodide of Zinc.

Chloride of zinc	30.0 g.
Potassium iodide	5.0 g.
Iodine	0.89 g.

Dissolve the above ingredients in about 15 to 20 cc distilled water. The solution does not keep long, and should be kept in the dark. Used as a test for cellulose.

Fehling's Solution.

A. Copper sulphate 34.65 g. dissolved in . . .	500 cc of water
B. Sodium or potassium hydroxide	125 g.
Sodio-potassium tartrate (Rochelle salts) .	173 g.

Dissolve in 500 cc of water.

Keep solutions separate until ready to use. Just before using mix equal parts of A and B. This solution is used to test for the presence of grape sugar.

Formalin.—Commercial formalin is a solution of formaldehyde gas in water (40 per cent). To use, this is considered as absolute and a 5 or 10 per cent solution made (*e. g.*, to make 5 per cent formalin mix 5 cc of commercial formalin and 95 cc of water). For practically all organisms, plant and animal, used in the laboratory or in the museum 5 percent formalin is an efficient preservative and for most things as satisfactory as alcohol. If the tissues are very watery the solution should be changed after twenty-four hours.

Glycerin.—Use pure or diluted with equal parts of water or alcohol. Useful as a clearing agent and as a temporary mounting medium.

Hematoxylin (Delafield's).—Hematoxylin crystals 1 g. dissolved in 10 cc of strong alcohol. Add this slowly to 100 cc of saturated aqueous solution of ammonium alum, stirring. Expose this solution to the air for several weeks to ripen. Filter and add 25 cc of glycerin and 25 cc of methyl alcohol.

Hematoxylin is one of the most satisfactory stains for tissues; it is a nuclear stain. To use, dilute the stain and let it act until the tissue is dark and overstained. Destain with acid alcohol or with very dilute aqueous hydrochloric acid (1 per cent of acid or less, in water). The slides holding the sections must now be washed for at least five minutes in running water, to remove the acid and restore the blue color. Now counterstain the sections, if desired, dehydrate, clear and mount.

Injection Mass.—The following is one of the best masses for injecting bloodvessels.

Dry corn starch	1 lb.
Chloral hydrate (2½ per cent)	600 cc
Alcohol (95 per cent)	150 "
Color	150 "

The chloral hydrate and alcohol of the above may be replaced by 750 cc of 5 per cent formalin; the resulting mass appears to act as well as the one above. To make the color take about 50 g. of dry insoluble color, such as chrome yellow or vermilion, grind in a mortar with 50 cc of glycerin and 50 cc of alcohol (95 per cent). Mix the color and the liquid and slowly stir in the starch to make a homogeneous mass. If the mass appears to be getting too thick use less starch, if too thin add more starch. Before using the mass should be strained through two thicknesses of cheesecloth, to remove all particles which might clog the cannula or artery. The injection mass does not spoil upon standing, but must be well stirred before using.

Iodine Solution.—Dissolve potassium iodide in distilled water to saturation, then saturate this solution with metallic iodine. To use dilute with several volumes of water. May be used as a stain for protoplasm, but chiefly used for starch test.

Lime (or Baryta) Water.—Shake up a little quick lime (or barium oxide for baryta water) in water and allow the mixture to settle. Decant or filter the clear liquid. In the presence of carbon dioxide this clear liquid will become milky, or will show a white precipitate.

Lyons Blue.—This is one of the anilin dyes. An alcoholic solution should be made. This is used as a contrast stain with borax carmine.

Methyl Green.—A strong aqueous solution (1 per cent) with 1 per cent of acetic acid. An excellent stain for fresh tissues. Stains the nucleus only, stains rapidly and does not overstain.

Methylene Blue.—Pure methylene blue added to water to make a light blue tint will stain parts of the living animals contained in the water. Several hours are usually necessary. Does not affect the animals, but the stain should be pure for this purpose.

Normal Salt Solution.—Dissolve 7 g. of common salt in 1000 cc of water. This solution is used as a medium for the examination of fresh tissues. The concentration approaches that of the lymph, and tissues and cells in it are not distorted as they would be in water.

Pasteur's Solution.

Ammonium tartrate	50 g.
Potassium phosphate	10 g.
Calcium phosphate	1 g.
Magnesium sulphate	1 g.
Cane sugar	750 g.
Water to make	5000 cc

This solution is used as a culture medium for yeast, moulds and bacteria. The Pasteur's solution without sugar is the same with the sugar omitted.

Worcester's Fluid.—This fluid is a saturated solution of corrosive sublimate (mercuric chloride) in 10 per cent formalin. For small animals and small pieces of tissue kill for fifteen minutes to an hour. Wash in water, preserve in formalin or alcohol. Especially good for killing Paramecium and Protozoa. If used hot Protozoa and hydra are killed instantly.

Zenker's Fluid.

Corrosive sublimate (mercuric chloride)	5 g.
Potassium bichromate	2.5 g.
Water	100 cc
Just before using add glacial acetic acid	5 cc

Fix for six to twenty-four hours, wash in running water for twelve to twenty-four hours. Preserve in alcohol 80 per-cent.

This is one of the standard killing mixtures, and for general histological use it is excellent. It would be well to treat the fixed tissue in alcohol with iodine for twenty-four hours to remove all excess of the mercury salt. After this the iodine must be thoroughly removed from the tissue by several changes of alcohol.

Tests for Organic Substances.

Grape Sugar or Glucose.—Into a test tube place the substance to be tested, add Benedict's or Fehling's solution and boil. The appearance of a yellowish or red color indicates the presence of the grape sugar.

Starch.—If a substance containing starch is acted upon by an iodine solution a blue color will result. The reaction takes place more quickly if the substance has been boiled and the starch grains swelled.

Cellulose.—This substance is common in plant tissues, in the fibers and cell walls; cotton is almost pure cellulose. The section, or material, to be tested for cellulose is treated with a drop or two of chloriodide of zinc. Cellulose is colored violet, lignified membranes a yellowish brown, membranes containing cutin or cork from yellow to yellowish-brown.

Fat.—Fats and oils are stained black by osmic acid. A 1 per cent solution acting on a thin piece of tissue will show the reaction within a few minutes. Sudan III in aqueous solution will stain fat or oil a yellowish color, and Scharlach R will give a red color. These stains will also act upon fat preserved in formalin. Ether or benzene may be mixed with the substance to be tested and allowed to remain for a few minutes, then filtered and the filtrate evaporated in a draft. The oil, if present, will be left behind in the dish.

Protein.—Place the substance to be tested in a test tube, add a few drops of strong nitric acid and boil. Cool and carefully add a few drops of ammonia. A yellow color appearing when the nitric acid is boiled and becoming a deep orange on the addition of the ammonia is an indication of the presence of the protein. This is one of the best and most easily made tests for protein.

GLOSSARY

A

abdomen.—In vertebrates that part of the trunk below or behind the thorax; in invertebrates the posterior region of the body.

aboral.—Opposite the oral or mouth region.

achromatin.—The material in the nucleus not colored by certain dyes.

adaptation.—The condition of a portion of the body such that it is adjusted or fitted to its functions.

adductor.—A muscle which draws some part toward the middle line of the body.

alga.—Simple plants, one or many celled; without definite leaves, stem or roots.

alternation of generations.—The alternation of sexual and asexual forms in the life history of a plant or animal.

alveolar.—Resembling little cells or sacs, a common appearance of protoplasm.

amitosis.—Simple or direct division of the nucleus, a mere pinching into two parts. Opposed to mitosis or indirect division.

analogous.—Similarity of function.

anaphase.—A stage in indirect division in which the chromosomes are pulled apart into two groups.

anastomosis.—The interjoining or fusing of nerves or blood-vessels.

animalcule.—A microscopic animal.

anterior.—At or toward the front or head end.

anus.—The posterior opening of the digestive tube.

aorta.—In invertebrates the chief artery of the body; in vertebrates the large artery supplying the main organs of the body.

aortic arch.—The arch or loop of the main arteries as they leave the heart.

apopyle.—In the sponge the opening of a radial canal into the central cavity.

appendage.—A subordinate part of an organ or body; especially an external organ or limb.

artery.—A bloodvessel carrying blood away from the heart.

asexual.—Non-sexual; reproduction by means other than sexual, as by budding or fission.

aster.—Star. The star-like structure found at the end of the spindle during mitotic division of the nucleus.

asymmetry.—Lack of symmetry, especially absence of bilateral symmetry.

B

bacillus.—A little staff. A rod-shaped bacterium.

barb.—A hook or point extending backward, which prevents the pulling out of the object.

bilateral symmetry.—Symmetrical with respect to the right and left sides.

biramous.—Having two branches, as a typical crustacean appendage.

bivalve.—Shell composed of two lateral valves or pieces as the shell of the clam.

blastopore.—The pore opening into the primitive gut of a developing animal.

blastostyle.—That portion of the fleshy axis which produces medusæ in certain hydroids.

blastula.—A hollow sphere of cells produced by the development of the egg.

body cavity.—Cœlom; the cavity between the digestive tube and the body wall.

brachial.—Pertaining to the arms.

branchial.—Pertaining to the gills.

buccal groove.—In infusoria the groove leading to the mouth.

C

cæcum.—A tube or sac open at one end only; usually applied to appendages of the digestive tract.

calcareous.—Composed of lime or calcium carbonate.

calciferous.—Esophageal glands in the earthworm containing calcium carbonate.

capsule.—A little case. In hydroids the cavity of a stinging cell which contains the poison.

carapace.—A shell or shield covering the head and thorax of crustacea.

cell.—One of the structural units of a living body; a mass of protoplasm containing a nucleus.

centrosome.—The central body or region of an aster in mitosis.

cephalothorax.—The region of the body composed of the fused head and thorax.

cerebral.—Pertaining to the cerebrum or brain; in invertebrates cerebral ganglia or brain.

chela.—The pincer-like claw of crustacea and other arthropods.

chitin.—The horny material forming the covering of insects and certain other animals.

chlorogog.—Gland cells surrounding the stomach-intestine of the earthworm.

chlorophyll.—The green coloring matter of plants.

chloroplast.—A chlorophyll body or granule.

chromatin.—The ingredients of the nucleus which stain deeply with certain dyes.

chromosome.—A distinct body formed from the chromatin, and present only at the time of nuclear division.

cilia.—Minute, vibratory, protoplasmic processes on a cell.

circum-esophageal.—About the esophagus. Refers to the nerve connectives joining the ventral cord and cerebral ganglia of invertebrates.

cleavage.—Splitting or division of the egg cell at the beginning of development.

clitellum.—A thickened, glandular region of the earthworm which secretes the egg case.

cloaca.—A chamber into which empty the intestine, kidneys, and reproductive organs.

coccus.—A spherical bacterium.

cœlom.—The body cavity; the space between digestive tube and body wall.

cœnosarc.—The fleshy stalk or stem of hydroids, uniting the various polyps.

colony.—A group of animals living or growing together, the various individuals being connected.

commissure.—A band of nerves connecting ganglia in invertebrates; tracts of nerve fibers within the central nervous system of vertebrates.

conjugation.—A temporary or permanent fusion of cells in reproduction.

contractile vacuole.—A pulsating vacuole in protozoa having an excretory function.

corpuscle.—A cell of an animal body floating in a fluid or separated by an intercellular matrix.

crop.—The pouch-like enlargement of the digestive tube used to store food.

cuticle.—The outer skin. In protozoa the cell wall.

cytology.—The science of cell structure and function.

cytoplasm.—The protoplasm of the cell proper, as contrasted with the nucleoplasm, or protoplasm of the nucleus.

D

desmid.
diatom. } Minute unicellular algæ.

digit.—A terminal division of an appendage of vertebrates, finger or toe.

distal.—Away from the point of attachment, opposed to proximal.

dorsal.—The back or upper surface.

E

ectoderm.—The outermost layer of cells.

ectoplasm.—The outer, denser protoplasm in protozoa.

embryo.—The young of an animal before its parts are fully developed, and before the commencement of independent existence.

embryology.—The science of the development of animals and plants.

encyst.—To enclose in a cyst or case, common in protozoa and bacteria for protection.

endopodite.—In crustacea the branch of a biramous appendage toward the median line of the body.

enteron.—The digestive tube, especially the simple tract of lower animals.

entoderm.—The inner tissue lining the enteron or digestive tube.

entoplasm.—The inner, more fluid protoplasm of protozoa.

enzyme.—An active substance secreted by a living cell which has the property, under certain conditions, of bringing about changes in other substances without itself entering into the composition of the substance which results.

excretion.—Substances produced in the body as the result of metabolism, which are of no further use to the body.

excurrent.—A pore or tube through which a current passes outward.

exopodite.—The outer terminal segment of a biramous crustacean appendage.

exoskeleton.—The external skeleton or shell.

F

ferment.—See Enzyme.

fertilization.—The union of a spermatozoön and an ovum.

fibrillar.—Composed of fibers.

fibro-vascular.—Bundles in a plant composed of fibers and large vessels through which fluids or gases pass.

fission.—A division, usually into two parts; the common method of reproduction in protozoa.

flagellum.—A long, whip-like, vibratory projection of a cell.

function.—The appropriate action of any special organ or part.

G

gamete.—A reproductive cell capable of union with another gamete.

gametophyte.—A plant which produces gametes.

ganglion.—A group of nerve cells usually forming a swelling in the course of a nerve.

gastro-vascular.—The inner cavity of hydra, hydroids and medusæ which performs both digestive and circulatory functions.

genital.—Pertaining to reproduction or the reproductive organs.

germ layer.—Any one of the three embryonic tissues, ectoderm, entoderm or mesoderm.

giant fibers.—A group of large tubes in the dorsal portion of the nerve cord of annelids. They may represent degenerated nerve fibers or supporting structures.

gizzard.—A muscular stomach in which food is crushed and ground.

gland.—A part or organ for secreting some substance to be used in, or eliminated from, the body.

glottis.—The opening from the mouth into the trachea.

gonangium.—A reproductive individual in some hydroids, covered by an enlargement of the perisarc.

granular.—Composed of granules or small grains.

H

hermaphrodite.—An animal containing both male and female sex organs.

histology.—The science treating of the microscopic structure of animal and plant tissues.

homology.—Similarity in structure and origin.

hydranth.—One of the individual polyps of a hydroid colony.

hydroid.—Resembling hydra; marine, usually colonial animals of the phylum Cœlenterata.

hydrotheca.—The vase-shaped expansion of the perisarc which covers and protects the hydranth of certain hydroids.

I

incurrent.—A pore or tube through which water enters an animal.

infusoria.—Protozoa found in infusions of organic matter; ciliate protozoa.

interstitial cells.—Cells of hydra which fill the spaces between the bases of the ectodermal cells.

irritability.—Susceptibility of protoplasm to the influence of stimuli.

L

labium.—One of the mouth parts of insects, the lower lip or second maxilla.

labrum.—One of the mouth parts of insects, the upper lip.

lamella.—A thin plate or layer.

larva.—The free living young of an animal in which development is accompanied by a metamorphosis.

lateral.—On or toward the side.

ligament.—A tough band which connects one part to another; in the clam the elastic band which unites the valves of the shell.

M

macronucleus.—The larger of the two nuclei present in ciliated protozoa.

mandible.—The hard jaw of arthropods, one of a pair.

mantle.—The fold of skin covering the body and secreting the shell in molluscs.

manubrium.—The proboscis or sac-like stomach of the medusa.

matrix.—The intercellular ground substance which separates the cells in such tissues as cartilage.

maturation.—Process of ripening; especially a stage in the formation of spermatozoa and ova.

maxilla.—One of the mouth parts of arthropods; in vertebrates the jaw bone.

maxilliped.—Foot jaws. Thoracic appendages of the crayfish modified as mouth parts.

medusa.—The free swimming, sexual individual in the life history of hydroids.

mesentery.—A thin fold of tissue which holds the intestine in place against the body wall.

mesoderm.—The middle one of the three germ layers formed in the development of most embryos.

mesothorax.—The middle segment of the thorax of insects.

metamere.—One of the serially arranged body segments or somites in animals such as Annelida and Arthropoda.

metamorphosis.—The striking changes in form undergone by certain animals in the course of development after the commencement of a free existence. For example, the change from a caterpillar through a pupa into a butterfly, the change of a tadpole into a frog.

metaphase.—The stage in mitosis during which the chromosomes are split.

metathorax.—The posterior somite of the thorax of insects.

micronucleus.—The small nucleus or nuclei found in certain protozoa, always accompanied by a macronucleus.

mitosis.—Indirect division during which the nucleus undergoes complicated changes, and the chromatin becomes divided into equal halves.

morphology.—The science of the form and structure of animals and plants.

mucosa.—Mucous membrane. An epithelial covering which is kept moist by secretions of mucus, as in the stomach.

N

nematocyst.—A stinging cell of Cœlenterates.

nephridium.—A much coiled tube serving as a kidney in annelids and other invertebrates. Typically they are paired segmental organs.

nucleolus.—A small dense spot within the nucleus.

nucleus.—The central, usually spherical, portion of the cell which contains the chromatin.

O

ocellus.—A simple eye of an arthropod.

operculum.—A lid which closes the aperture of the shell of some snails; the covering of the gills of a fish; the skin which overgrows the gills of the tadpole.

oral.—Pertaining to the mouth, opposed to aboral.

organ.—A part of an organism capable of performing some special action which is essential to the life of the whole.

organism.—An organized being or living body capable of independent existence; often the organism is composed of organs.

osculum.—The excurrent opening in the sponge through which water passes to the exterior.

ostium.—A mouth-like opening, as the pores on the outer surface of the sponge, and the pores in the heart of arthropods.

ovary.—The organ which produces the ova or female sex cells.

oviduct.—The duct or passageway from the ovary to the outside of the body.

ovipositor.—The organ by which many insects deposit their eggs.

ovum.—The egg or female sex cell.

P

palp (palpus).—In arthropods a feeler, especially the jointed palps on the mouth parts; in the clam soft, fleshy, ciliated flaps near the mouth.

parapodium.—A fleshy unsegmented appendage of a somite of annelids.

parenchyma.—The soft cellular tissue of plants and animals. In the fern the pith; in flatworms the soft tissue which fills the body cavity.

pectoral.—Of or pertaining to the breast or chest, as pectoral muscles, pectoral girdle.

pelvic.—The girdle, in vertebrates, which attaches the hind legs to the vertebral column.

pericardium.—The membrane which surrounds the heart.

perisarc.—The protective, horny, secreted sheath about hydroids.

peristome.—A lip around the mouth in Vorticella and other protozoa.

peritoneum.—A smooth serous membrane which lines the body cavity and covers the viscera.

photosynthesis.—The process by which starch is manufactured in green plants, in the presence of sunlight.

planula.—The larva of many Cœlenterates; it is usually oval in form and covered with cilia.

plasmolysis.—The separation of the protoplasm of a cell from its enclosing cell wall.

plexus.—An aggregation of vessels or nerves forming an intricate network.

polyp.—An organism or a part having a structure similar to that of the fresh water hydra.

posterior.—At or toward the hind or tail end.

proboscis.—The long flexible sucking mouth parts of the bee.

prophase.—The preparatory stage of mitosis; the period of formation of chromosomes and spindle.

prosopyle.—In the sponge a pore connecting the incurrent and radial canals.

prostomium.—The region which overhangs the mouth in annelids.

prothorax.—The first somite of the thorax in insects.

protoplasm.—The living substance.

protopodite—The basal portion of a crustacean appendage from which extend the two distal branches, exopodite and endopodite.

protractor.—A muscle that draws forward.

pseudopodium.—A temporary and changing protoplasmic projection in amœba and similar protozoa.

pyrenoid.—Bright globules embedded in the chloroplasts of green algæ, which function to produce starch.

R

radial.—Diverging from a common center, as the radial canals of a medusa.

retractor.—A muscle which draws parts back.

rhizome.—The underground stem of the fern.

S

sclerenchyma.—Woody or hard cells in plants which serve to stiffen and support.

secretion.—A substance, made by parts or organs of an animal, which is of use within the body.

septum.—A wall or partition, especially the partitions dividing the cœlom of annelids.

serosa.—Serous membrane; a delicate tissue which lines closed cavities and is bathed by lymph.

seta.—A chitinous spine or bristle in annelids used in locomotion.

sexual.—Of or pertaining to sex. Sexual reproduction involves the two sexes and the two kinds of sex cells, spermatozoa and ova.

skeleton.—The bony framework which supports the vertebrate body.

somite.—A metamere; one of the serial segments of which an animal like the insect or annelid is composed.

spermatozoön.—The male sex cell.

spicule.—A small, spine-like skeletal body embedded in the wall of sponges.

spindle.—The barrel-shaped structure of threads in a cell at the time of the mitotic division of the nucleus.

spiracle.—One of the openings to the tracheæ or air tubes of insects.

spirillum.—A spiral-like bacterium.

spore.—An asexually produced body which gives rise to a new organism.

sternum.—In vertebrates the breast bone; in arthropods the ventral portion of the exoskeleton of a somite.

stomach-intestine.—The posterior portion of the digestive tube in annelids, with the functions both of stomach and intestine.

symmetry.—Orderly and similar distribution of parts in an organism.

system.—An assemblage of parts or organs essential to the performance of some particular function.

T

tarsus.—The jointed foot of an insect.

telophase.—The stage in mitosis in which the cell is divided, and the nucleus reformed into a typical spherical form.

tentacle.—A slender, unsegmented, tactile or prehensile organ near the mouth.

tergum.—The dorsal portion of the exoskeleton of a somite in arthropods.

testis.—The male reproductive organ.

thorax.—The middle of the three divisions of the body of an insect.

tissue.—A group of similar cells having a similar function.

trachea.—The windpipe of vertebrates; a branching air tube of insects.

trichocyst.—A sac or rod-like body in the ectoplasm of Paramecium.

tubule.—A small tube.

tympanic membrane.—The ear drum or membrane of an auditory organ.

typhlosole.—A longitudinal fold in the intestinal wall of annelids, molluscs and certain other animals.

U

umbo.—One of the lateral prominences just above the hinge of a bivalve mollusc shell.

ureter.—The duct of the kidney.

urino-genital.—Relating to the urinary and genital organs, as urino-genital artery.

V

vacuole.—A globular space within a cell containing a gas or liquid.

valve.—One of the pieces of the shell of a clam; a flap or fold within a cavity which permits the passage of a liquid in one direction only.

variation.—A modification, alteration, or deviation from the typical or usual condition.

vein.—A vessel which carries blood to the heart; one of the ribs in the wings of insects.

velum.—A circular membrane that partly incloses the space beneath the umbrella in medusæ.

ventral.—At or toward the under or belly surface.

viscera.—The internal organs taken as a whole.

Y

yeast.—A unicellular, colorless plant which causes an alcoholic fermentation of carbohydrates.

Z

zoöid.—One of the single individuals in a colony of animals.

zoöspore.—A spore provided with one or more flagella by which it swims in the water.

zygospore.—A spore formed by the union of two zoöspores, or by union of protoplasm from two plants.

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