LABORATORY DIRECTIONS IN GENERAL BIOLOGY

LABORATORY DIRECTIONS

IN

GENERAL BIOLOGY

Prepared to accompany Text Book on General Biology

By P. W. CLAASSEN, Ph.D.

ASSISTANT PROFESSOR OF BIOLOGY IN CORNELL UNIVERSITY

ITHACA, N. Y.
THE COMSTOCK PUBLISHING CO.
1922

PRESS OF W. F. HUMPHREY
GENEVA, N. Y.

PREFACE

Although the following Laboratory Directions in General Biology have been prepared particularly to accompany Needham's text in General Biology, most of the exercises will be found adaptable for use with other texts. The majority of the studies included have been selected from Needham's text and have been modified or elaborated to suit the conditions for general class use.

For a number of years it has been found desirable to supplement the outlines of the practical exercises in the text by printed or mimeographed sheets until they have reached the present proportions. All of the exercises included have been used satisfactorily in both large and small classes in General Biology in Cornell University for a number of years.

In order to save the student from spending much time in doing non-productive routine work, such as preparing tabulation sheets etc., a number of partially finished drawings, tabulation sheets etc., are included in the envelope in the back of the book. These may, or may not, be used as the instructor sees fit. In the back part of the manual are also included figures and brief descriptions of the genera of plancton organisms. For the beginning student these figures and descriptions will simplify the identification of the more common plancton organisms encountered.

The writer is greatly indebted to Dr. J. G. Needham for his encouragement in the preparation of this manual; and for his permission to incorporate material from his text book in General Biology; to Dr. O. A. Johannsen for the use of material from his "Laboratory Directions in General Biology" which were prepared by him and used in the course in General Biology in Cornell University fora number of years; and to Dr. Johannsen and Dr. J. T. Lloyd for the use of the plates of plancton organisms, and to other colleagues for helpful suggestions and criticisms.

P. W. C.

CONTENTS

LABORATORY DIRECTIONS IN GENERAL BIOLOGY

1. Equipment. Each student will provide himself with the following:

1. A copy of Needham's General Biology.
2. A copy of Claassen's Laboratory Directions in General Biology.
3. Six manila covers 8 x 10½ for laboratory reports.
4. Two kinds of paper to fit the covers: (a) plain drawing paper and (b) ruled paper for notes.
5. One drawing pencil 6H.
6. A good rubber eraser.
7. Six glass slides.
8. One dozen ¾ inch cover glasses No. 2, square or circular.
9. One piece of absorbant cloth for cleaning slides and cover glasses.
10. A set of dissecting instruments consisting of: scalpel, scissors, forceps, two dissecting needles, medicine dropper and a ruler graduated in millimeters.

This equipment should always be brought to the laboratory.

2. Laboratory Reports. Laboratory notes and drawings must be original. Copied work will not be accepted. Drawings are to be finished in the laboratory and left properly labeled and enclosed in manila covers at the place designated by the instructor. All papers handed in must bear the student's name, day and time of his section, and seat number.

Drawings. Every line and spot in the drawing should represent some feature in the object, and no mark should be made which does not find its counterpart in the object. Outlines should be complete without loose ends, hazy joints or dim angles. Impressionist drawings, though perhaps artistic, have no scientific value. All parts should be labeled.

Summary. The answers called for in the summary should be brief but to the point. The summary is to be handed in at the beginning of the following laboratory period.

3. Grades, etc. The records for each section will be in the hands of the laboratory instructor. All questions concerning grades, excuses, and make-ups after excused absences, are to be taken up directly with him. Any further requirements as to note-books

will be explained by the instructor in charge. Diligence, punctuality and sustained effort will be considered in making up the final grades. A student who fails to hand in reports, summaries, or lecture notes on time will not receive a passing grade at the end of the term.

No credit will be given on:—

a. Reports, lecture notes, and summaries that have been copied from the work of another.

b. Reports, etc., another student has used as a copy.

c. Reports, lecture notes and summaries that are late.

d. Work done in sections other than the one to which the student has been assigned.

e. Reports, etc., done in collaboration.

4. Absences from Laboratory. A student unavoidably absent from the laboratory, upon presentation of a properly certified excuse from the Secretary of his College, will be given the opportunity to take a "make-up." "Make-ups" will only be given on certain Saturday afternoons. A list of these "make-up" periods will be found posted in the laboratory. Students wishing to attend the "make-up" section must deposit a slip of paper in the "make-up" box in the laboratory, stating the subject of the laboratory work which they have missed and which they wish to make up. These slips must be deposited in this box at least two days previous to the time of the "make-up." The "make-up" must be taken within three weeks after the absence is incurred, unless a further extension (in writing) is granted by the instructor in charge.

5. Lecture Attendance. The names of the students with their seat numbers will be found posted at the door of the lecture room. Students are not permitted to change their assigned places without the consent of the instructor. The lecture notes, which must bear subject, number, and date, are to be handed in with the laboratory report at the following laboratory period.

EXERCISE 1

USE OF THE COMPOUND MICROSCOPE

REFERENCES. Needham, General Biology, pp. 513-519; Gage, The Microscope.

MATERIAL AND APPARATUS NEEDED. Compound microscope, lens paper, glass slides and cover glasses, prepared slide marked "M", alcohol, ruler, paper and pencil.

CAUTION. Do not handle the microscope until after the instructor has explained its mechanism. The compound microscope is a very delicate instrument and should be treated with great care. Keep the lenses clean, wipe them only with lens paper which the instructor will provide.

LABORATORY EXERCISE

a. Record on your paper the mark or number with which the microscope is marked (i. e. B20 or B43, etc).

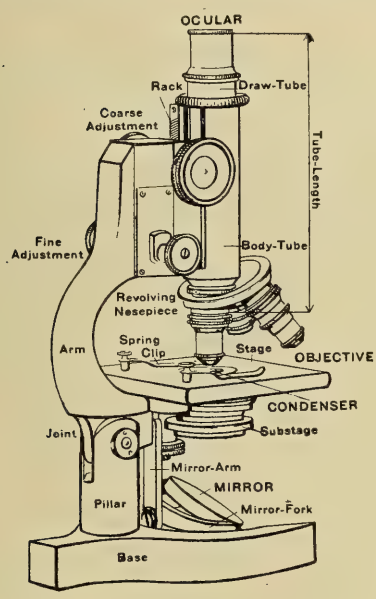


Fig. 1

b. ADJUSTMENTS. Compare figure 1 with your microscope and learn to recognize the different parts of the microscope. Learn something of the mechanism of the microscope. Slowly turn the milled head (wheel) at the side of the tube and note the movement of the objective. This is known as the *coarse* adjustment. *Never move the tube down until it touches the stage or goes through the opening in the stage.* Next turn the milled head (wheel) at the head of the pillar (in some microscopes located at the side) and note that while there is a similar movement as with the coarse adjustment, the motion is much slower. This is known as the *fine* adjustment. Hence the approximate focusing should be done with the coarse adjustment, and final focusing with the fine adjustment. Determine both limits for each adjustment, i. e., the approximate number of millimeters up and down which each adjustment will move the objective. *Record* your results in your note book.

Place a little talcum powder on a glass slide and examine under the low power of the microscope. (The instructor will explain the dif-

ference and use of low and high power magnification.) Note the size of the particles. Then turn the high power objective on the slide and examine again. Now place a few pollen grains on the slide in a drop of water, put on a cover glass, and examine under low and high power. What is the distance (in millimeters) between the lower surface of the lens and the top of the glass slide when an object is in focus (a) for low power, (b) for high power? With the low power objective clearly in focus, touch the front of the objective lightly with the moist finger, and observe how the appearance of the objective is altered. The fingers are never optically clean. The slightest deposit on the surface of a lens disturbs its refractory harmony. Do not touch the glass of your lenses with the finger again, or with anything else, except on the occasions when it is necessary to clean them. Now clean your lenses with lens paper. *Draw three or four* of the pollen grains, each with a diameter of at least one inch.

Examine also a hair, threads of cotton or wool and other objects which the instructor will provide.

d. Air entangled under the cover glass is a frequent source of trouble. The air may cling to the cover—will be likely to do so if the cover be dropped flat upon the object. Breathe upon one side of the cover to moisten it, and let it down with one edge in advance of the other. *Learn to recognize air bubbles* so as not to confuse them with structures. Mount a dry thread in a drop of water, cover and examine with low power. *Draw* a portion of the thread as it appears under the microscope. Alcohol may be used to remove the air. Remount the thread in a drop of alcohol; cover, allow a little time to soak, and observe the disappearance of the air. Then *draw* a portion of the thread again.

e. Magnification of the Microscope. Determine the apparent diameter of the field by the method of *double vision.* Place the microscope in a vertical position, (never tilt it backward), then look through it with one eye, keeping the other eye fixed on a sheet of paper on the table below. Adjust the mirror so that there will be a clear image of the circular field apparently projected upon the paper. Now draw two parallel tangents to this circular image and measure the distance between. Next measure the distance from the eye to the table (suppose this to be 12 inches.) Since the normal visual distance is 10 inches, the apparent diameter of the field will be 10/12 of the distance between

the parallel lines just drawn. Repeat for higher power. Note that the apparent diameter, being independent of the magnification of the object, is practically the same for both the high and low powers.

f. Actual Diameter of the Field for Both Powers. Examine the slide marked "M", under the compound microscope. Each mesh of the silk bolting cloth under the cover glass is just .0078 inch from center to center of the thread. Count the meshes (heeding the fractional mesh if there be one) in a row through the center of the field. To determine the actual diameter of the field multiply this number of meshes by .0078.

g. Determine the magnification for both low and high powers. Divide the apparent diameter of the field by the actual diameter to obtain the magnification.

Summary

1. What is the focal distance of a lens?
2. What is the working distance?
3. What is the effect of water between objective and cover glass?
4. Why must a cover glass be used when examining wet objects under the compound microscope?
5. Why do you use the low power for "finding" the object?
6. What effect has an increase of magnification on size of field and working distance?

EXERCISE 2

A STUDY OF COMMON GALLS

References. Needham, General Biology, pp. 35-47; Felt, E. P., Key to American Insect Galls; Thompson, M. T., An Illustrated Catalogue of American Insect Galls, etc.

Material and Apparatus Needed. Dissecting instruments, simple microscope, vegetable insect galls and tabulation sheets.

A gall is an abnormal growth of plant tissue occasioned by a stimulus external to the plant itself.

LABORATORY EXERCISE

A number of galls and their inhabitants will be studied. Upon the sheet furnished, *record* the results of your observations on both gall and insect. The galls, properly labeled, will be found on the laboratory supply table. Begin with a large gall, such as the Round Gall of the goldenrod. *Make a drawing* of the gall twice natural size. With a knife or scalpel carefully cut open the gall until the larva in the central cavity is disclosed. Be careful not to cut directly through the center thereby destroying the insect inside. Examine the gall maker with the microscope and then record your observations in tabulated form on the sheet provided. To determine what type of gall you have consult the information under the heading "Types of Galls" on page 13.

In order to determine the name of the insect in the gall and the order and family to which it belongs examine the specimen carefully under the microscope and identify it by means of the table or key found on page 13.

Study as many different types of galls as the time will permit, following the directions given for the goldenrod.

Before handing in your sheet study it carefully and copy the data which you will need in preparing the summary which is due next week.

TYPES OF GALLS[1]

Galls are classified into types according to their structure. They may first be divided into two classes, open and closed galls, i. e.,

[1]Examine examples of these types on demonstration table.

galls which either have a natural opening through which the insect may escape or else they are entirely closed up, so that if the insect wishes to escape it must cut an opening through the wall to the outside. The open and closed galls again may be subdivided according to the following table:

			Caused by	*Found on*
Open	Felted		Mites	Boxelder, grape etc.
	Mantle	Scroll	Aphids	Elm, etc.
		Pocket	Aphids	Witch hazel, etc.
		Fluted	Aphids	Elm, etc.
		Covering	Gall midges, etc.	Hawthorn, etc.
Closed	Simple		Midges, sawflies, moths, wasps, beetles	Oak, willow, goldenrod, ragweed, hickory, etc.
	Compound		Wasps	Oak, etc.
	Nucleated		Wasps	Oak, etc.

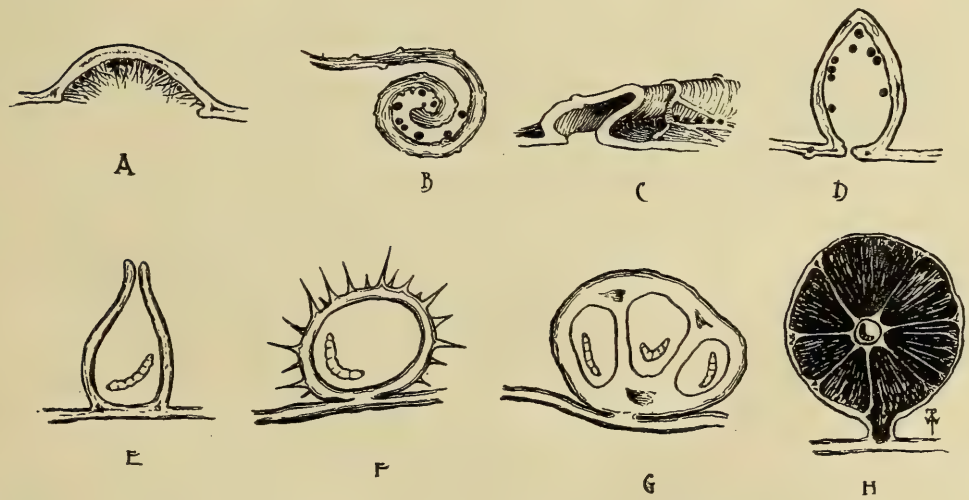


FIGURE 2. DIAGRAMS OF TYPICAL FORMS OF GALLS.

A. open felted; B. open scroll; C. open fluted; D. open pocket; E. open covering; F. closed simple; G. closed compound; H. closed nucleated.

KEY TO THE COMMONER INSECT LARVAE AND MITES FOUND IN GALLS

Note. This table cannot be used for the pupae or adults.

A. Body short and thick; legs rather long, small animals, found only in open galls.

B. Head fused with body and not distinct; 2 or 4 pairs of legs; very small animals always gregarious and found in felted galls.

Order—Acarina
Family—Eriophiidae
Common name—Mites

BB. With a distinct head, three pairs of legs; small insects found in open galls.

Order—Hemiptera
Family—Aphididae
Common name—Aphids or plant lice.

AA. Body cylindric, worm-like, legs minute or none.

B. With 3 pairs of minute legs under the thoracic segments; found singly in closed galls.

C. With a brown shield covering the prothorax above, body covered with stiff bristles.

Order—Lepidoptera
Family—Several
Common name—Moth larva

CC. Prothorax not covered by a brown shield.

D. With rudimentary legs (fleshy prolegs) underneath some of the abdominal segments.

Order—Hymenoptera
Family—Tenthredinidae
Common name—Sawfly larva

DD. With no prolegs underneath the abdomen.

Order—Coleoptera
Family—Several
Common name—Beetle larva

BB. Legless—Found in either open or closed galls, usually singly.

C. With a distinct head segment; body arcuate (curved), color white.

D. Body segments deeply wrinkled; head brown; skin dull white; singly in closed galls.

Order—Coleoptera
Family—Curculionidae
Common name—Weevil larva

DD. Body segments smooth, shining, head mostly white; in closed galls.

Order—Hymenoptera
Family—Cynipidae
Common name—Gall wasp larva

CC. With the head segment greatly reduced, very minute, or wanting; in either open or closed galls.

D. Under side of first segment behind the head with a narrow blackish horny structure extending lengthwise with the body; color of larva often red or yellow.

Order—Diptera
Family—Cecidomyidae
Common name—Gall midge larva

DD. Without the horny structure, color white.

Other dipterous larvae.

Summary

1. Summarize the results of the preceding study in a table of the orders of the gall makers prepared under the following column headings:

Order	Mouth-parts	Habits	Gall type
of insects or mites	biting or sucking	solitary or gregarious	pocket, nucleated etc.

2. What relation is there (a) between the type of mouth-parts and type of gall, and (b) between the order of insect and type of gall.
3. List ten plants on which galls are commonly found.
4. What is the economic importance of galls?
5. What other agents, besides insects and mites, produce galls?

EXERCISE 3

THALLOPHYTES

ALGAE—THE SIMPLER PLANTS

References. Needham, General Biology pp. 56-68; Ward and Whipple, Fresh Water Biology; Tilden, J. Minnesota Algae etc.

Material and Apparatus Needed. Compound microscope, glass slides and cover glasses, forceps, pipette, and a variety of algae representing unicellular, unbranched filamentous and branched filamentous forms. This should include Pleurococcus, Diatoms, Desmids, Spirogyra, Cladophora and others.

From an evolutionary point of view it would probably be best to begin the laboratory work with the unicellular or simplest algae and then take up the more highly developed forms; but in order to simplify the work for the beginning student it is best to start with a form such as Spirogyra where the structures are more easily seen and the depth of focus more readily appreciated. Having studied this form the student will not be likely to have much difficulty in seeing the structures in the simpler and more obscure forms.

LABORATORY EXERCISE

a. Spirogyra. This unbranched filamentous alga, called pond scum, occurs in fresh water ponds and streams.

1. Upon a clean glass slide mount a few filaments of Spirogyra in a small drop of clean water. Cover with a clean cover glass. Care should be taken not to get too many filaments on the slide for then they may obstruct a clear view. Find a single filament under the low power of the microscope and note the general structure. Note that the filament is unbranched and is made up of elongate cylindrical cells placed end to end. Now examine the specimen under the high power. Make a *drawing* of a single cell on a large scale. The drawing should be at least 3 or 4 inches long and proportionately wide. Remember that you see only in one plane and in order to make out the detailed structure it is necessary to focus carefully up and down with the fine adjustment so that the entire structure may be determined. In your drawing *label* cell wall, chloroplast, pyrenoids, nucleus, cytoplasmic strands and vacuole.

2. *Draw* on a large scale (one half inch wide) a portion of the spiral band showing the pyrenoids and other structures in detail.

b. Pleurcoccus. This unicellular alga occurs very commonly on the bark of trees, especially on the north or shady side, on moist

rocks, bricks etc. Into a small drop of water on a glass slide scrape a very small amount of the alga, cover with a cover glass, tap the top of the cover glass gently with a pencil to separate the masses of algae, and examine under the high power. Note that the globular cells have a definite, fairly thick wall, a large lobed chloroplast whose lobes suggest several chloroplasts, and a nucleus, which in fresh specimens is difficult to see. *Draw* a single cell on a large scale (one inch in diameter). *Label*: cell wall, chloroplast and (nucleus). These cells multiply rapidly by division, the daughter cells adhering to each other and forming colonies of two, three, and four or more cells. *Draw* one or two colonies composed of several cells.

c. Desmids and Diatoms. Examine also a Desmid (Closterium) or Diatom. These also are one-celled plants occurring very commonly in fresh water. Some species of diatoms are also found in salt water. *Draw* and *label* cell wall, nucleus, chromatophore and other details which the instructor will point out.

d. Cladophora. This is a branched filamentous alga and is very commonly found attached to rocks in the bottom of fresh water streams. The cells are remarkable in containing many nuclei. In addition to the nuclei, the Cladophora cells contains many chloroplasts in the peripheral layer of cytoplasm, and numerous pyrenoids in the plastids. Place a small bit of the plant on a glass slide in a drop of water and cover with a cover glass. Examine under low power and *draw* a portion of the plant to illustrate the branching structure. Examine under the high power and *draw* a single cell in detail and *label*: cell wall, nuclei, and chloroplasts.

e. Examine and draw other forms of algae which the instructor will provide.

Summary

1. Define a plant cell.
2. What are the main constituents of a plant cell?
3. Define cytoplasm, protoplasm, chloroplast, nucleus.
4. *Draw* a cross section of Spirogyra through the nuclear region and label all the parts.

EXERCISE 4

PROTOZOA, THE SIMPLER ANIMALS

References. Needham, General Biology, pp. 68-82; Hegner, Introduction to Zoology; Hegner, College Zoology; Hertwig, Manual of Zoology; Parker and Haswell, Text-book of Zoology.

Material and Apparatus Needed. Compound microscope, glass slides, cover glasses, pipette, methyl green, iodine, and cultures of Amoeba, Paramoecia and Vorticella.

Protozoa are the simplest animals. More so than in the Algae, the Protozoa consist of single cells. If colonial, the cells are all potentially alike. There are no tissues or organs present in the Protozoa, the individual cell performing all the functions, such as ingestion, digestion, metabolism etc.

LABORATORY EXERCISE

a. Amoeba. This animal is selected as the first specimen for study because it represents one of the simplest forms of animal life. It is microscopic in size and is found both in fresh and salt water. It averages about one-onehundreth of an inch in diameter, but the size varies in different species. Specimens for study may be procured by collecting such water plants as water milfoil, lily leaves, algae and various decaying organic materials from ponds and ditches, and placing them in jars of water and allowing them to stand in a warm room. In a week or two a brown scum will appear on the surface of the water and in this scum *Amoeba* will usually be found.

1. *Mount* a drop of the Amoeba culture on a glass slide and cover lightly with a cover glass. Find a specimen under low power. The Amoeba is not easy to find and it may require a little time to locate a specimen. It appears like a little drop of jelly spreading out on a flat surface, quite translucent in the central portion and very transparent around the border.

2. *Describe* the general appearance of the Amoeba, the shape, color, or lack of color etc. Be brief and specific.

3. *Study* the specimen under the high power and observe:

   a. *Pseudopodia*, the blunt projections which are slowly pushed out from the body wall or drawn into it. Do they change position or shape?

   b. *Ectosarc*, a transparent outer border so clear that it is liable to be overlooked.

c. *Endosarc*, the granular material within the ectosarc comprising the greater bulk of the animal.

d. *Nucleus*, a rounded, highly refractive, somewhat grayish body within the endosarc. (If you do not see the nucleus clearly in your specimen, examine the demonstration specimen which has been stained.)

e. *Contractile Vacuole*, a rounded clear spot within the body.

f. *Indigested Food Particles*. These appear darker and are of various sizes, aggregated usually more or less into round food balls or vacuoles, which may be seen moving about in the endosarc.

4. Make an enlarged *drawing* of the amoeba, not less than two inches in diameter, showing all the structures. *Label*: ectosarc, endosarc, nucleus, contractile vacuole and food vacuole.

b. PARAMOECIUM. Paramoecia can usually be found in the same localities as Amoebae. A hay infusion, (pond water to which some dead grass and leaves have been added) a week or more old will usually yield great numbers of specimens for study. The Paramoecia will be found in the scum on the surface of the water. They are much larger than Amoeba and may be seen as small white specks, just visible to the unaided eye. They measure about one fiftieth of an inch in length. Paramoecium, like Amoeba, consists of a single cell, but it is much more highly specialized and always tends to preserve a definite form.

1. *Mount* a drop of the Paramoecium culture on a glass slide. Include a little trash from the jar. *Do not* put on a cover glass. Examine under low power and by carefully and slowly moving the slide about, follow some of the Paramoecia as they go swimming around. Observe the *spiral* course of swimming, and the resultant rapid motion directly forward. What relation does the oblique groove (oral groove) bear to the axis of the spiral course in which the animal swims? *Describe* clearly the details of this motion.

2. Place a cover glass over a drop of water containing the Paramoecia, including some particles of trash to avoid crushing the specimens, and find a place where a Paramoecium is repeatedly meeting with obstructions to his swimming. *Describe* carefully the movements by which an obstruction is avoided. What relation does his turning aside bear to the position of the oral groove?

3. *Detailed Study of Structure of Paramoecium*. Mount another drop containing Paramoecia, adding thereto a little methyl green or iodine. This kills and stains the animal and renders

its structure more readily visible. Cover lightly with a cover glass and study the details of structure. *Draw* on a large scale (5 inches in length) a Paramoecium. *Note* and *label*:

a. *Ectosarc*, the clear outer layer of cytoplasm.

b. *Endosarc*, the more granular inner cytoplasm.

c. *Peristome*, the fring of cilia, around the mouth or opening to the gullet or oesophagus.

d. *Cilia*, the delicate hair-like projections of the body wall.

e. *Gullet* or *oesophagus*, the tube leading from the peristome into the body.

f. *Oral groove*, the oblique groove on the side of the body.

g. *Meganucleus*, the large elongate nucleus near the center of the body.

h. *Micronucleus*, the small nucleus just beside the meganucleus.

i. *Contractile vacuoles*, two clear spaces, one near each end of the body. These vacuoles alternately, and rather regularly, contract and as they do so, from six to ten radiating canals may be seen extending in all directions from the center.

c. VORTICELLA. This is a Protozoan often found adhering to submerged twigs and leaves, and can usually be obtained by placing the trash from a pond or pool into jars and letting it stand in the room for a few hours. Vorticella commonly occurs in groups.

1. *Mount* on a glass slide a bit of vegetable substance from water containing Vorticella and examine it first under the low power and then under the high power. Study an individual organism and note that it is made up of a *bell-shaped body* and a long slender *stalk*. The *stalks* will be attached to some object and may be either contracted or extended. When extended the stalk is very slender and hair-like, but when contracted it is coiled up, somewhat in the manner of a spring.

2. *Study and Observe the Following:—*

a. The *contraction* and *extension* of the stalk. (This may require slight jarring or tapping of the slide).

b. The closing and opening of the *peristome*, a flaring rim or flange.

c. The action of the *cilia* and the effect on free particles in the water.

d. A curved, often horse-shoe-shaped, *nucleus* (meganucleus) near the center of the body. This is best distinguished by staining with methyl green or iodine.

e. A clear *contractile vacuole*, near the nucleus, periodically appearing and disappearing.

f. *Food balls* or *food vacuoles* within the endosarc.

3. *Draw* a group of vorticella showing individuals in various positions.

Draw on a large scale a single specimen and *label*: body, stalk, peristome, cilia, nucleus, contractile vacuole, and food vacuole.

Summary

1. Define Protozoa.
2. What are the four classes of Protozoa? Give an example under each class.
3. What is the economic importance of Protozoa?
4. What characters distinguish the Protozoa studied in the laboratory?
5. In what way is Paramoecium more highly developed or organized than Amoeba?
6. What is the relative thickness of Paramoecium to its length?
7 Of Amoeba?

EXERCISE 5

PHYSIOLOGY OF THE CELL

References. Needham, General Biology, pp. 82-92; Coulter, Barnes and Cowles, A Textbook of Botany, Vol. 1, part II, Physiology; Palladin, V. A., Plant Physiology; Huley, Thomas H., Lessons in Elementary Physiology; Verworn, Max, General Physiology.

Material and Apparatus Needed. Compound microscope, glass slides, cover glasses, forceps, ruler, test tubes, tumblers, petri dishes, salt solution, copper sulphate solution and crystals, crystals of potassium ferrocyanide, 95% alcohol, Spirogyra, Elodea, potato strips, strips of gelatine.

Physiology is the study of the life process or functions in living organisms. The fundamental physiological processes in both plants and animals are very much alike. In the simpler plants and animals the individual cell carries on all of the essential life processes associated with growth and reproduction. In the more complex organisms cells or tissues are differentiated in structure or function, or both. All living organisms exhibit certain properties which distinguish them from non-living matter. Among these may be mentioned automotism, metabolism, reproduction, adaptive response to environment etc. Only a few of the functions of living organisms will be studied in this exercise.

LABORATORY EXERCISE

a. Movement of Protoplasm. On a glass slide in a drop of water mount a young green leaf of Elodea and cover with a cover glass. (Chara or Nitella may be substituted if necessary). Examine under low power and note the structure of the leaf. Note that it is made up of a number of cells. Under the high power note the numerous chloroplasts in the cell. Look for the movement of cytoplasm in some of the cells. The cytoplasm is so nearly transparent that it would be impossible to see the movement if it were not for the chloroplasts imbedded therein. The chloroplasts are carried along in the protoplasmic stream and the movement is therefore apparent only because of the moving chloroplasts. *Note* the time required for a complete rotation. Compare the rate and direction of rotation in adjacent cells. Calculate the rate of movement of the cytoplasm in millimeters per hour. (The instructor will give the measurements of the cell.) *Record all results. Draw* a cell (2 inches in length) and indicate by arrows the direction of the cytoplasmic movement.

b. Diffusion. Into a test tube half filled with water drop a small crystal of copper sulphate. Set the tube aside and at the end

of the laboratory period examine to see what has taken place. Why is not the entire solution equally colored? What will be the result if you leave the test tube undisturbed for a period of five ar six days? If feasible this should be done and the results recorded in the note book the following week.

c. Osmosis and Osmotic Pressure. Osmosis is the diffusion of water or any other solvent through a semipermeable membrane from a region of low concentration of solute to a region of high concentration of solute. The pressure developed by the entrance of this water is called osmotic pressure.

1. Observe the demonstration experiment. A strong solution of sugar, 20%, has been placed in the semipermeable membrane of artificial parchment. Water diffuses from a region of pure water (100% H_2O) to a region of lower water concentration, (80%) developing a pressure which raises a column of water or which would burst the membrane if left stoppered.

Sketch the apparatus used, *label* all parts and show what takes place.

2. Growth of a Chemical Cell. In a test tube half filled with a 1% solution of copper sulphate ($CuSO_4$) drop a crystal of potassium ferrocyanide ($K_4Fe(CN)_6$). Place the test tube in a rack or tumbler and watch the reactions. The two salts react producing copper ferrocyanide ($Cu_2Fe(CN)_6$) and potassium sulphate (K_2SO_4). The copper ferrocyanide forms a rather tough membrane which is *semipermeable*, being permeable to water and relatively impermeable to solutes. Because of the high concentration of salt within the membrane due to the dissolving of the crystal, water diffuses into the membrane developing a pressure which bursts the cell. On bursting, the inner solution of potassium ferrocyanide comes in contact with the outer solution of copper sulphate. The reaction immediately forms a new membrane which again closes the cell. *How long will this growth continue*? Note especially that only water and not the solution of copper sulphate enters the cell. If the solution entered, the internal solution would not be pale yellow, but would be filled with a brown precipitate of copper ferrocyanide. *Note*. Remember this is a chemical reaction of non-living matter and is used only to show the formation and growth of a dead cell with a semipermeable membrane, and does not carry with it any other processes incident to a living cell.

d. Plasmolysis. If the concentration of solutes is greater within the cell than outside, water will enter under pressure and the cell will be turgid due to endosmosis. If the concentration of solutes is greater outside of the cell, water will diffuse out and the cell will collapse, or become plasmolyzed due to exosmosis. Place a few strands of *spirogyra* (or strips from the under epidermis over the midrib of the leaf of Zebrina pendula) on a glass slide in a drop of 1% solution of salt (NaC1). Cover with cover glass and examine under low and high power. *Note* the position of the cell contents. Immediately replace the salt solution with fresh water. What change do you observe? *Explain. Draw* a normal and a plasmolyzed cell showing the relative positions of the contents.

e. Turgor. Examine strips of potato tissue that have stood over night in salt solutions of different concentrations, 1%, ¼% and 0%. Measure and *record the length* of these strips and also note which are the most turgid and which are the most flaccid. Each strip was 5 cm. long when placed in the solutions. *Explain the results. What keeps the strip turgid?* Place the most turgid strip in the solution from which the most flaccid strip was taken and the most flaccid strip in the one where the turgid strip was. Measure and test turgidity at the end of about an hour. *Record* your results.

f. Colloidal Hydration or Imbibition. Many colloidal substances such as gelatin, starch, cellulose, proteins, etc., will absorb water and swell. Measure the strip of gelatin provided, then place it in a petri dish or watch glass of water. After 15–20 minutes (not longer) measure and note the increase in length. This swelling is due to colloidal hydration. Now place the swollen strip in a dish of 95% alcohol and note the effect on the length. *Record* all results. This is a crude experiment indicating how a muscle may contract due to loss of water and elongate on its reabsorption.

Summary

1. What holds a succulent green plant erect?
2. Why do plants wilt?
3. Why does a strip of potato which has been placed in a salt solution become flaccid.
4. What is a semipermeable membrane?
5. What is the function of water in plants?

EXERCISE 6

FLAGELLATES, THE INTERMEDIATE ORGANISMS

References. Needham, General Biology, pp. 104-109; Parker & Haswell, Textbook of Zoology Vol. I; Coulter, Barnes & Cowles, A Textbook of Botany.

Material and Apparatus Needed. Compound microscope, glass slides, cover glasses, pipette, copper sulphate solution, iodine solution, and cultures of Euglena and other Flagellates.

The group Flagellata, or whip bearing organisms, is a very large one containing an immense number of forms most of which are extremely minute. The genera and species of this group show a wonderful diversity in structure and habit. The one character common to them all is the presence of one or more flagella. Some flagellates are so plant like in character that they are claimed as plants by many botanists; others are hardly to be distinguished from animals. In structure they vary from single celled forms to colonial forms in which the colonies are made up of many cells.

LABORATORY EXERCISE

a. Euglena. This is one of the largest Flagellates and is composed of a single cell. Euglenae are found in ditches and temporary pools, where, when present in large numbers, they often color the water green or form a greenish deposit upon the sides and bottoms of the pools.

1. From the material in the jars on the supply table take a small drop of water containing Euglenae, and place it on a clean slide in a *flattened drop*, made by spreading out the water with the tip of the pipette. Do *not* put on a coverglass. *Examine* under low power for living Euglenae. *Note* the mode of swimming. Which is the anterior end? The anterior end bears the propelling mechanism, *the flagellum*. This structure cannot be seen until the specimen is stained. Does Euglena rotate, like Paramoecium, as it swims? Watch the activities of Euglena for 10 or 15 minutes and then *describe* carefully the manner of swimming.

2. *Measurement of Euglena*. To gain an appreciation of the size of Euglena, place in the mount on the slide, a hair from your head. The average diameter of the human hair is 50 microns, or 1/20 of a millimeter. Watch the Euglenae as they swim near the hair and *record* the average length and width of the specimens. In your drawing (called for in the next paragraph) be sure to make your relative dimensions correct.

3. Cover the mount with a coverglass and examine the Euglenae under high power. If they do not remain quiet add a tiny drop of copper sulphate solution. This kills the specimen without staining it.

Make a drawing of the Euglena at least 3 inches long. *Label* the following parts:

a. *Mouth*, the short channel-like opening in the anterior end of the body.

b. *Pulsating vacuole*, just posterior to the mouth. It appears as a clear globule-like space in the body plasm (endoplasm).

c. The *red eye-spot* or *stigma*, the organ sensitive to light, lying near the contractile vacuole. It is usually red but may appear as a blackish speck.

d. *Chromotophores*, the bright green oval refringeat bodies distributed throughout the organism. Determine whether one or several or any definite number of chromotophores are present. Are the chromotophores in any way connected with each other?

e. The *nucleus* near the center of the body. If this is not visible in the living specimen note it in the stained specimen. (See under f.)

f. The *flagellum* or cilium at the forward end of the body. In order to be able to discern the nucleus and flagellum clearly, make a fresh mount of Euglena and before putting on the coverglass add a small drop of the iodine solution. This will stain the flagellum and nucleus.

4. Make a series of 4 or 5 outline *drawings* to show the different shapes which Euglena may assume. This series should include a spherical or globular form, the encysted or resting stage.

b. Other Flagellates. Observe other flagellates which the instructor will provide and follow the directions given.

Summary

1. What is the probable relation of the Flagellates to plants?
2. What are their animal characteristics?
3. Their plant characteristics?
4. Name four flagellates.
5. How does Euglena obtain its nourishment?

EXERCISE 7

BACTERIA AND FUNGI

References. Needham, General Biology pp. 92-101; Jordan, General Bacteriology; Conn, The Story of Germ Life; Coulter, Barnes and Cowles, A Text-book of Botany; Atkinson, Mushrooms; etc.

Material and Apparatus Needed. Compound microscope, glass slides, cover glasses, forceps, dissecting needles, hay infusion, cultures of bacteria, clover plants, black mold on bread, blue mold on fruit etc.

I. BACTERIA

Bacteria are the simplest as well as the smallest of all known living organisms. They occur almost literally everywhere. The cells are either solitary or they may form filaments or they may cling together in masses so as to suggest colonial forms. Bacteria vary greatly in shape and form but in general they may be grouped under three types; (a) spherical or coccus; (b) rod-shaped or bacillus, (c) curved or spiral (spirillum). On account of the minuteness in size practically no internal structure can be made out, even under the best microscopes. Some bacteria have flagella. These can only be seen after the specimens have been carefully stained by special technique.

LABORATORY EXERCISE

a. Bacteria on Potato. These potato slices were partially sterilized by steaming them for about five minutes. This kills most of the fungus spores but does not kill the spores of the spore-forming bacteria. The potato slices were then incubated for several days at blood temperature.

1. Examine the slice of potato in the petri dish and note the different colored growths or colonies on the surface of the slice. In what other ways do they differ? List the likenesses and differences in the growths.
2. *Draw* an outline of the potato slice and show the structure of the different growths present, the location and relative size of the colonies.
3. In a drop of clean water mount on different slides a bit of growth from different colonies of bacteria. Cover with a cover glass and examine under high power.
   a. Note form, size, arrangement and whether or not the bacteria are motile. Do these organisms exhibit any evidence of chlorophyll?

b. *Draw* the different forms of bacteria observed, specifying the type to which each belongs. None of these drawings should be under ½ inch in length or diameter.

b. Bacteria in Hay Infusion. A hay infusion is prepared by placing some dead grass or leaves in a jar, covering this with water and allowing it to stand in a warm room for a week or so. A brown scum will form on the surface of the water and in this scum will usually be found myriads of bacteria. A very large spirillum is usually present in such infusions.

1. Mount a little bit of bacterial jelly from the surface of the hay infusion on a glass slide, cover and examine it for bacteria under high power. Make *drawings* of any types not previously seen in this laboratory period.

c. Root-nodule Forming Bacteria. These are the nitrogen bacteria of the soil which are able to utilize the free nitrogen that exists in the air. They are best known in connection with the tubercles of certain plants belonging to the family Leguminosae, such as pea and clover. Such plants can therefore be used in the restoration of nitrogen compounds to impoverished soil.

1. Examine the roots of the clover plants furnished and note the nodules of varying size. Make a *drawing* of a small part of the plant showing some of these nodules.

2. Remove one of the nodules, place it on a glass slide in a drop of water and crush it under the cover glass. Examine under high power the material which has oozed out. *Draw* some of the bacteria.

II. FUNGI

This is an enormous assemblage of Thallophytes comprising the yeasts, molds, mildews, rusts, smuts, mushrooms, toadstools, and puffballs. Fungi range in size from the minute microscopic cells of the yeast plant to the highly organized body of the mushroom often of considerable size and extent. The group is characterized by the absence of chlorophyl; consequently they are either parasites or saprophites.

LABORATORY EXERCISE

a. Black Bread Mold (Rhizopus nigricans). This mold is easily obtained by allowing bread to remain a few days in a closed moist jar in a warm place.

1. Examine a piece of bread on which the mold occurs. Note that the mold plant is made up of many white fleecy threads or filaments, called *hyphae*. (All the hyphae of a single mold plant

are collectively called the *mycelium* or *thallus*.) Do these hyphae occur only on top of the bread or do they also penetrate into the bread below the surface? Where do these plants obtain their nourishment?

2. Mount in a drop of water on a glass slide a small quantity of the mycellium of the bread mold. Cover with a cover glass and examine under low and high power.

NOTE:—

a. *Mycelium*, the much branched thread-like structures. What is inside these mycelial tubes or hyphae? Are the mycelial branches divided into cells by cross walls?

b. *Cytoplasm*, within the hyphae. Are any vacuoles present?

c. The delicate *cell wall* of the hyphae.

d. *Sporangiophores*, the filaments which bear at the end the sporangia or reproductive bodies.

e. *Sporangia*, the enlarged rounded reproductive bodies at the tip of the sporangiophores.

f. *Spores*, the small reproductive cells within the sporangia. The spores correspond to the seeds in the higher plants.

g. *Columella*, the dome-shaped enlarged tip of the filament around which the sporangium is formed.

h. *Rhizoids*, the branching filaments at the base of a group (stolon) of sporangiophores. What is the function of the rhizoids?

3. Make an enlarged *drawing* of a portion of the mold showing and labeling the following parts: mycelium, cytoplasm, cell wall, sporangiophore, sporangium, spores, columella, and rhizoids.

b. BLUE MOLD (PENCILLIUM). (If time permits). This is the mold which commonly occurs on preserves, lemons, oranges, bread etc.

1. Examine a lemon or other article of food on which this mold occurs and in a few brief statements compare the structure and appearance of this mold with the black bread mold.

2. Mount a little of the mold in a drop of water on a glass slide, cover with a cover glass, and examine under high power.

NOTE:

a. *Mycelium*. Are the mycelialbranches in this mold divided into cells by cross walls?

b. *Conidiophores*. These are the sporebearing filaments which correspond to the sporangiophores in the black mold. In what

way do the conidiophores differ from the sporangiophores in black mold?

c. *Conidia.* These are the spores at the end of the conidiophores. How many conidia do you find at the end of one filament?

3. *Draw* as in black mold, and label: mycelium, conidiophore and conidia.

Summary

1. What strikes you as the most distinctive characters of bacteria and fungi, as setting them apart from each other and from the algae?
2. Why can not bacteria and fungi develop in water alone which would permit growth of algae?
3. Cite three definite instances in which bacteria are of benefit to man.
4. In what manner do bacteria reproduce?
5. What is a parasitic fungus? A saprophytic fungus?

EXERCISE 8

REPRODUCTION AMONG THE SIMPLER ORGANISMS

References. Needham, General Biology, pp. 109-115; Coulter, The Evolution of Sex in Plants; Coulter, Barnes and Cowles, Textbook of Botany Vol. I; Bergen and Davis, Principals of Botany; Hegner, College Zoology; Parker and Haswell, A Textbook of Zoology, Vol. I.

Material and Apparatus Needed. Compound microscope, slides, cover glasses; cultures of pleurococcus, yeast, paramoecia, black mold; live earthworms, fruiting chara, conjugating spirogyra, and prepared slides of budding hydra, dividing and conjugating paramoecia.

Reproduction is the process by which plants and animals give rise to offspring. It consists essentially of the separation or setting apart a portion of the living substance of the parents body and its subsequent growth and differentiation into a new individual. The reproduction may be *asexual*, in which case the offspring is derived from a single parent; or it may be *sexual*, the offspring being commonly derived from two parents.

LABORATORY EXERCISE

ASEXUAL REPRODUCTION

This is division without cell union and is represented by at least three different types.

1. Division by Fission. Reproduction takes place by binary fission each cell dividing into two equal parts.

a. Plants. Pleurococcus or some other unicellular alga. Mount a small drop of the culture on a glass slide, cover and examine under the microscope. Make a *drawing* showing cells in the process of division.

b. Animals. Paramoecium or some other protozoan. Mount a small drop of Paramoecia culture on a slide and examine under low power for individuals which are undergoing division. Such individuals are characterized by the presence of a transverse constriction about the middle of the body. If dividing animals are found note the place and depth of the constriction. How many contractile vacuoles are present?

Examine stained specimens under both powers of the microscope and determine what becomes of the meganucleus and micronucleus. Make a *drawing* of a Paramoecium in the process of division. This drawing should be at least three inches in length

and should show very clearly the condition of the mega—and micronucleus. *Label* all parts shown.

II. Division by Budding. Reproduction takes place by the protuberance of a portion of the cell or body of an organism, which then develops into a new individual.

a. Plants. Yeast. Mount a small drop of yeast culture on a glass slide, cover and examine under the high power. *Draw* yeast cells, showing both single and budding cells. The drawing of each cell should be at least one inch in diameter.

b. Animals. Hydra. This is a metazoan animal made up of tissues. Examine a budding hydra under low power and note that the bud is produced by the outpushing of the body wall which is composed of two layers of cells. The body cavity of the parent and bud is therefore continuous. A bud thus formed developes a mouth and tentacles and when fully formed, it breaks loose and functions as a new individual. Make an outline *drawing* of a hydra with bud.

III. Division by Spore Formation. Certain cells set aside for reproducing new individuals.

a. Plants. Black Mold. This plant has been studied in a previous laboratory period and need not be taken up again. It illustrates one type of spore formation in the fungi.

b. Animals. Monocystis. This is a parasitic protozoan (Sporozoa) found in the seminal vesicles of the earthworm. Examine a slide, containing these specimens, under low and high power and look for the *sporocysts*. These spores have been produced by numerous divisions of a single cell. *Make a drawing* of a sporocyst showing the spores within. Record in your notes your estimate of the number of spores present in each cyst.

SEXUAL REPRODUCTION

Division, in sexual reproduction, is preceded or accompanied by the union of two cells. These cells which unite are called *gametes*. When the *gametes* are similar or identical they unite to form a *zygospore*. When they are dissimilar, composed of *sperm* and *egg cell*, they unite to form the *fertilized egg*.

I. Plants.

a. Spirogyra. Examine preserved material of Spirogyra. Note the various stages in the process of conjugation. The cells

of adjacent filaments each push out conjugating tubes. These tubes fuse as soon as they come in contact with each other. The protoplast (cell contents) of one cell passes through the conjugating tube into the connected cell, the two protoplasts fuse and form a thick walled oblong *zygospore*. Make at least *two drawings* of the cells of spirogyra showing conjugation in different stages of the process.

b. CHARA. This plant is much more highly organized than Spirogyra, the reproductive bodies being highly complex structures differentiated into definite male and female organs, the male organs being known as *antheridia or spermaries*, and the female organs as *oogonia or ovaries*. The reproductive organs are located at the nodes of the plant and are visible to the unaided eye, the mature antheridia being orange red.

Examine under low power a small branch of Chara. Look for the reproductive bodies at the node and note:—

1. THE OOGONIUM. An elongate oval body surrounded by spiral elongate cells. Above the oogonium each of these spiral cells cuts of a tip cell, the cluster of tip cells forming the *crown*. The single ovum or egg cell is invested by these spiral cells.

2. ANTHERIDIUM. A globular body just beneath the oogonium. This is more complex in structure. The wall is composed of eight triangular, dentate, plate-like cells which are known as *shields*. Projecting into the body from the center of each shield is an elongate cell the *manubrium* which bears a terminal *head cell*. These head cells give rise to several similar cells and each ultimate cell produces a pair of long filaments. Each of these filaments consists of approximately 200 cells and each of these cells produces a single sperm. There may thus be produced from 20,000 to 50,000 sperms by a single antheridium.

Draw a small branch of Chara showing antheridium and archegonium. Crush an antheridium under a cover glass and note the large number of filaments present. Under high power look for the sperms in the cells of the filaments.

II. ANIMALS.

PARAMOECIUM. Examine Paramoecia cultures for individuals swimming about in pairs. Such specimens are conjugating. Examine prepared slides. The essential part of this process consist of the exchange of portions of the micronuclei. The mega-

nuclei degenerate. After this exchange of micronuclear material, the Paramoecia separate and for a period again reproduce by fission.

Make an *outline drawing* of two Paramoecia conjugating and show the nuclei in detail.

Summary

1. How many parents are concerned in asexual reproduction?
2. In sexual reproduction?
3. In what way does sexual reproduction differ in Spirogyra and Chara?
4. Define gamete, zygospore, oogonium, antheridium.

EXERCISE 9

BRYOPHYTES (LIVERWORTS AND MOSSES)

References. Needham, General Biology pp. 118-128; Coulter, Barnes and Cowles, Text book of Botany vol. I: 92-121; Grout, Mosses with a Hand-lens; Campbell, Mosses and Ferns: etc.

Material and Apparatus Needed. Simple and compound microscopes, glass slides, dissecting instruments, fresh specimens of Conocephalus and Marchantia and either fresh or preserved specimens of Marchantia bearing sex organs; fresh specimens of Polytrichum showing gametophyte and sporophyte; prepared slides showing cross sections of the thallus of liverwort, slides showing archegonial discs with sporophyte.

Bryophytes is a phylum of plants which comprises the liverworts and mosses. This group is much more highly organized than the Thallophytes. The liverworts are related to the green algae on the one side and to the higher plants on the other. Through them the aerial habit of green plants has probably been established. In the Bryophytes we find division of labor, certain cells or tissues being set aside to perform definite functions. Here we also have a definite alternation of generations, asexual and sexual plants alternately producing each other.

HEPATICAE—LIVERWORT

Liverworts are commonly found growing in moist shady situations, although some species grow in more exposed places.

LABORATORY EXERCISE

a. Conocephalus or Marchantia.

1. External Features. Study a small portion of the liverwort and note that the main body of the plant is made up of a flattened leathery leaf-like body, the *thallus*. On the under side of the thallus look for the fine hair-like *rhizoids* which appear as little rootlets. These are the feeding organs of the plant and serve to absorb the moisture and mineral salts from the soil. Are the rhizoids equally distributed over the entire lower surface? Note also the short *scales* on the under side which serve to fasten the thallus to the soil. On the upper surface note under the simple microscope the irregular hexaognal areas, in the center of each of which there is a small opening, the *pore*. These areas are called *pore areas*. The pores open into the air chambers within the thallus and thus facilitate the diffusion of oxygen and carbon dioxide. Note also the manner of branching of the thallus and at the tip of

the branches the *growing point*. There may also be present small cup shaped bodies on the upper surface of the thallus. These are special reproductive bodies which will be studied later.

Draw a surface view of a portion of the thallus, twice natural size, showing its form, mode of branching, location of growing point, and some of the "breathing pores."

2. Detailed Structure.

a. Examine a prepared slide of the cross section of the thallus of the liverwort under low power. This will show the general cellular structure of the thallus. Make an *outline drawing* of the entire cross section showing the upper and lower surface, the rhizoids and scales. Label.

b. Examine the cross section of the thallus under the high power. Find a place where the section has been cut through a pore and note:

1. *Upper epidermis*, a single layer of cells on the upper surface, elevated in the region of the pore.

2. *Assimilatory parenchyma*, pear-shaped cells containing chloroplasts; these cells are situated immediately underneath the epidermis where they may have direct communication with the air through the pores.

3. *Common parenchyma*, large colorless cells composing the greater bulk of the thallus. These cells serve to give form and body to the thallus.

4. *Lower epidermis*, the single layer of cell on the under side.

5. *Rhizoids*, the root-like feeding organs composed of modified lower epidermal cells.

6. *Scales*, the outgrowths of the lower epidermis which serve to fasten the thallus to the soil.

Draw on a large scale, a portion of the cross section of the thallus in the region of a pore showing detail of the cellular arrangement. Label: upper epidermis, pore, assimilartoy parenchyma, common parenchyma, lower epidermis, rhizoids, and scales.

c. Reproduction.

1. Vegetative. On the upper surface of the thallus of Marchantia look for little cup-shaped bodies, the *cupules*. Within the cupules are found small buds (gemmae) and these, when liberated, give rise to new thalli. This is a vegetative mode of reproduction. If any of these cupules are prcsent in your specimen add one or more to your drawing (under a, 1).

2. Gametophyte Generation: Sexual reproduction is brought about in the gametophyte generation by the production of sperms in the male reproductive organ, called *antheridium*; and eggs in the female reproductive organ, called *archegonium*. The sperms, in the presence of water, find their way to the archegonia and there one sperm fertilizes each egg cell.

Examine the thallus of Marchantia and note the branches arising therefrom. If the branch bears at the top a disc with a lobed margin it constitutes the male reproductive organ and is called the *antheridiophore*; if the branch bears a disc with finger-like processes around the margin it constitutes the female reproductive organ and is called the *archegoniophore*. *Make a drawing* of a portion of the thallus showing antheridiophore and archegoniophore.

3. Sporophyte Generation. The fertilized egg of the gametophyte generation develops, not into a new thallus, but into a small, dependent, spore bearing plant, the *sporophyte*.

Examine a prepared slide of the section of an archegonial disc of Conocephalus under the microscope and study the sporophyte in detail.

Note:

1. The tissue of the archegonial disc. (Gametophyte).
2. The pear-shaped *sporophyte* with its base imbedded in the archegonial disc. The sporophyte is composed of three main regions:
   a. *Foot*, the base or attachment.
   b. *Neck*, the narrowed part of the sporophyte.
   c. *Sporangium*, the enlarged head which contains:
      1. *Spores*, the asexual reproductive cells.
      2. *Elaters*, sterile, elongate cells with spiral thickenings. These, when they become moist, expand and thus aid in the scattering of the spores.

These spores develop into a green thallus (gametophyte). *Make a large drawing* of the section of an archegonial disc showing the sporophyte in detail. Label: gametophyte tissue, sporophyte, and in the sporophyte, foot, neck, sporangium, spores, and elaters.

MUSCI—MOSSES

The mosses include a group of Bryophytes comprising many more species than the liverworts. They are found in all situations except in salt water. The mosses, like the liverworts, have a definite alternation of generations, the gametophyte being produced from spores of the sporophyte generation, while the sporophyte is derived from the fertilized egg of gametophyte gener-

ation. In the mosses, however, the spore upon germinating first produces a branching filamentous agla-like structure which is called the *protonema*. This protonema then forms buds which give rise to the "leafy" moss plant. This intermediate structure, the protonema, is the distinguishing character of the mosses and liverworts.

LABORATORY EXERCISE

a. POLYTRICHUM.

1. EXTERNAL FEATURES. Study the moss plant and note that it is made up of an erect stem which bears numerous leaves on the upper portion. Note the many hair-like rhizoids at the basal part of the stem. These, as in liverworts, are the feeding organs. The leafy stem with the rhizoids is gametophyte and has developed from the protonema. Where did the protonema originate? The sex organs, archegonia and antheridia, are borne at the tip of the leafy stem. From the fertilized egg develops the stalked *sporophyte* which remains attached to the leafy stem. In the sporophyte *note*:—

1. The long slender *stalk*.
2. The capsule, (sporangium), the enlarged "head" of the stalk.
3. The *calyptra*, the hairy scale-like body at the top of the capsule. This is part of the archegonium. How does it come to be at the top of the sporophyte?
4. The *cap* (operculum), the cap-like structure on top of the capsule, better made out after the calyptra has been removed. *Make a drawing* of the entire moss plant indicating clearly which part is sporophyte, and which part is gametophyte. Label: stem, leaves, rhizoids, sporangium, operculum, and calyptra.
5. Remove the operculum from the capsule and examine the top of the capsule with the simple microscope. Note that the edge of the capsule is provided with a fringe of incurving teeth. These teeth collectively constitute the *peristome*. The functon of these teeth is to assist in the scattering of the spores.

Draw the "mouth" of the capsule showing the teeth.

SUMMARY

1. By a series of sketches properly labeled compare the life histories of the liverworts and mosses.
2. What distinguishes liverworts from mosses?
3. Which is more highly developed? Why?
4. What is the difference between a spore and an oogonium? Between a zygospore and an oospore?

EXERCISE 10

PTERIDOPHYTES

(Ferns, horse-tails, club mosses etc.)

References. Needham, General Biology, pp. 128-136; Coulter, Barnes and Cowles, A Text-book of Botany Vol. I: 122-179; Campbell, Mosses and Ferns pp. 218-507; etc.

Material and Apparatus Needed. Simple and compound microscopes, dissecting instruments, fern prothallia, young and mature sporophytes, prepared slides of cross section of rhizome, of cross section of leaflet and slides of prothallia.

This phyllum includes the clubmosses, horse-tails, true ferns, etc. The clubmosses (ground pines) constitute about one-eight of the entire phyllum, the horse-tails (scouring rush) about 25 species and the true ferns more than 3000 species. The Pteriodphytes are distributed over the entire world being especially abundant in the tropics.

LABORATORY EXERCISE

The Fern (Pteris or Polypodium). In the fern we have, as in the Bryophytes, a definite alternation of generations. The gametophyte generation is represented by a small, inconspicuous, short lived, heart-shaped plant body called *prothallium*. The sporophyte generation is represented by the large independent fern plant which is differentiated into stem, roots and leaves or fronds.

I. Gametophyte Generation (Prothallium). This corresponds to the thallus body in the liverwort. It has developed from the spore. Prothallia may be obtained by sowing fern spores on moist soil in a box and covering with a piece of glass and allowing the box to remain in a lighted place at constant temperature.

a. Examine the specimen of fern prothallium and *note*:—

1. Shape, size and color. *Describe.*

2. The *notch* in the margin of the prothallium. At the base of the notch is located the *growing point.*

3. *Rhizoids*, on the under side of the prothallium. How do they compare with the rhizoids in the liverworts and mosses which you have studied.

4. *Archegonia*, on the under side below the notch in which are developed the eggs.

5. *Antheridia*, below the archegonia and more or less obscured by the rhizoids. In them are developed the sperms (antherozoids).

Draw on a large scale the ventral view of the fern prothallium showing and labeling; notch, growing point, rhizoids, archegonia and antheridia.

b. Examine the prothallium under high power and *draw on* a large scale an *antheridium* showing details of structure.

c. If a section of an *archegonium* is available examine it under high power and make a detailed drawing showing the egg cell within.

II. Sporophyte Generation.

A. Young Sporophyte. Study the specimen provided and note that the sporophyte is attached to the under side of the prothallium.

In this young sporophyte *note*:—

1. The developing *stem or rhizome*.
2. The primary *root* and probably secondary roots.
3. The primary *leaf* (frond).

Make a drawing of the young sporophyte and gametophyte which is still attached to the developing sporophyte. Designate clearly which is sporphypte and which gametophyte. In the sporophyte label, stem, root and leaf.

B. Mature Sporophyte.

a. Study the mature sporophyhte and note its complexity of structure.

Note:—

1. *Rhizome*, the horizontal underground stem.
2. *Scales*, the dark coverings over the entire surface of the rhizome.
3. *Roots*, attached to the rhizome.
4. *Fronds*, the leaves. Study the manner of development of the frond (incurled tip), and the differentiation of the frond into a central leaf stalk and small leaflets which are called *pinnae*.
5. *Sori*, the asexual reproductive bodies on the underside of the leaflets, each composed of a large number of *sporangia*.
6. *Indusium* (in Pteris), a protective scale-like covering over the sporangia.

Make a drawing of an entire mature sporpohyte showing the parts enumerated. Label: rhizome, scales, roots, fronds, pinnae and sori.

b. Sporangia. Scrape from the under side of a leaflet of the fern one of the clusters (sorus) of sporangia and mount some of the sporangia in a drop of water on a glass slide. Cover with a cover glass and examine under the microscope.

In the individual sporangia *note*:—

1. The *stalk* on which the sporangium is borne.
2. The *annulus*, a single row or chain of cells with thickened walls surrounding the sporangium about two-thirds of the way.
3. The *irregular cells*, thin walled and making up the greater portion of the wall of the sporangium.
4. The *spores*, within the sporangium.

Make an enlarged drawing of the sporangium showing and labeling all the parts enumerated.

c. Rhizome. Examine under low power the prepared slide of the cross section of the rhizome and *note*:—

1. *Epidermis*, the single outer layer of cells.
2. *Peripheral layer of supporting tissue*, a thick layer of supporting cells just inside the epidermis.
3. *Inner supporting tissue*, the dark transverse patches of supporting cells called *sclerenchyma* cells.
4. The scattered *vascular bundles* in which are found the *tracheids* and *sieve tubes* which constitute the conducting tissue.
5. The undifferentiated *parenchyma cells* which fill the remainder of the stem.

Make a drawing of the entire cross section of the rhizome showing the arrangement of the layers of cells. Label all parts enumerated.

d. Vascular Bundle. Under high power study the detailed structure of a single vacsular bundle and *draw* a small section of a bundle showing several cells in each layer.

e. The Leaf. Strip off a bit of the lower epidermis of a leaflet, mount in water under the cover glass and examine under low power.

Note:—

1. *Interlocking Epidermal Cells.* These are quite irregular in outline.
2. *Stomates*, the "breathing pores" of the leaf.
3. *Guard cells*, the two bean-shaped cells, one on each side of the stomate.
4. *Chloroplasts* within the guard cells and epidermal cells.

Make a drawing of part of the epidermis showing and labeling all the parts enumerated.

f. Cross Section of Leaflet. Examine the prepared slide and note the arrangement of the different cells.

Make a drawing of the cross section of the leaflet and label all the parts which you are able to identify.

Summary

1. In tabulated form compare by words and diagram the sporophyte and gametophyte generations in the liverwort, moss and fern which you have studied in the laboratory.
2. What are the main features which distinguish the Pteridophytes from the Byrophytes?
3. What is the function of the tracheids? Of the sieve tubes?

EXERCISE 11

COELENTERATES

References. Needham, General Biology pp. 156-163; Hegner, College Zoology pp. 108-144; Parker and Haswell, Textbook of Zoology Vol. 1: 118-220; and other textbooks of Zoology.

Material and Apparatus Needed. Compound microscope, forceps, pipette, watch glass, living hydra; prepared slide of hydra showing buds, spermary and ovary; prepared slides of cross section of hydra; prepared slides of Campanularia showing nutritive zooids and reproductive calycles.

Coelenterata is a phylum of multicellular invertebrate, usually radially symmetrical, animals, including the corals, sea anemones, jelly fishes and hydroids. They possess an internal digestive cavity. The body wall consists of two cellular layers, an ectoderm and an entoderm, between which is a gelatinous layer, the mesogloea. The coelenteron usually has a single opening or mouth surrounded by tentacles. The majority of Coelenterata possess nettling cells. The animals belonging to this phyllum, although much more complex than the Protozoa, are quite simple in structure, the body being composed of tissues only.

HYDRA

The hydra is a fresh water animal which lives in shallow ponds and permanent pools in still water. In warm weather it is often found near the surface, attached to the stems or reeds, or hanging from the lower surface of floating leaves. In winter it will more often be found attached to leaves that have fallen on the bottom. Its narrow, cylindrical body is about half an inch long, its tentacles are of equal length, and its color is pale brown (Hydra fusca), or, in another species, (Hydra viridis) clear green. Hydras may be obtained for class use by collecting leaves, sticks and plants from several fresh water pools and placing them in aquaria. The hydra, if present, will collect on the sides of the aquaria toward the light and may then be transferred, by means of a pipette, to watch glasses for study.

LABORATORY EXERCISE

a. Living Hydra. Study a living specimen in a watch glass containing a small amount of fresh clean water and *note:*—

1. *Shape.* Elongated, cylindrical, with the body attached at its posterior or foot end, free at its anterior end, and crowned with a circle of long radiating *tentacles.* How many tentacles are there in your specimen?

2. *Color.*

3. *Actions.* Note the swaying about of the long tentacles in the water. These capture the food. Jar the watch glass a little

and note that the hydra contracts until it is all lumped into a compact little mass. Do the tentacles contract and expand like the rest of the body?

b. External Structure. Examine hydra under the low power of the microscope and *observe*:—

1. *Foot*, the end by which the hydra is attached.
2. *Tentacles*, the radiating fingerlike processes at the distal end.
3. *Hypostome*, the cone-shaped prominence at the anterior end, between the bases of the tentacles.
4. *Mouth*, at the top of the hypostome.
5. *Nettling cells* or *cnidoblasts*, the knob-like prominences on the tentacles. These are the defense organs of the hydra.
6. *Body wall*, a double layer of cells, the outer transparent layer (*ectoderm*) and the inner darker layer (*entoderm*).

Make two drawings of hydra (1) contracted; (2) extended. The drawing of the extended hydra should be at least 3 inches long. Show and label: foot, tentacles, hypostome, mouth, nettling cells, ectoderm and entoderm.

c. Reproduction in Hydra.

1. *Budding*. This has been observed in a previous laboratory period and need not be taken up again.
2. *Sexual*. The sexual reproductive bodies are developed in low elevations upon the sides of the body. They are of two kinds and both may occur on the same individual.
   a. *Spermaries* or *testes*, conical, pointed elevations near the anterior end of the body, just below the tentacles, of varying number, each producing many sperms.
   b. *Ovaries*, rounded, obtuse elevations nearer the foot, rather larger than the spermaries, usually fewer in number, and each containing a single egg cell.

Both spermaries and ovaries are developed from the ectoderm. Examine the prepared slides which show the reproductive organs. Add to your drawing of the extended hydra a spermary and an ovary.

d. Cellular Structure. Examine under the microscope a prepared slide of the cross section of the body of hydra. Study the detailed cellular structure and *note*:—

1. *Ectoderm*, the outer layer of cells.
2. *Entoderm*, the inner layer of cells, composing about two-thirds of the body wall. Are all the cells alike in structure?
3. *Gastro-vascular cavity*, the digestive cavity.

4. *Mesogloea*, a thin structureless substance which separates the ectoderm and entoderm. This will be stained as a deep blue line in your specimen.

5. *Interstitial cells*, small cells at the bases of the larger ectodermal cells.

6. *Nettling cells*, the stinging organs located in the ectoderm.

Make a drawing of a small portion of the cross section of hydra showing the cellular structure in detail. Label: ectoderm, entoderm, gastro-vascular cavity, mesogloea, interstitial cells, and nettling cells.

CAMPANULARIA

This is a colonial form of Colenterate which lives in the sea, where it is found attached to rocks or plants.

a. Examine the prepared slide under low power and note:

1. General Structure. That the colony resembles the structure which would be formed by a budding hydra if the buds remained attached to the parent and in turn produced buds which would remain fixed.

2. *Nutritive zooid* or *hydranth*, the hydra-like structures arising from the main stalk, and bearing at its end numerous tentacles. How many tentacles do you find on a hydranth?

3. *Reproductive calycles or gonangia*, the reproductive organs which arise in the angles where the hydranths are attached to the main stalk (hydrocaulus). Within the gonangia note the reproductive bodies or *medusa-buds*.

4. *Perisarc*, the clear chitinous covering of the colony which serves to protect the soft parts.

Make a drawing of a *part* of the colony of Campanularia showing and labeling, nutritive zooid, reproductive calycle, hydrocaulus, perisarc, tentacles and medusa-buds.

Summary

1. How do the cells of the ectoderm differ from the cells of the entoderm in hydra?
2. What are the functions of the following in hydra: tentacles, nettling cells, ectoderm, entoderm, interstitial cells?
3. What is radial symmetry?
4. What methods of reproduction has hydra?

EXERCISES 12 and 13

ANNELIDA

(Earthworms, leeches etc. *Lumbricus Terrestris*)

References. Needham, General Biology, pp. 163-178; Hegner, College Zoology pp. 215-241; Parker & Haswell; Text-book of Zoology pp. 417-427; and other textbooks of Zoology.

Material and Apparatus Needed. Compound and simple microscopes, dissecting instruments, trays, pins, live and preserved earthworms, prepared sections of ovary and of cross sections of the body of the earthworm.

The phylum Annelida is a group of animals whose chief characters are: an elongate bilaterally symmetrical body composed of a series of segments or rings; usually with a coelom or body cavity; a vascular or circulatory system containing red blood; a nervous system composed of a supra-oesophageal ganglion and a double ventral nerve cord; paired nephridia in some or most of the segments; and commonly having setae.

THE EARTHWORM

The earthworm is common in garden soil everywhere. It is strictly nocturnal in its habits. Specimens for study may be obtained by digging, or at night, by the aid of a flashlight or lantern, they can be picked up when they are out of their burrows and extended on the ground.

LABORATORY EXERCISE

a. General External Characters. Examine both the living and the preserved specimens and note the following:

1. *Shape*, the long cylindrical body which is divided by transverse constrictions into *segments or somites*. There may be more than three hundred of these segments.
2. *Anterior end*, the end at which the segments are larger and more rotund, and which is tapering and bluntly pointed.
3. *Posterior end*, the end which is flattened and obtusely pointed.
4. *Dorsal surface*, which is convex, brownish red and with a median darker line.
5. *Ventral surface*, which is flat and whitish.
6. *Locomotor setae*, the bristles on the ventral surface of the segments, two pairs on each side, Draw the specimen over the back of the hand or arm and determine the location of the setae. Examine under simple microscope.
7. *Cuticle*, the delicate iridescent membrane investing the entire external surface.

8. *Prostomium*, the minute ball-like knob at the extreme anterior end. This is not a true segment, but forms a sort of upper lip for the mouth, which is situated just below and behind it. In numbering the segments, the one just behind the prostomium is counted as the first.

9. *Clitellum*, the saddle-like swelling between the thirtieth and fortieth segments (counted from the front). Its exact position varies slightly. How many segments does it cover in your specimen?

10. Apertures.

a. *Mouth*, at the anterior end, below the prostomium.

b. *Anus*, the small opening, at the posterior end of the body, which terminates the digestive tract.

c. *Dorsal or peritoneal pores*, (probably not visible in your specimen) a row of pores on the median dorsal line, one at the anterior edge of each segment. Through these pores is secreted the slimy fluid which commonly covers the body of the worm.

d. Sexual Apertures.

1. *Openings of the sperm ducts*, situated on the ventral surface of the fifteenth segment just outside of the inner row of setae.

2. *Openings of the oviducts*, smaller similar apertures on the ventral surface of the fourteenth segment. (Not easily made out).

3. *Openings of the seminal receptacles*, two pairs of pores on opposite sides of the median ventral line, a pair on the groove between segments 9 and 10 and another pair on the groove between segments 10 and 11. (These openings are very difficult to see and need not be looked for at present).

e. *Nephridiopores*, a pair of openings of the nephridia or excretory organs on the outer ventral margin of each segment except the first three and last one. (These will be seen in the prepared sections later).

Draw the ventral view of the first forty segments. Show and label: prostomium, mouth, clitellum, setae, openings of the sperm ducts, oviducts, and seminal receptacles. The instructor will point out in a diagram on the board the location of the openings of oviducts and seminal receptacles.

b. Internal Anatomy. Place the freshly killed or preserved specimen in the tray, dorsal side uppermost, and cover with water. Thrust one pin through the prostomium only, and another through the last segment, with the body slightly stretched between the pins. Handle specimens carefully. Follow directions closely and do not cut more than directed.

Dissection. Carefully insert the point of the thin sharp scissors through the body wall at about the middle of the body a little to one side of the median dorsal line and cut backward to the posterior end and then forward to the anterior end being careful always to cut a little to one side of the median line and especially careful not to cut deep so as to injure the organs which lie beneath, and as you get to the anterior end not to injure the brain which lies just below the body wall in the third segment. At the middle of the body draw the edges of the cut apart, and observe the *septa* (or partitions) which extend transversely across the body cavity. Note that these correspond in position with the depressions between segments seen on the exterior, and show internal segmentation. Observe that each septum is perforated in the center for the passage of the alimentary canal and other vessels.

Beginning at the anterior end, cut the septa close to the body wall on each side, and pin back the flaps. The pins should be slanted outward so as not to interfere with the work later.

Internal Organs.

1. Reproductive System. The earthworm is hermaphroditic, each individual producing both male and female reproductive organs.

a. *Sperm Vesicles.* These are the three pairs of large white lobes between the ninth and thirteenth segments. The posterior lobes are larger, they surround and overlap the oesophagus. The testes within the vesicles produce the spermatozoa which are then discharged into the vesicles where they undergo further development and where they then are stored.

b. *Sperm Receptacles.* Two pairs of small, white round sacs situated between the ninth and tenth, and tenth and eleventh segments attached to the septa. These sacs open directly downward to the outside. In these organs the sperms from another individual are stored until the time when the eggs are laid. In order to see these receptacles, carefully push the sperm vesicles aside.

c. *Testes.* Two pairs of minute white bodies, one pair in segment ten, and the second pair in segment eleven, situated close to the median ventral line. They are covered or surrounded by the sperm vesicles and need not be looked for at this time. Behind the testes is a funnel-like opening which leads into a tube which leads backward through the septa and in segment twelve unites with a similar tube from the testes in segment eleven. This single tube or duct then passes backward to segment 15 where it opens through the ventral surface to the outside. This duct is known as the *vas deferens.*

d. *Ovaries.* One pair of small bodies in segment thirteen, located on the ventral side near the middle line and attached to the septum which divides segments twelve and thirteen. Just posterior to the ovaries are found the funnel-like openings which lead into a short tube. This tube passes through the septum into the fourteenth segment where it enlarges to form the *egg sac*, and from this sac the tube passes through the ventral side and opens to the exterior on segment fourteen. This tube is called the *oviduct.*

Examine the prepared slide of the ovary. On the sheet furnished you, *complete the drawing* by putting in the sperm vesicles and the sperm receptacles. Label: sperm vesicles, sperm receptacles, testes, vas deferens, ovaries, egg sac, and oviduct.

2. Digestive System. Beginning at the anterior end study the digestive system or alimentary canal which extends the entire length of the body and note:—

a. *Buccal pouch*, the thin-walled mouth cavity within the first three segments.

b. *Pharynx*, the elongate, barrel-shaped, thick-walled portion extending from segment three to six. It is held in place by numerous radiating muscle fibers.

c. *Oesophagus*, the long thin-walled tube, much smaller than the pharynx, extending from the seventh to about the fourteenth segment. This is in part hidden by the aortic arches and sperm vesicles.

d. *Crop*, the small thin-walled pouch-like organ located in the fifteenth and sixteenth segments.

e. *Gizzard*, the firm-walled, cylindrical organ located in the seventeenth and eighteenth segments.

f. *Intestine*, all that portion of the digestive tract which extends from the gizzard back to the posterior end where it opens to the exterior by the *anus*.

On the sheet furnished, with the body outline drawn, *draw* the digestive system of the earthworm. Label: buccal pouch, pharynx, oesophagus, crop, gizzard and intestine.

3. Circulatory System. In your specimen note:—

a. *Dorsal blood vessel*, this is the reddish tube which lies on the dorsal surface of the alimentary canal closely united with it. In living specimens it can sometimes be seen to pulsate.

b. *Hearts or aortic arches*, five pairs of large vessels encircling the oesophagus in segments seven to eleven, and connecting the dorsal vessel with the ventral vessel. They can be plainly seen by pushing the lobes of the sperm vesicles gently aside.

c. *Ventral blood vessel*, (to be seen later) the small reddish tube extending along the ventral side of the alimentary canal.

d. *Subneural blood vessel*, a longitudinal tube which lies below the nerve cord.

e. *Lateral-neural blood vessels*, one longitudinal tube on each side of the nerve cord.

Add to your drawing of the digestive system the following parts of the blood system: dorsal blood vessel and hearts. Label.

4. Nervous System. Beginning at the posterior end carefully remove with forceps the entire alimentary canal *except the pharynx*. Cut off the alimentary canal just back of the pharynx.

Note:—

a. *Brain or supra-oesophageal ganglion*, the white, bilobed structure in the third segment, resting on the buccal pouch.

b. *Ventral nerve-cord*, the white cord just beneath the ventral blood vessel, extending the entire length of the body.

c. *Ganglia*, the swellings of the cord in each segment.

d. *Lateral nerve fibers*, the lateral branches which are given off from the ganglia in each segment.

e. *Circum-pharyngeal connectives*, the cords which extend down on each side from the brain to the ventral nerve cord, forming a nerve collar which completely encircles the pharynx.

On the sheet furnished, with the body outline drawn, *make a drawing* of the nervous system. Show and label: brain, ventral nerve cord, ganglia, lateral nerve-fibers and circum-pharyngeal connectives.

5. Excretory System.

a. *Nephridia*, (*the excretory organs*) little, tangled, whitish thread-like bodies, attached to the posterior side of each septum, one on each side of every body segment except the first three and the last one. Each of these organs opens to the exterior by a minute pore (nephridiopore). Each opens internally at the end which floats free within the body cavity, by a minute ciliated orifice. These organs drain out waste and worn-out materials from the body.

Select a segment in which the nephridia have not been disturbed and examine under low power. The nephridia are indicated in a few segments on the sheet which contains the drawing of the rproductive organs. *Label* them.

6. Muscular System. Spread out part of the body wall perfectly flat, and pin it so. Observe its muscular lining.

Note:—

a. *Longitudinal muscles*, which in the fresh specimen show up as glistening strands running lengthwise on the inner surface of the body wall.

b. *Circular muscles*, with a dissecting needle stir up some of the longitudinal muscles and observe the circular ones underneath which run transversely to the long axis of the body.

c. Other muscles are best observed in the prepared slides of the cross section of the worm.

EXERCISE 14

THE CELLULAR STRUCTURE OF THE EARTHWORM

a. Cross Section Through the Region of the Intestine. Examine the prepared slide of the cross section under the simple microscope or under low power of the compound microscope. There are several sections on each slide, select the one most perfect.

Determine which is dorsal and which ventral side. Note that the body is made up of two tubes, one within the other,—the inner one, the intestine; the outer one, the tube formed by the body wall, which is relatively thick. Between these two tubes is the *body cavity* (*coelomic cavity*).

Study in detail under compound microscope:

1. The Body Wall. In the body wall note:

a. *Epidermis*, the layer of polygonal-shaped cells forming the outer cellular layer of the body. The *cuticle* is on the outer surface of the epidermis and is secreted by it but is so delicate that it may not be possible to determine it in this exercise.

b. *Circular muscles*, the narrow, continuous, circular band lying just inside of the epidermis.

c. *Longitudinal muscles*, more or less feathery looking structures situated just within the circular muscles. They occupy a much broader area than the circular muscles and are broken up into four areas, due to the insertion of the setae.

d. *Peritoneum*, a very thin layer of cells, just inside the longitudinal muscles, lining the body cavity.

2. The Intestine. This is the large darkly stained organ in the center of the section. It is also composed of four layers. Examine the intestine and note:

a. *Typhlosole*, the deep, inward fold of the dorsal wall of the intestine.

b. *Digestive epithelium*, the inner layer of slender cells, which lines the intestine.

c. *Circular muscles*, a layer of muscles surrounding the digestive epithelium on the outside (toward the body cavity).

d. *Longitudinal muscles*, isolated longitudinal muscle fibers, represented as small dots, outside of the circular muscles.

e. *Chloragogue cells* (modified peritoneum), a thick layer of yellowish cells all around the intestine, lining the body cavity.

3. Nerve Cord. The solid body between the intestine and the ventral body wall. In some of the sections there are lateral prolongations from the cord. These are the *lateral nerve fibers.*

4. Blood Vessels.

a. *Dorsal blood vessel*, closely united to the intestine just above the typhlosole.

b. *Ventral blood vessel*, located between the intestine and nerve cord.

c. *Sub-neural blood vessel*, on the ventral side of the nerve cord.

d. *Lateral neural blood vessels*, one on each side of the nerve cord. (Probably not visible in your section).

5. *Setae*, the four pairs of minute bristles on the outer lower side, by which the animal moves.

6. *Nephridia*, these are represented, by varying fragments, on each side, between the body wall and intestine.

Make an outline drawing of the entire cross section of the earthworm showing the form and position of the various layers of tissues and other organs. Do not attempt to show cellular detail. *Label*: body wall, intestine, typhlosole, nerve cord, dorsal blood vessel, ventral blood vessel, subneural blood vessel, nephridia and setae.

Draw a portion of the body wall, showing cellular structure in detail. *Label*: epidermis, circular muscles, longitudinal muscles, and peritoneum.

Draw a portion of the intestine, showing cellular structure in detail. Label: digestive epithelium, circular muscles, longitudinal muscles and chloragogue cells.

b. Sperm Cells. Examine a drop of the fluid from the sperm vesicles and note the sperm cells in various stage of development.

Summary

1. List the organs in the earthworm which function in respiration, excretion, digestion, reproduction.
2. In what way is the earthworm more highly specialized than the hydra?
3. What are the functions of each of the four layers of the body wall?
4. Of each of the four layers of the intestine?
5. What is the purpose of the typhlosole?

EXERCISE 15

ARTHROPODA

References Comstock, Manual for the Study of Insects; Folsom, Entomology; Comstock, An Introduction to Entomology; Hegner, College Zoology.

Material and Apparatus Needed. Simple microscope, trays, dissecting instruments, pins, live or pickled grasshoppers.

The phylum Arthropoda is composed of animals whose body is made up of a series of rings or segments, some or all of which bear jointed appendages. It includes the Crustacea (crayfish, crabs etc.), Arachnida (spiders, scorpions etc.), millipedes, centipedes, insects etc.

This phylum includes more species than all other phyla combined.

INSECTA (*Grasshopper*)

An adult insect is an air-breathing arthropod whose body is divided into head, thorax and abdomen. It possesses one pair of antenna, three pairs of legs and usually one or two pairs of wings.

The Grasshopper. Grasshoppers are common almost everywhere where green vegetation occurs. Specimens for study are usually preserved in alcohol or formalin.

LABORATORY EXERCISE

a. External Anatomy.

1. General Structure. Examine the grasshopper and note:

a. *Exoskeleton*, the hardened (chitinous) covering over the entire body.

b. Division of body into:

1. *Head.*
2. *Thorax*, to which are attached the wings and legs.
3. *Abdomen.*

Make a drawing of a side view of the grasshopper. This drawing should be at least four inches long. Show and label: head, antennae, eyes, thorax, wings, legs and abdomen.

2. The Head and its Appendages. Study the head and find the following parts:

a. *Antennae*, the slender filaments or feelers at the upper part of the head.

b. *Compound eyes*, the prominent eyes on the upper and outer portion of the head. Examine the surface of the eye with a lens and note that it is made up of numerous hexagonal areas called *ommatidia*. Examine a mount of this under the demonstration microscope.

c. *Ocelli*, three simple eyes located between the compound eyes in the front part of the face.

d. *Labrum*, the upper lip which covers the other mouthparts. *Make a drawing* of the front view of the head and label antennae, compound eyes, ocelli, and labrum.

e. *Mouthparts*. Study the mouthparts with especial care, for in the grasshopper all the typical mouthparts of an insect are present and well developed. Proceeding from the front find and separate the mouthparts and place them on a piece of paper as directed by the instructor.

1. *Labrum*, the large lobed upper lip.

2. *Mandibles*, two toothed horny jaws covered by the labrum.

3. *Maxillae*, two jointed compound organs, each bearing at its summit three appendages:

(1) The *lacinia*, the innermost part.

(2) The *galea*, a spoonshaped lobe.

(3) The *maxillary palpus*, a jointed, tactile organ. How many segments does it contain?

4. *Labium*, the two-lobed lower lip, bearing a pair of jointed *labial palpi*.

5. *Tongue*, a fleshy organ between and below the maxillae. After separating these mouthparts and arranging them in order on a piece of paper make an enlarged drawing of each of these *mouthparts* and label the parts as indicated above.

3. The Thorax and its Appendages. Note that the thorax is made up of three main regions: the *prothorax*, the large saddle-like part bearing below the first pair of legs; the *mesothorax*, bearing the front pair of wings and the middle pair of legs; the *metathorax*, bearing the hind wings and the last pair of legs.

a. *The Wings*. Cut off the front wing and note that it is narrow and leathery in structure. The front wings in grasshoppers are called *tegmina*. Now cut off the hind wing and note how it is folded. The hind wings are used in flight and the front wings serve as protecting covers when the grasshopper is at rest. Spread out the hind wing and pin it down.

Make an *outline drawing* of the tegmina and the hind wing showing relative size.

b. *The Legs*. Compare the first and second pairs of legs with the third pair, in color and surface markings, position,

size and use. Find in one of the hind legs the following segments beginning at the point of attachment to the body.

1. *Coxa*, the small globular joint.

2. *Trochanter*, the second segment, smaller than the coxa and more readily seen from the inside.

3. *Femur*, the large and most prominent part of the leg. Within this are the powerful muscles used for leaping.

4. *Tibia*, the long slender segment bearing on the sides a double row of *spines*, and *spurs* at its lower end.

5. *Tarsus*, the three end segments bearing pads below and the end segment bearing two claws, and a lobe (*pulvillus*) between the claws.

Make an enlarged drawing (side view) of one of the hind legs in its natural resting position and label the following parts: coxa, trochanter, femur, tibia, tarsus, pulvillus, spines, spurs, and claws.

4. The Abdomen. Count the segments of the abdomen as seen on the ventral surface. In the female there are eight, and in the male nine. The abdomen of the female terminates in an *ovipositor*, having four subequal points, which are used for making holes in the ground for the reception of eggs. The four points are repeatedly pressed together, pushed into the ground, and there separated, thus pressing the earth aside until a hole is made of sufficient depth, when the eggs are deposited in the bottom. The abdomen of the male terminates in an enlarged rounded blunt point.

On each side of the abdomen notice a longitudinal groove, and just above it a row of *spiracles*, the breathing pores. How many spiracles are there in the abdomen? In the thorax?

On each side of the first abdominal segment note a semicircular depression, across which is stretched a thin membrane. This is the organ of hearing and is called *tympanum*.

Make a drawing of the tympanum at least two inches in its greatest diameter.

Summary

1. Name 5 beneficial and 5 injurious arthropods.
2. Distinguish between a spider and an insect.
3. In what ways is the grasshopper more highly organized than the earthworm.

EXERCISE 16

VERTEBRATES

THE EMBRYOLOGY OR DEVELOPMENT OF THE FROG

References. Needham, General Biology pp. 193-206; Holmes, Biology of the Frog pp. 81-120; Hegner, College Zoology pp. 506-510.

Material and Apparatus Needed. Compound and simple microscopes, watch glasses, forceps, dissecting needles, successive stages of development of frog from the egg to the adult stage.

Embryology is the study of the development of an individual from the egg to the adult stage. The embryology of the different groups of vertebrates is very similar. The frog serves as a very good example for the study of the successive developmental stages.

LABORATORY EXERCISE

Caution. The different stages of development have been carefully sorted and put in vials each of which bears a label designating the stage which it contains. *Be sure to return* the contents to the properly labeled vials when through studying them.

Study the following stages in the development of the frog. Pour the contents of a vial into a watch glass and examine under the simple microscope.

1. One Cell Stage. Note that one half of the egg is colored black and the other half white. The black end is called the *animal pole* and the white end the *vegetative pole*. Note that the egg is surrounded by layers of jelly which serve as a protection for the eggs. How many layers are there?

Draw a side view of the unsegmented egg with the animal pole toward the top. *Label*: animal pole, vegetative pole, jelly layers. The drawing of the egg should be one inch in diameter and the layers of jelly proportionate in size.

2. Two Cell Stage. Note the groove which divides the egg into two equal halves. Is it equally deep all around?

Draw, omitting the jelly layers. Label poles and groove.

3. Four Cell Stage. Note how the grooves are placed with reference to each other and to the poles. *Make a drawing* of the egg in such a way that you show both grooves. Label poles.

4. Eight Cell Stage. Note here the manner in which the grooves divide the egg into eight parts. Are the parts of equal size?

Draw the eight cell stage. Label parts.

5. Sixteen to Thirty-two Cell Stage. Cleavage or division takes place more rapidly in the region of the animal pole because the protoplasm is more dense there. The cells at the animal pole are therefore much smaller than those at the vegetative pole. *Make a drawing* of either a sixteen or thirty-two cell stage. Label poles.

6. Morula or Blastula Stage. As cell division increases the cells become smaller and smaller until the whole egg appears somewhat like a mulberry. A cavity appears near the center of the egg so that the egg becomes a hollow sphere called the *blastula*. *Make a drawing* of the blastula stage.

7. Yolk Plug or Gastrula Stage. After the blastual stage has been formed the cells near the border of the black and white areas begin to be pushed inward along a crescentric line. This is called the *blastopore*. The crescentric line soon becomes a circle which incloses a small area of the white which is known as the *yolk plug*. *Make a drawing* of this stage and label parts shown.

8. Open Neural Groove Stage. On the upper surface of the embryo an elevation appears now and forms two parallel ridges called the *neural folds*. These folds are confluent in a loop, the wider part later forming the brain and the remainder the spinal cord. The groove between the neural folds is called the *neural groove*. *Make a drawing* of this stage. Label: neural groove, neural folds, anterior and posterior ends.

9. Closed Neural Groove Stage. As development proceeds the embryo begins to elongate somewhat. The neural folds of the sides meet and fuse above the neural groove and thus form the *neural tube*. Draw the closed neural groove stage and label the parts shown.

10. External Gill Stage. All the above stages take place while the egg remains within the jelly. About the eighth or ninth day the young embryo breaks through the layers of jelly and becomes a free swimming tadpole. Note the long tail with its upper and lower fins. Above note the developing *eyes*, on the sides of the body the external tufted *gills*, and on the ventral side the *mouth*, and on each side and a little back of the mouth a *sucker disc*. *Make a drawing* of the ventral view of the tadpole showing and labeling mouth, sucker-discs, external gills. How many gills does your specimen have?

11. Internal Gill Stage. In addition to the external gills there are developed later four pairs of internal gills. The external gills then disappear and a fold called the *operculum* grows backward from the head and covers the gill region. On the left side of the body just back of the gill region is an opening, the *spiracle*. The water is taken in through the mouth, passed through the gill slits and then out through the spiracle. *Make a drawing* of the left side view of this stage and label all the parts shown.

12. Transforming Tadpole. As the tadpole reaches the stage where it is transformed into the young frog it undergoes marked changes. The intestine, which in the tadpole is long and coiled, shortens, the mouth becomes much wider and the horny jaws of the tadpole stage are shed. The hind legs develop first as buds on each side at the base of the tail and gradually become fully formed. The fore legs develop underneath the skin. The left leg passes through the spiracle and the right one breaks through the wall of the operculum. The tail is reabsorbed by the body. As the lungs develop the internal gills are reabsorbed and the transforming tadpole begins to breathe air directly.

Study the transforming tadpole and then *make a drawing*, ventral view, showing and labeling all the parts which you are able to find.

13. The Brain of the Tadpole. Study the demonstration specimen showing the brain of the tadpole.

Note the following:

a. *Olfactory lobes*, the two anterior prolongations of the brain.

b. *Cerebral hemispheres*, the pear-shaped lobes just back of the olfactory lobes.

c. *Optic lobes*, the large globular lobes.

d. *Cerebellum*, the narrow transverse fold of the brain just back of the optic lobes.

e. *Medulla*, the part just back of the cerebellum.

Draw the brain of the tadpole and label the parts just enumerated.

EXERCISES 17 and 18

VERTEBRATES

THE FROG (AMPHIBIA)

References. Needham, General Biology pp. 179-220; Holmes, Biology, of the Frog; Hegner, College Zoology pp. 477-526 and other textbooks of Zoology.

Material and Apparatus Needed. Simple and compound microscopes, dissecting instruments, trays, pins, live and freshly killed frogs.

The Vertebrates constitute a comprehensive division of animals, containing all those with a back bone, or segmented spinal column (which is represented in the embryo by a notochord), together with a few obviously related but more primitive forms in which the back bone is represented by a notochord throughout life. It contains the mammals, birds, reptiles, amphibians, fishes etc.

Frogs are commonly found in marshy places or near brooks and ponds. They spend part of the time on land and part in water. In the winter they hibernate in the mud in the bottom of ponds. In the spring and summer specimens for study may be obtained by collecting the frogs at night, with the aid of a light, along the edges of ponds and brooks In cold weather live specimens may be dredged up from the bottom of ponds or they may be obtained from dealers. By placing the frogs in a cool moist place they may be kept alive for a long period of time; for during the winter season they are normally inactive and take no food.

LABORATORY EXERCISE

1. Study of the Live Frog. Study the live frog and observe:
   a. The *form* of the body.
   b. The presence of well developed *legs*.
   c. The *eyelids*. Are they of one sort? Touch the eye gently with the point of the pencil and note the eyelids.
   d. *The breathing*, note especially the throat, nostrils and sides of the body.
   e. *The tympanum*, or eardrum, the circular tightly stretched membrane of the ear situated just back of the eyes.

   Make a drawing of the side view of the head showing eyes, mouth, nostrils and tympanum.

2. Study of a Chloroformed Specimen. Note:
   a. Color and markings of body. Of what use?
   b. Character of the skin. Why is it kept moist?
   c. Size and shape of mouth.
   d. Eyes. How do the eyelids function?

e. Structure of tympanic membrance.

f. Nostrils. Note how these may be closed. For what purpose?

g. Teeth, open mouth and note where they are.

h. Tongue. Where is it attached?

i. Note that the nostrils are connected with the mouth by a passage. Why?

Enter the answers to the above questions in your laboratory book.

3. Dissection of the Frog. Dissect the frog under water. Place the frog upon its back, thrust a pin through each leg, slightly stretching the body. Be careful not to cut too deeply. Cut through the *skin* along the median ventral line, from the mandible to the posterior end of the body. Make a second cut at right angles to the first, entirely across the middle of the ventral surface, and turn back the four flaps of the skin thus formed. This will expose the thin, muscular abdominal wall. Observe a dark vein showing through the abdominal muscle on the median line. Make a longitudinal cut through the body wall, a little to the left of the median line, so as to avoid injuring the vein and continue to cut forward to the shoulder girdle avoiding blood vessels below. Then cut along one side of the elongated median bone of this girdle without injuring it, cutting forward through the transverse bone to the base of the tongue. Now make a cut at right angles to the longitudinal axis of the body posterior to the bone (shoulder girdle) but *over* the anterior abdominal vein so as to leave this uninjured. Next cut down on the right side of the abdominal vein, which will now have attached to it the narrow strip of the abdominal wall. Turn back the edges of the incision and expose the organs.

a. Internal Features. Without unduly disturbing the internal organs of the body study their relative position, shape and size. Find the following organs:

1. *Liver*, which is the conspicuous large mottled reddish organ consisting of a large double lobe on the right side of the body, and of a smaller single lobe on the left side.

2. *Heart*, In front of the liver and enclosed in a thin sac, the pericardium. Pinch up the pericardium with forceps and cut it away with the scissors. Cut away also its attachments to the body wall taking care not to cut the heart, blood vessels or other organs.

3. *Lungs*, the pinkish strawberry shaped organs in front of and under the lobes of the liver. By gently lifting the lobes of the liver the lungs may be exposed without injuring the other organs.

4. *Gall bladder*, the greenish small organ attached to one of the lobes of the liver. Find a duct leading from the gall bladder to the intestine. This is the *bile duct.*

5. *Stomach*, the whitish organ to the left of the liver, connecting in front with the oesophagus and behind with the small intestine.

6. *Small intestine*, coiled and of considerable length.

7. *Large intestine*, the caudal enlarged portion of the intestine.

8. *Pancreas*, a light colored gland between the stomach and small intestine (duodenum).

9. *Spleen*, the dark red roundish organ near the beginning of the large intestine.

10. *Urinary bladder*, the whitish bilobed bladder attached to the posterior part of the alimentary canal.

Drawing. On the sheet which contains an outline drawing of the frog *draw in position*, as nearly as possible, and label the following parts: liver, heart, lungs, gall bladder, stomach, small intestine, large intestine, pancreas, spleen and urinary bladder.

4. Circulatory System. The circulatory system is composed of the *heart*, the central organ of circulation, the *arteries* and *veins*.

Study the circulatory system and note:

a. *The heart*, composed of three divisions:

1. *Ventricle*, the conical posterior division.

2. *Auricles*, the two anterior, thin-walled divisions.

b. Arterial System. This is the system of tubes which carries the blood to all parts of the body. In your specimen note:—

1. *Arterial trunk* or *bulbos arteriosus*, the large cylindrical tube which arises from the anterior end of the ventricle, and passes obliquely forward across the uppermost auricle, soon dividing into two principal branches.

2. *Aortic arches*, the two branches arising from the arterial trunk and each soon dividing into three arches:

a. The anterior *carotid artery*, which goes forward to the head.

b. The posterior *pulmo-cutaneous* artery which lends one branch to the lung and the other to the skin.

c. The lrger middle *aortic arch* which curves upward and then backward where it unites with its fellow to form the *dorsal aorta.*

3. *Dorsal aorta,* which extends along the dorasl wall of the body.

4. *Coeliac artery,* the artery which branches off from the dorsal aorta and gives off subsequent branches to the liver, stomach and other organs of the body cavity.

5. *Renal arteries,* the short branches from the dorsal aorta leading to the kidneys.

6. *Iliac arteries,* the branches from the dorsal aorta which go to the hind legs.

c. Venus System. The right auricle receives the blood from all parts of the body except from the lungs. The blood from the lungs is returned to the left auricle. Study the venus system and find the principal avenues by which the blood is returned to the heart, after being distributed throughout the tissues.

Abdominal Vein. This is the vein that was seen through the thin abdominal wall before the body cavity was cut open. Trace this vein backward far enough to see the large *femoral veins* coming up from the hind legs. Trace the abdominal vein also forward. Observe that it soon leaves the body wall, and descends through the body cavity to the liver, where it branches, sending one branch to each lobe of that organ. This is the ventral route to the liver; there is also a dorsal route through the kidney. Turn the organs that cover the kidneys to one side, and find a longitudinal vein, *renal portal vein,* coming from the posterior end of the body cavity, and passing along the exteral margin of the kidney, and dividing up into numerous branches, which enter the mass of the kidney. Then find a corresponding set of venous branchlets coming from the inner side of the kidney, meeting branchlets from the other kidney, and uniting into another large vein, which proceeds forward to the heart, receiving important branches from the viscera at several points. This is the *postcaval vein.* Trace it to the heart. Then draw the liver backward, and turn the ventricle over forward, and see the large *hepatic vein* which conveys the blood from the liver into the *venus sinus,* and thence

into the right auricle. Draw the heart gently backward, and see the two large veins, *the precavae*, which bring the blood into the same chamber from the anterior parts of the body. The blood flows from the auricle into the ventricle, and is forced out again, by the contraction of the ventricle, through the arterial trunk.

From the lung a *pulmonary vein* conveys the aerated blood back to the left auricle of the heart, whence it passes into the ventricle, to be mixed with the venous current from the right auricle.

Make a drawing of the heart and the main blood vessels showing and labeling the following: ventricle, left auricle, right auricle, arterial trunk, carotid artery, pulmo-cutaneous artery, aortic artery, precaval veins, pulmonary veins, and postcava.

Make a drawing of the kidneys and the blood vessels associated with them. Show and label: renal portal vein, dorsal aorta, renal arteries and renal veins.

5. The Digestive Tract and its Appendages. Beginning at the posterior end of the body, carefully dissect out and remove the digestive tract with its appendages. Be careful not to injure the other organs. After you have removed the entire tract with is appendages spread it out so as to clearly show the relationships of all the parts.

Make a drawing of the digestive tract and its appendages showing and labelling; pharynx, oesophagus, lungs, stomach, liver, gall bladder, pancreas, small intestine, large intestine, cloaca and urinary bladder.

6. Reproductive System. A pair of digitate, yellow fatty bodies are attached to the dorsal wall of the body cavity, behind the stomach, and close beside the median line. The paired reproductive organs lie just posterior to these,—rounded yellow *testes* in the male, and folded or lobed, lighter colored *ovaries* in the female. In the breeding season, the ovaries may be found so distended with eggs as to fill most of the body cavity. The *oviducts*, which convey the eggs to the cloaca, are very long and much convoluted tubes, having no connection with the ovary, but opening by a funnel-shaped orifice into the body cavity near the oesophagus.

7. Renal Excretory Organs. A pair of reddish brown *kidneys* lie on the dorsal side of the body cavity, near the cloaca; and ducts

from these pass to the large whitish bilobed *urinary bladder*, which occupies the extreme posterior end of the body cavity as already noticed.

The small, roundish red body, dorsal to the cloaca, and near the anterior end of the kidneys, is the *spleen*.

Make a drawing of the reproductive organs and the kidneys.

8. The Nervous System.

a. The Sympathetic System. Having removed the organs of the body, or by gently turning them to one side, observe the *spinal column*. Observe the white *spinal nerves* extending out from it, along the body wall, just beneath the smooth, transparent peritoneum. Note that each spinal nerve, near its origin, sends a branch ventrally into the body cavity to meet a very delicate nerve cord that extends longitudinally, ventral to the spinal column, and near the median plane of the body. Examine this nerve cord carefully with a lens to find the minute *ganglionic* swellings on it at its juncture with the branches of the spinal nerves. Find also minute nerves arising from its ganglia, and extending to the internal organs. Trace it forward to the head. Find another similar nerve cord on the outer side of the median plane. Find minute *commissural nerves* connecting the ganglia of the two chains.

Make a drawing of several spinal nerves and a portion of the sympathetic system. Consult the demonstration dissection.

b. The Cerebro-Spinal System. Remove the skin from above the cranium and from one side of the head. Cut away the bony roof of the cranium, taking great care not to injure the delicate brain underneath. By means of a pipette or gentle stream of water wash out the soft substance which covers the brain. Make out the following parts:

1. *Olfactory lobes*, a pair of conical processes extending forward from the extreme anterior end, and tapering into the *olfactory nerves*.

2. *Cerebral hemispheres*, the large white lobes behind the olfactory lobes which make up the *cerebrum*.

3. *Optic lobes*, the large conspicuous rounded eminences, well marked off from each other, and from other parts.

4. *Cerebellum*, a single narrow transverse band of nervous tissue just back of the optic lobes.

5. *Medulla*, the portion of the nervous tissue just behind the cerebellum and in front of the spinal cord.

6. *Spinal cord*, the nervous tissue found within the spinal column.

Make a drawing of the brain and spinal cord as seen from the dorasl side. Label all parts enumerated above.

Summary

1. Make a cross section drawing of the frog through the region of the heart showing and labeling all organs.

2. What is the function of the following organs in the frog; liver, spleen, olfactory lobes, left auricle, kidneys, pancreas?

EXERCISE 19

HISTOLOGY OF THE FROG

References. Needham, General Biology p. 208; Holmes, Biology of the Frog.

Material and Apparatus Needed. Compound microscope, simple microscope, glass slides and cover glasses, live frogs; prepared slides of sections of the frog's skin, lung, kidney, and intestine.

The Vertebrates are multicellular animals and all tissues can be resolved into cell units. In some of the tissues it is difficult to make out the individual cells but by special preparation of sectioning and staining it is possible to detect the cells and usually see the nuclei within.

LABORATORY EXERCISE

1. Circulation of the Blood in the Web of the Foot. Examine the demonstration of the circulation of the blood in the web of the frog's foot. Note the numerous small tubes (capillaries) through which the corpuscles are carried by the blood plasma. Note the branching capillaries. Some of these branches are so small that the corpuscles must pass through them in a single file order.

Make a drawing of a small portion of the web of the foot showing the capillaries and the blood corpuscles within.

2. Blood. Place a small drop of frog's blood on a clean glass slide, cover with a cover glass and examine under high power of the microscope.

Draw a few of the blood corpuscles.

Now in like manner study a drop of human blood and *draw* a few of the blood corpuscles. How do the corpuscles of man and corpuscles of the frog compare as to: color, structure and size. Enter these notes in your notebook.

3. Skin. Examine the prepared sections of the skin of the frog under the high power of the microscope. Note that the skin is made up of two main layers, epidermis and dermis.

a. *Epidermis* (stained blue), is made up of there kinds of cells.

1. Transverse or elongate and flattened cells.
2. Columnar or elongate and upright cells.
3. Startified cells or squarish cells several layers deep, lying between the *transverse* and *columnar* layers.

b. In the *dermis* (stained pink), may be seen round structures or glands. (Look over the slide carefully and locate some glands where the ducts may be seen). These glands are of two types:

1. Mucous Glands. The smaller and more abundant glands which pour a mucus upon the surface of the skin. The epithelium which forms the boundary of the gland is cellular. (The secretion stains bluish).

2. Poison Glands. The larger and less regularly placed glands secrete a milky fluid which is said to be harmful to fish and other small animals. The epithelium which forms the boundary of these glands is non-cellular in appearance (The secretion stains yellow).

Draw a portion of the skin showing the layers and structures mentioned above and label each.

4. Intestine. Examine the prepared slides of the cross section of the intestine and note:—

a. On the outside a thin *peritoneum*.

b. *Longitudinal muscles*.

c. *Circular muscles*.

d. *Submucosa*, a non-cellular substance in which occur blood vessles.

e. The folded digestive epithelium made up of:

1. *Goblet cells*, which possess a large vacuole and therefore appear empty.

2. *Absorptive cells*, which are narrow with an oval nucleus.

Draw a cross section of the intestine, showing details in a small portion, and label the structures noted above.

5. Lung.

a. Study the entire cross section of the lung under the simple microscope and note that it contains many open spaces. These are air spaces or alveoli.

Make an outline drawing of the whole cross section of the lung and show the position of the air spaces.

b. Study a single fold of the lung under the low power of the compound microscope and note:—

1. That each air space is lined with a single layer of epithelial cells.

2. That the fold between the air spaces is composed of the epithelial layer, and that between the epithelial layers lies a substance called connective tissue in which muscles and blood vessels are located.

3. Locate the end of a fold and note the muscle and blood vessel situated there.

Make a drawing of a fold and label: epithelium, connective tissue, muscle, blood vessel.

6. Kidney:

a. Refer to the diagram of a cross section of the kidney on the blackboard, and note the various structures indicated.

1. *Bidder's canal.*
2. *Collecting tubules.*
3. *Uriniferous tubules.*
4. *Ureter.*
5. *Renal portal vein.*
6. *Glomeruli.*

b. Study the cross section of the kidney under the compound microscope and note:—

1. *The uriniferous tubules.*
2. *Glomeruli*, the masses of bright cells.

Copy the diagram. *Draw* either a cross section or a longitudinal section of a tubule showing the cellular epithelium. *Draw* a glomerulus. What is its relation to a tubule?

Summary

1. In what respect does the structure in cross section of the intestine in the frog resemble, and in what respect does it differ from that of the earthworm?
2. What is the function of the kidneys? Of the blood? Of the mucous glands?

EXERCISE 20

HOMOLOGY

References. Needham, General Biology pp. 223-230; Conn, Biology pp. 364-370; Comstock, Manual for the study of Insects; Comstock, The Wings of Insects.

Material and Apparatus Needed. Simple microscope; prepared slides of cranefly wings; sheets of insect wing diagrams.

Homology is true likeness,—likeness in form of parts, origin of parts and relation of parts. "Two organs are homologous when composed of like parts in similar relations, each to each." Thus the hand of man is homologous to the forefoot of the frog because they are composed of essentially like parts in similar relations. If the relationship is only superficial, that is, similar in function or shape, it is called *analogy*. The wing of a bat and the wing of a butterfly are analogous, for their likeness is only in function and not in fundamental structure. The wing of the bat however is homologous to the wing of a bird because they both are built up of similar bones, muscles. etc.

Nature affords numerous examples which may be used for a study of homologies, Entire skeletons or parts of skeletons of a series of different species of animals might well be used. Insects, being very common and numerous, serve especially well for such a study. Most insects are provided with one or two pairs of wings. These wings are membraneous and are thickened or strengthened along certain lines. These thickened lines are called *veins* and the system of veins in the wing is spoken of as venation. Although the wings of the different species of insects vary greatly in shape and arrangement of the veins there exists a definite relationship between them. Probably all the different types of insect wings have been derived from a common ancestor which is called the *hypothetical wing*.

The following drawing, figure 3, represents the hypothetical wing.

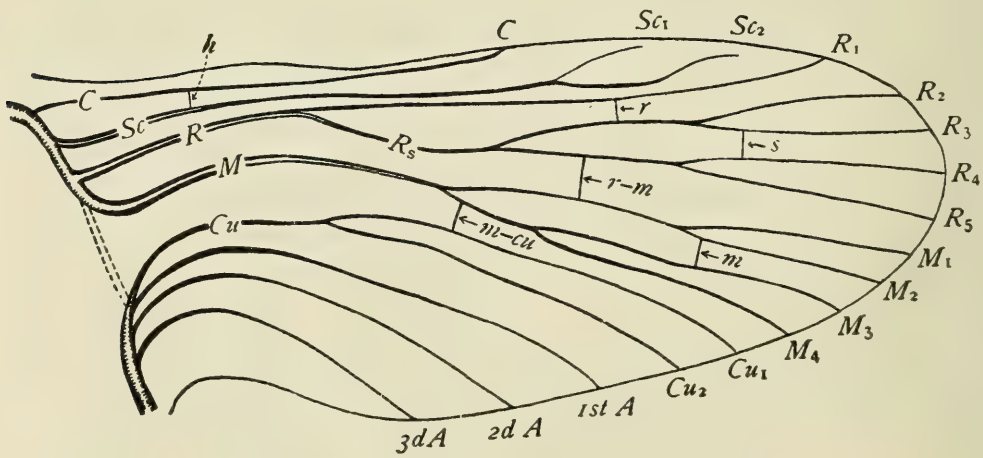


Fig. 3—The hypothetical insect wing

The veins of the wing can be grouped under two heads: first, *longitudina veins*, those that normally extend lengthwise of the wing; and second, *cross veins*; those that transversely connect one longitudinal vein to another. These veins are designated by names. There are eight principal longitudinal veins, some of which are branched toward the outer end. The names which are given to these veins are as follows: (with the abbreviations which are used).

1.	Costa	= C	5.	Cubitus	= Cu
2.	Subcosta	= Sc	6.	1st anal	= 1st A
3.	Radius	= R	7.	2nd anal	= 2nd A
4.	Media	= M	8.	3d anal	= 3d A

The subdivisions of these main longitudinal veins are indicated as shown in the figure of the hypothetical wing.

There are five cross veins in the hypothetical wing and they are named as follows: (with their abbreviations).

1.	humeral crossvein	= h
2.	radial crossvein	= r
3.	radio-medial crossvein	= r-m
4.	medial crossvein	= m
5.	medio-cubital crossvein	= m-cu

Modifications in the venation is brought about in two ways: *first*, by a reduction in the number of veins, two or more veins may fuse into one, or one or more veins may atrophy or drop out; *second*, by the addition of more veins. The manner of designating modified veins will be explained by the instructor.

LABORATORY EXERCISE

1. Hypothetical Wing. Study the hypothetical wing and get acquainted with the system of naming the longitudinal veins and crossveins. Note that the longitudinal veins are designated by capital letters on the *outside* of the margin while the cross veins are designated by *small* letters *within* the wing.

2. Examine the prepared slide of a cranefly wing (Tipula) under the simple microscope and *make a drawing* of it. Then try to homologize the veins with the veins in the hypothetical wing. Note. The *costa* in all wings corresponds with the front or upper margin of the wing and need not be designated. *Label* all veins and cross veins.

3. Diagrams of Cranefly Wings. Upon the sheet of cranefly wings furnished, mark *in pencil* the names of the longitudinal veins and crossveins. The instructor will assist you in labeling this sheet. Begin with a wing which most nearly approaches the structure of the hypothetical wing.

4. Diagrams of Psocid Wings and Fungus Gnat Wings. In labeling these two sheets of wing diagrams, assistance will be given only on one of the sheets. The third one (to be designated by the instructor) must be worked out *independently* by each student.

Summary

1. Which of the cranefly wings on the sheet do you consider most primitive or generalized? Which most specialized? Why?

2. Why is or isn't the flapper of a whale homologous to the wing of a bird?

3. Are the teeth of a rabbit homologous or analogous to the teeth of a lobster? Why?

Note. When the wing sheets have been corrected and returned to you, take the sheets to the laboratory and color subcosta, media and the anal veins *red* and the cross veins *blue*. For this work refer to the diagrams which you will find in the laboratory. These corrected sheets form the basis of a study on *Phylogeny*, Exercise 22, and should be brought to the laboratory at that time. (The instructor will give further details).

EXERCISE 21

SERIAL HOMOLOGY

PLASTICITY OF FORM AND PERSISTENCE OF TYPE IN MALACOSTRACA

References. Needham, General Biology pp. 230-236; Calkins, Biology pp. 166-172.

Material and Apparatus Needed. Simple microscopes; living and preserved specimens of crayfish, Gammarus, and Asellus and preserved specimens of Squilla; Riker mounts of the appendages of the crayfish, squilla and asellus; tabulated blanks; dissecting trays, and dissecting instruments.

Serial homology is homology repeated in a series. The segments of the earthworm back of segment thirty are serially homologous because they are all made up of essentially the same structures.

The body of the crayfish, Gammarus; Asellus and Squilla is made up of a series of twenty segments and each of these segments bears a pair of jointed appendages. These appendages are all built on the same general plan, and although they are of different shapes and perform different functions, the parts can all be homologized. Thus we find that the appendages are serially homologous. The appendages of the abdomen are the simplest in structure and the fundamental parts may be more easily distinguished in them than in the more specialized appendages, such as the legs or the mouth parts.

LABORATORY EXERCISE

1. Crayfish (Cambarus).

a. Study the living specimen and determine the different uses to which the appendages are put.

b. Study the appendages of a preserved crayfish, referring to the Riker mounts for guidance. Begin with the series of appendages and, for convenience in dissecting, proceed from the posterior end forward. Remove each appendage of one side in order, being very careful to get each one off entire. Place the appendages on a sheet of paper in their proper order. The twentieth segment (*telson*) does not bear any appendages. The broad finlike appendages (*uropods*) on each side of the telson belong to segment 19. The appendages on the abdomen are called *swimmerets*. If the specimen you have is a female, the appendages of the first abdominal segment are much reduced; if a male, the appendages of the first and second abdominal segments are specialized, bent strongly forward under the thorax, and variously forked or twisted at the tip. They function in reproduction.

Before removing the appendages of the thorax, remove the side piece (carapace) which covers the gill chamber. This will expose the feathery gills. Move the legs backward and forward and note that the gills are attached to the basal segments of the legs. Remove each leg, with its attached gill, proceeding from the rear. Examine each leg and determine whether it is used for defense, grasping or walking. In what way do the legs differ in structure? There yet remain three pairs of thoracic appendages. These are the *maxillipeds* (foot jaws). They cover the mouth, being directed forward. These maxillipeds assist in manipulating the food. Remove the maxillipeds carefully and compare them in structure with the typical abdominal appendages already studied. Which of the maxillipeds bear gills? The remaining appendages belong to the head. Closely following the maxillipeds, and covered by them, are two pairs of very thin and delicate *maxillae*. Be careful to remove them separately and entire. In front of the maxillae find the *mandibles*, a pair of hard toothed jaws, each with a small, three-jointed palpus lying in a groove on its anterior surface. Remove one of the mandibles. On the front of the head are two pairs of feelers, the larger single ones the *antennae*, and the smaller two-forked or double ones the *antennules*. After having removed all the appendages from one side and properly arranged them on a sheet of paper compare their structure. They are all homologous having been modified from one type of structure.

Record. Upon the sheet, "Table of Malacostracan Appendages." provided, *record* in the first column the results of your observations. For the names of the appendages use the following abbreviations:

antennae and antennules = ant.	*cheliped* = chp.
mandibles = md.	*grasping leg* = gr. 1.
maxillae = mx.	*walking leg* = walk. 1.
maxillipeds = mxp.	*swimmerets* = sw.

2. Gammarus.

a. Living Specimen. Study the living specimen and note its mode of locomotion.

b. Study the appendages of a preserved specimen, referring to the glass slide mounts for help. Note that the body of this animal is likewise made up of twenty segments, each of which, except the last one, bears a pair of appendages. Study each of the appendages carefully and see in what way they differ from the appendages of the crayfish.

RECORD. In the second column of the sheet record your observations, using the abbreviations given for the crayfish. The appendages of the last few abdominal segments are used for jumping and should be recorded as jumping appendages = jump. ap.

3. ASELLUS.

a. LIVING SPECIMEN. Examine under the demonstration microscope a living Asellus which has been placed on its back. The appendages of segments 17 aud 18 have been modified into gills and the appendages of segments 16 into a gill cover (*operculum*). Note that the movement of these appendages produces a current of water which passes over the gills. Note also the locomotion of an Asellus. They do not swim, but walk or crawl on their legs.

b. Study the appendages of Asellus from the prepared slides. Segment 20 has no appendages and segment 19 bears a pair of processes, called *stylets*.

RECORD. In the third column record your observations of the appendages of asellus.

4. SQUILLA. Study the preserved specimens and Riker mounts of Squilla. Note the similarity of the appendages to the appendages of the crayfish. To what appendages are the gills attached?

RECORD. In the fourth column record your observations of the appendages of Squilla.

5. FUNCTIONS OF MALACOSTRACAN APPENDAGES. Having studied and recorded the kinds of appendages found in the four types of Malacostraca, fill out the table of "Functions of Appendages" on the right half of the sheet. Conclusions should be based, first on what you have observed of the uses of the appendage while studying the living specimens, and second on the inferences which you are able to draw from the form and location of the appendages. In this table indicate by number the segments which are involved in each function. Thus in Cambarus, swimming involves 16-19 in the male, and 14-19 in the female, etc.

SUMMARY

1. In your own words express the meaning of serial homology.
2. How do you account for the general resemblance in number of segments and form of appendages in the four species?
3. How do you account for the difference in use of homologous appendages in the four forms?

EXERCISE 22

PHYLOGENY

References. Needham, General Biology pp. 236-238.

Material and Apparatus Needed. The corrected wing sheets which were used in the study of Homology. These wing sheets should now have been corrected, with the subcosta, media and anal veins marked in red, and the cross veins in blue.

Phylogeny is the study of the ancestral history of organisms. It is the study of the race. "A common device for expressing graphically one's conception of phylogeny is the so-called 'genealogic tree'." In building up such a tree the most primitive or generalized forms are placed near the bottom, the most highly specialized ones at the top and the intermediate forms on branches between. The phylum Arthropoda represents one branch on the genealogic tree of life. The insects represent a smaller branch of this one branch, and so on.

LABORATORY EXERCISE

With the corrected wing sheets at hand construct a genealogic tree for each of the three series of wings, showing a possible genetic relationship (based only upon the data furnished by the venation of the figures). Assume that the figure of the hypothetical wing is most primitive.

A. Begin With the Poscid Wings. The instructor will assist in the interpretation of the wings of this sheet. Pick out the wing which is most primitive (nearest to the hypothetical wing) and place the number corresponding to it near the base of the tree. Single out in each series the different ways in which the type has been modified, and make as many principal branches as there are different kinds of divergence. Pick out the most specialized forms for the tips of the longest branches. Arrange the others in position in accordance with their degrees of divergence, and let the branching and length of the twigs represent this. In order to get related forms on the same branch study carefully the "behavior" of the different veins and cross veins. Note, for instance, that in several of the *Psocid* wings Cu_2 does not bend upwards to meet M but stretches out in a nearly straight line to the margin of the wing. These three wings undoubtedly belong to the same branch, and the most highly specialized one of them to the longest twig of this branch. Compare all wings together with respect to each character, the length of Sc, the fusion of the tips of M or Cu, the number of cross veins etc.

B. Cranefly and Fungus-gnat Wings. Each student will independently construct a genealogic tree of each of these series of wings. In each case briefly state your reasons for placing the wings in their respective relationships.

Summary

1. Which of the longitudinal veins, in the wings studied, seems to be most constant? Which most variable?
2. In what way is modification in venation, from the hypothetical wing, brought about?
3. Draw a genealogic tree to show the relationship of the following: Amoeba, Hydra, earthworm, Parmoecium, frog, sponge, grasshopper and horse.

EXERCISE 23

ONTOGENY

References. Needham, General Biology, pp. 255-261; Ecker, Anatomy of the Frog; Holmes, Biology of the Frog.

Material and Apparatus Needed. The results of the previous laboratory studies of the animal types, together with whatever additional available data may be at hand; tabulated sheet on which to record results.

Ontogeny is the development of the individual from the egg to the adult stage. "Ontogeny repeats phylogeny," i. e. the development of the individual repeats the development of the race. In tracing the development of an individual we find that the successive embryonic stages correspond, in general, to the series of types of animals from the simplest to the highly developed forms.

LABORATORY EXERCISE

A. With the data of the studies on the frog and tadpole at hand, enter on the tabulation sheet the ontogenetic changes which are found in the development of the frog, under the four headings given.

B. On the lower half of the sheet enter the data called for under B.

Summary

1. What is the biogenetic law?
2. Distinguish clearly between ontogeny and phylogeny.
3. Of what evolutionary significance is the correspondence between ontogeny and phylogeny?

EXERCISE 24

MITOSIS

References. Needham, General Biology. pp. 289-306; Shull, Principles of Animal Biology, pp. 70-83; Sharp, An Introduction to Cytology; Wilson, The Cell in Development and Inheritance.

Material and Apparatus Needed. Compound microscope, prepared sections of the onion root tip, hyacinth, or some other tissue which illustrates the various phases of mitotic cell division; newly laid eggs of pond snails.

Mitosis is an indirect method of cell division in plants and animals. It is sometimes also called *karyokinesis*. It is a very complicated process in which the nucleus undergoes a series of remarkable changes before the cell actually divides into two new cells. *Amitosis* is a *direct* method of cell division in which the nucleus divides directly into two equal parts. Both methods are found in plants and animals but *mitotic* division is more common and illustrates how hereditary qualities may be transmitted. Mitosis, in plants and animals, is essentially alike; the main difference being that in animal cells a *centrosome* is present while in the higher plants a centrosome has not been found.

For convenience the process involved in mitotic division, is usually divided into four stages: *prophase, metaphase, anaphase* and *telophase*. By selecting some growing plant or animal tissue, such as the tip of an onion root, hyacinth, or the epidermis of a salamander etc, and cutting it into thin sections, all the successive stages of division can be seen.

LABORATORY EXERCISE

Onion Root Tip. Examine the prepared slide of the onion root tip under low and high power of the microscope.

1. Resting Stage. Find a cell on the slide which contains a large *nucleus* surrounded by a *nuclear membrane*. Within the nucleus find a small round body, the *nucleolus*. The granular material within the nucleus is called *chromatin*. The chromatin is deposited in a network of very fine and almost invisible threads of a substance, called *linin*. Outisde of the nucleus is the cytoplasm of the cell.

Make a drawing of the resting cell, at least two inches in diameter, showing and labelling the following parts: cell wall, nuclear membrane, nucleus, nucleolus, chromatin and linin.

2. Prophase. This is the first stage in the process of mitotic division.

a. Early Prophase. Find a cell in which the chromatin of the nucleus has assumed the form of a long, tangled thread. This is the *spireme*. Note that the nuclear membrane and the nucleolus are still present.

Make a drawing of the early prophase stage labeling all parts shown.

b. Late Prophase. Now find a cell in which the spireme has broken up into a number of short pieces which are called *chromosomes*. The chromosomes migrate to the center of the nucleus where they form an *equatorial plate*, and apparently are held in position there by the linin threads which have now formed a spindle, called the *nuclear spindle*. In the late prophase stage the nuclear membrane and nucleolus have usually disappeared.

Make a drawing of this stage and label: cell, chromosomes and nuclear spindle.

3. Metaphase. This is the stage in which each chromosome splits *lengthwise* into two identical halves, Thus the chromatin material becomes equally divided so that each one of the two resulting daughter cells will contain just one half of the chromatin material of the original cell.

Find a cell which represents this stage. *Make a drawing* of this phase and label all parts shown.

4. Anaphase. This is the stage in which the daughter chromosomes move apart toward the ends of the spindle where they will form the chromatin material in the nuclei of the daughter cells. (This and the following stage is the reverse process of the prophase and metaphase). In the late anaphase the spindle fibers become thickened in the equatorial region and form the *cell plate* which later becomes part of the cell wall. (This formation of the cell plate is found in plants only).

Find a cell in which the chromosomes have moved to the opposite ends of the spindle and *make a drawing* of this phase, labeling all parts shown.

5. Telophase. This is the final stage in the division, in which the nuclei and cells are fully reconstructed. The chromosomes have first united in the form of a spireme and then broken up into granular chromatin material. The spindle has disappeared and a new nuclear membrane and nucleolus have been formed. A wall completely surrounds each cell. The cells appear much as the cell of the resting stage except that they are only half as big as the mother cell from which they arose.

Find two newly formed cells representing the telophase. *Make a drawing* of this stage and label all parts.

6. Polar Bodies in Snail's Eggs. The history of the germ cell and the origin of the polar bodies should be studied in the text before taking up this subject in the laboratory.

Pond snails, when brought into the laboratory and placed in a dish of water with a few lettuce leaves for food, will usually begin to lay eggs within a few days. In these eggs one may observe the polar bodies.

Examine the newly laid eggs of snails and note that just outside of the egg there are found three (sometimes only two) small round bodies. These are the *polar bodies.*

Make a drawing of an egg showing the polar bodies.

Label: egg and polar bodies.

Summary

1. What is the significance of mitotic division in plants and animals?
2. What is the significance of the reduction in the number of chromosomes?
3. What is parthenogenesis? Where does it occur?

EXERCISE 25

THE RELATION BETWEEN FECUNDITY AND NURTURE

Reference. Needham, General Biology pp. 318-325.

Material and Apparatus Needed. Button balls (seeds) of Sycamore, fern fronds with sporangia, or seeds of the elm, maple or oak. Fishes.

This study consists, in part, of a field trip to the fish hatchery and students should come prepared to make this trip.

The object of the study is to demonstrate the relation which exists between fecundity and nurture. The plants, such as the sycamore tree, do not exercise any parental care and therefore they must produce an enormous number of seeds in order that the continuation of the species may be insured. The altricial birds produce only a few eggs and their young receive parental care for a long period of time. The precocious birds produce many eggs and give no or little parental care to their young. Ultimately about the same number of altricial and precocious birds reach maturity. The fish, which care for their young, produce comparatively few eggs while those which give no care to the young produce a much greater number of eggs.

EXERCISE

1. Sycamore Tree. Select a large sycamore tree and note the button balls (seed balls). These balls are composed of a number of seeds. Count the number of button balls on a large limb. Then estimate what proportion this limb bears to the whole tree. In this manner determine the number of button balls on the entire tree. Now divide a button ball into 6 or 8 equal parts and count the number of seeds in one part. By multiplying this number by the number of parts into which the button has been broken, the entire number of seeds in one button ball is found. Estimating that only about 75 percent of the button balls have remained on the tree and that the fruiting life of the tree extends over a period of 75 years, calculate the number of seeds which a sycamore tree may produce during its lifetime.

This method, though crude, will give one a fair idea of the possible number of seeds the tree may bear.

2. Fishes. To appreciate the reduction in numbers which goes with a little parental care a comparison will be made on the number of eggs which are produced by some nesting fish, such as the stickleback, sunfish, bass or bullhead, with those produced by the pike or carp, which scatter their eggs broadcast.

Since the number of eggs which a fish lays is very large, an estimate may be made as follows: Place the ripe ovary containing the

eggs into a graduate in which there is a known quantity of water of such volume that when the eggs are placed in it, they are entirely submerged. Deduct from the new reading, the quantity of water first introduced. The result is the *volume* of the eggs in the ovary. Next measure the diameter of a single egg and then, by means of the table on page 84 compute the number. Calculate the number of eggs produced by the various species of fishes which are studied.

Summary

1. Distinguish clearly between the terms *altricial* and *precocious*.
2. What would be the result if the pike or carp exercised parental care as does the stickle-back?

TABLE FOR FINDING NUMBER OF FISH EGGS OF GIVEN DIAMETER PER LIQUID QUART.

Diameter	Number	Diameter	Number	Diameter	Number	Diameter	Number
Inch.		*Inch.*		*Inch.*		*Inch.*	
0.300	2,506	0.230	5,562	0.160	16,521	0.090	92,826
	2,531		5,635		16,835		95,990
	2,557		5,709		17,157		99,297
	2,583		5,785		17,487		102,762
	2,609		5,862		17,825		106,390
0.295	2,636	0.225	5,941	0.155	18,172	0.085	110.190
	2,663		6,021		18,528		114,172
	2,690		6,102		18,894		118,346
	2,718		6,185		19,270		122,730
	2,746		6,269		19,655		127,333
0.290	2,775	0.220	6,355	0.150	20,050	0.080	132,170
	2,804		6,442		20,456		137,251
	2,833		6,531		20,874		142,600
	2,863		6,622		21,303		148,220
	2,893		6,715		21,744		154,155
0.285	2,923	0.215	6,809	0.145	22,197	0.075	160,400
	2,954		6,905		22,662		166,995
	2,985		7,002		23,140		173,950
	3,017		7,102		23,633		181,300
	3,050		7,204		24,140		189,070
0.280	3,083	0.210	7,307	0.140	24,661	0.070	197,290
	3,116		7,412		25,197		205,992
	3,150		7,520		25,748		215,204
	3,184		7,629		26,316		224,995
	3,219		7,741		26,901		235,377
0.275	3,254	0.205	7,855	0.135	27,504	0.065	246,410
	3,290		7,971		28,125		258,141
	3,326		8,089		28,764		270,631
	3,363		8,210		29,422		283,936
	3,400		8,333		30,101		298,132
0.270	3,438	0.200	8,459	0,130	30.801	0.060	313,289
	3,476		8,587		31,523		329,490
	3,515		8,717		32,268		346,828
	3,555		8,851		33,036		365,405
	3,595		8,987		33,829		385,331
0.265	3,636	0.195	9,126	0.125	34,647	0.055	406,733
	3,677		9,268		35,492		429,750
	3,719		9,413		36,364		454,539
	3,762		9,561		37,265		481,270
	3,806		9,712		38,198		510,139
0.260	3,850	0.190	9,866	0.120	39,161	0.050	541,362
	3,895		10,023		40,156		575,173
	3,940		10,184		41,186		611,893
	3,986		10,348		42,251		651,776
	4,033		10,516		43,354		695,223
0.255	4,081	0.185	10,688	0.115	44,494	0.045	742,613
	4,129		10,863		45,676		794,400
	4,178		11,042		46,899		851,128
	4,228		11,225		48,166		913,380
	4,279		11,412		49,480		981,852
0.250	4,331	0.180	11,603	0.110	50,841	0.040	1,057,350
	4,383		11,799		52,254		1,140,780
	4,436		11,999		53,720		1,233,250
	4,490		12,203		55,239		1,335,960
	4,545		12,412		56,817		1,450,406
0.245	4,601	0.175	12,627	0.105	58,456	0.035	1,578,320
	4,658		12,846		60,159		1,721,630
	4,716		13,069		61,925		1,883,020
	4,776		13,298		63,766		2,065,130
	4.835		13,533		65,680		2,271,500
0.240	4,895		13,774	0.100	67,670	0.030	2,506,310
	4,956	0.170	14,020		69,741		
	5,019		14,272		71,899		
	5,083		14,529		74,146		
	5,148		14,793		76,486		
0.235	5,214	0.165	15,064	0.095	78,927		
	5,281		15,341		81,473		
	5,350		15,625		84,130		
	5,419		15,916		86,904		
	5,490		16,215		89,800		

CONVERSION TABLE

1 inch	= 25.4 millimeters.	1 liter	= 1.0567 quarts.
1 millimeter	= 0.03937 inch.	1 pound	= 0.4536 kilogram.
1 quart	= 57.75 cubic inches.	1 kilogram	= 2.2046 pounds
1 quart	= 0.9464 liter.	Fahrenheit	= 9/5 centigrade ± 32°.
1 liter	= 61.0234 cubic inches.	Centigrade	= 5/9 Fahrenheit ± 32°.

From von Bayer in Rept. 4th Internat. Fisheries Congress.

EXERCISE 26

EXTERNAL METAMORPHOSIS OF INSECTS

References. Needham, General Biology, pp. 343-347; Comstock, An Introduction to Entomology; Comstock, Manual for the Study of Insects.

Material and Apparatus Needed. Simple microscope, watch glasses, forceps, larval and adult forms of about a dozen different insects, tabulation sheets for recording the observations.

Metamorphosis means "change of form." It is the name applied to the change of form which takes place in an individual in its development from the time when it hatches from the egg until it reaches maturity. It covers the postembryonic period of development. In the Vertebrates the transformation of the tadpole into a frog may be cited as an example. In the Invertebrates the insects illustrate metamorphosis in a marked manner and serve admirably for a study of this phenomenon.

There are two main types of metamorphosis in insects, *incomplete* and *complete*. Insects which undergo *incomplete metamorphosis* pass through three developmental stages, *egg*, *nymph* and *adult*. The nymph, in general, resembles the adult form and differs externally chiefly in not having the wings fully developed but represented as short wing "pads." The grasshopper illustrates this type of metamorphosis. Insects which undergo *complete metamorphosis* pass through four developmental stages, *egg*, *larva*, *pupa* and *adult*. The larva bears no resemblance to the adult form and the wings are developed *internally* underneath the skin. The pupa is the resting stage in which the larva is "made over" into the adult form. The butterfly illustrates this type of metamorphosis.

LABORATORY EXERCISE

In this exercise a study will be made of the external differences which are found in the young (larva or nymph) and adult forms of a number of different species of insects, representing both types of metamorphosis.

Carefully examine each insect with a lens or simple microscope and then *record* the results of your observations upon the tabulation sheet furnished. Refer to the footnotes on the sheet for explanation of the data called for.

Before handing in your laboratory report, study the questions called for in the summary and make notes of any data which will be needed in writing up the summary.

Summary

1. Divide the insects studied into two groups, those with incomplete metamorphosis and those with complete metamorphosis.
2. Group those having similar habitats and feeding habits in both young and adult stages.
3. Group those having similar feeding habits but differing in habitats.
4. Group those having totally different habits in the two stages.

EXERCISE 27

INTERNAL METAMORPHOSIS IN INSECTS

References. Needham, General Biology pp. 347-352; Comstock, An Introduction to Entomology pp. 194-205.

Material and Apparatus Needed. Compound microscope, prepared slides of the cross-section of the damselfly nymph and weevil larva, larvae and pupae of the willow cone gall midge, sheet with diagrams of the larva and pupa of the gall midge, red pencils.

In the exercise on External Metamorphosis in Insects a study was made of the difference in structure in the young and adult forms of a number of insects representing complete and incomplete metamorphosis. In this exercise a comparative study will be made of the internal structures found in the larva (complete metamorphosis) of a weevil and the nymph of the damselfly (incomplete metamorphosis). The sections have been made through the region of the thorax so as to include the structure of the developing legs and wings.

LABORATORY EXERCISE

1. Damselfly Nymph. Under the low power of the microscope study the cross section of the damsefly. Arrange the slide so that the *dorsal* part of the section is away from you.

In the cross section identify the following parts:

a. *Wings.* These are located on the dorsal surface and will appear as *upward* projecting lobes. In some of the sections one pair of wings may be detached from the body, due to the manner of sectioning the specimen.

b. *Legs.* These are located on the outer lower side and will be represented as disjointed or disconnected parts.

c. *Digestive tract* in the center of the section. Though this is typically cylindrical it may appear as a flattened or collapsed structure.

d. *Dorsal blood vessel or heart,* just above the digestive tract, a small, somewhat triangular, tube, cut transversely.

e. *Nerve cord,* located below the digestive tract, stained light blue and surrounded by reddish-blue muscle tissue.

f. *Air Tubes or Tracheal Trunks.* One tube, on each side of the median line above the digestive tract, cut transversely.

g. *Muscle.* This fills a large part of the body, especially in the region of the wings and legs, and appears as bluish stained tissue. Where the muscle has been cut transversely it appears as closely set reddish-blue dots.

h. *Fat.* This is the loose yellowish tissue or cells found scattered within the body.

Make a drawing of the cross section of the damselfly to show the arrangement of the cell layers, organs etc. The cellular structure need not be shown in detail. Label all the parts enumerated above. The diameter of the drawing should be at least 4 inches.

2. Weevil Larva. Study the cross section of the weevil larva. In this specimen the wings project or hang downward on the side. Arrange the slide so that the dorsal side is away from you.

Identify the following parts:

a. *Cuticle.* This is the outer covering of the body and will be represented as a light bluish thin line surrounding the entire section.

b. *Wings*, on each side a downward projecting wing bud.

c. *Legs*, found in similar location as in the damselfly nymph.

d. *Digestive tract*, in the center of the body, much smaller than in the damselfly.

e. *Nerve cord*, below the digestive tract, stained light blue and surrounded by reddish-blue muscular tissue.

f. *Fat.* The main part of the body filled with yellowish stained tissue.

g. *Muscle.* Bluish tissue, in the region of the wings and legs.

The dorsal blood vessel is so small that it can not easily be distinguished among the fat.

Make a drawing of the cross section of the weevil larva, showing and labeling all parts enumerated above.

3. Larvae and Pupae of the Gall Midge. This midge produces the cone gall of the willow. The larva overwinters within the gall and will be found in the central part of the cone gall. The blood of this larva is red and as it becomes full grown it will appear yellowish white, because it is filled with white opaque fat and this covers the red blood within. As the transformation into the pupal stage proceeds the fat is used up and so the red color of the blood reappears. The progress of the metamorphosis may, therefore, be guaged by the extent of the red color; later as the end of the pupal period approaches, the black pigmentation of the adult will gradually overspread the surface, beginning with the eyes. The early pupal stage will therefore be red while the later pupal stage will be blackish.

Upon the sheet of diagrams provided, indicate with black and red pencils, the distribution of pigment to indicate the external evidence of the internal changes. Show thus the place of beginning and the order of progression in fat solution, and later progress in pigmentation.

Summary

1. Of what significance is the distribution of fat with reference to the manner of metamorphosis in the insect?
2. What is the advantage of complete metamorphosis to insects?
3. Give an illustration, other than that studied in the laboratory, of complete metamorphosis;—of incomplete metamorphosis.

EXERCISE 28

PLANCTON

References. Needham, General Biology pp. 525-527; Ward & Whipple, Fresh Water Biology.

Material and Apparatus Needed. Compound microscope, glass slides, cover glasses, pipette, and a collection of living plancton freshly obtained from some nearby lake or pond.

In all lakes, ponds and streams there exists a population of microscopic plants and animals suspended in the open water, or floating or drifting or swimming about, collectively known as *plancton*. It is a vast assemblage of minute, transparent organisms, the existence of which was not suspected a hundred years ago. Being invisible they were unnoticed. Yet they constitute a vast population, well adjusted to its place in the world, self-sufficient, self-maintaining, and independent of the life of the land. Both plant and animal forms show many adaptations to a life of drifting about in the open waters. Their very minuteness greatly favors drifting, but in addition to this they secrete internally bubbles of gas or drops of oil, lightening their specific gravity, or they develop long hairs and spines which greatly increase superficial area, and surface friction with the water. Plancton organisms include of necessity many chlorophyl bearing forms, (green, or blue-green or light amber-brown in color): these constitute the producing class. Animal forms are present also in great variety, and constitute, as on land, the chief consuming class.

Material for laboratory study may be obtained by straining a large amount of water through a fine silk net in which the organisms are retained, or better, by towing a cone-shaped net through the water behind a boat. In this manner a large number of organisms collect in the cone of the net from which they are transferred to a jar of water.

LABORATORY EXERCISE

Mount on a clean glass slide a small drop of the plancton culture, put on cover glass and examine under the microscope. By means of the figures and description in the "Genera of Plancton Organisms" on page 102 identify the plants and animals found. When in doubt, ask the instructor. As soon as you identify an organism *make a drawing* of it.

Examine and make drawings of as many different specimens as you can. Hasten slowly. Distinguish carefully.

On a separate sheet make a table with the following column headings and list the organisms which you have studied.

Name, class, color, relative size, relative abundance, consumer or *producer.*

Summary

1. Select 5 examples of plancton organisms studied, and state in what way each is particularly adapted to its mode of life.

2. What relation do the different groups of plancton organisms bear to each other?

EXERCISE 29

WOODLAND PLANT SOCIETY

References. Needham, General Biology, pp. 368-374; Gray, Manual of Botany; Britton & Brown, Illustrated Flora of the Northern States and Canada.

Material and Apparatus Needed. A wood lot which has not been unduly disturbed by "improvements;" tabulation sheet on which to record the observations; a pick axe or some other instrument for use in digging up plants.

To study the adjustment of organisms to their environment we select a wood lot which has retained its natural condition as nearly as possible. Here we find an assemblage of plants each adjusted in its place, thus effecting a mutual adjustment to the environment. This adjustment in place is determined by such factors as light, water, food supply, time of fruiting etc.

LABORATORY EXERCISE

This study consists of a field trip and students should come prepared to take a tramp through the woods.

Upon the tabulation sheet enter the data called for.

Summary

Give very briefly such reasons as you can find for the great abundance of the dominant forms, for the localization and limitation of the others and for the persistence of all in a permanent self-adjusting association.

EXERCISE 30

POLLEN PRODUCTION AS AFFECTED BY ITS MODE OF DISTRIBUTION

REFERENCES. Needham, General Biology, pp. 400-404; Gray, Manual of Botany; Britton & Brown, and other works of Botany.

MATERIAL AND APPARATUS NEEDED. Compound microscope, glass slides and cover glasses, forceps, dissecting needles and flowers of the three types indicated below:

I. Wind pollinated	1. Tree—oak, hickory, poplar, boxelder or horn beam. 2. Herb—sedge, grass or meadow rue.
II. Insect polinnated	3. A large open solitary flower such as trillium or may-apple. 4. An open, loosely clustered flower, such as spring beauty or buttercup. 5. A highly specialized bilateral flower, such as wood betony or sweet pea. 6. A composite flower, such as the dandelion.
III. Self pollinated	7. Open, chickweed (Stellaria media) or door weed (Polygonum). 8. Clistogamous, the blue violet.

All flowers except the violet should be freshly collected specimens in which the anthers have not yet begun to shed their pollen. The clistogomous flowers of the violet should be collected in the summer and may be preserved in formalin or alcohol. With some of the smaller flowers it may be found desirable to make glycerin jelly mounts of the pollen grains.

The study of pollen production and its mode of distribution serves to illustrate the adjustment of organisms to environment and particularly adjustment in manner of life. It illustrates the principle methods in which the pollen of plants is distributed so that fertilization is affected and the continuation of the species may be insured. The immediate object of the study is to learn what the ratio is of the number of pollen grains to the ovules produced in the different types of plants.

LABORATORY EXERCISE

Begin this work on a large flower, such as trillium. Place the anther on a glass slide and with a sharp scalpel cut it into two equal halves. In similar manner subdivide one half until you have only one fourth or one eight of the entire anther on the slide. Upon this place

a drop of water and cover with a cover glass. Gently tap the cover glass until the pollen grains separate out. Put under low power of the microscope and count the pollen grains present and then multiply to get the whole number per anther. Then fill in the data called for on the tabulation sheet.

Small anthers, like those of the dandelion, may be mounted entire under a cover glass, and their pollen grains counted at once. Study all eight types of flowers furnished and enter the data on the tabulation sheet. With perfect flowers the ratio of pollen grains to ovules produced will be the same for the whole plant as for the single flower, but with monoecius and dioecious species it will be necessary to count and estimate for equivalent proportions of the total of male and female inflorescens.

Summary

1. Does the degree of clustering of the flower aggregation have any effect on the amount of pollen produced?
2. What are the methods of pollination and what is the effect upon the amount of pollen produced in each case?

EXERCISE 31

READAPTATION OF INSECTS TO AQUATIC LIFE

References. Needham, General Biology pp. 407-415; Needham & Lloyd, Life of Inland Waters pp. 273-280.

Material and Apparatus Needed. Simple and compound microscopes; prepared slides of different types of insect gills; living and preserved larvae of dragonfly, damselfly, mayfly, stonefly, caddisfly, and blood worm or blackfly.

This study illustrates how some insects, which primitively were terrestrial, have adapted themselves to aquatic life by the development of various types of respiratory gills. Gills are found only in the immature stages (larvae or nymphs). All adult insects breathe air directly through open spiracles which lead to the tracheal tubes within the body.

The gills of insect larvae are of two principal types: *bloodgills* and *tracheal gills*. Blood-gills are cylindric outgrowths of the body into which the blood flows. The exchange of gases takes place between the blood inside the gills and the water outside. These gills are similar to gills in vertebrates. Tracheal gills are cylindric or flattened outgrowths of the body, traversed by fine tracheal tubes. The exchange of gases is between the air within the tracheal tubes and the water outside. There is a great diversity of form, position, arrangement, number and size of tracheal gills in the insects selected for study.

LABORATORY EXERCISE

1. Study the following insect larvae and notice in each case the form, structure, arrangement etc., of the gills: (1) Midge or Blackfly; (2) Dragonfly; (3) Damselfly; (4) Stonefly; (5) Mayfly; (6) Caddisworm. Upon the sheet furnished, *complete the figures* by adding the gills in their proper position.

2. From the prepared slide mounts *make drawings* of the following gill types.

   a. A *blood-gill* of the midge or blackfly.

   b. An *external lamelliform tracheal gill* of the damselfly and mayfly.

   c. An *external tracheal gill* of the caddisworm and stonefly.

   d. An *internal lamelliform tracheal gill* of the dragonfly nymph.

3. Prepare a table showing comparative development of gills in each of the insect larvae studied under the following headings: *Name; gill type; number; form: on segments: arrangements.*

Summary

1. How do you distinguish blood gills from tracheal gills?
2. What biologic principle does this study illustrate?

EXERCISE 32

ANIMAL COLORATION

References. Needham, General Biology pp. 422-433; Folsom, Entomology, chapters 5 and 6.

Material and Apparatus Needed. A number of living and preserved animals to illustrate the different types of animal coloration as listed on the record sheets.

The study of animal coloration is used to illustrate the adjustment of organisms to their environment, and particularly adjustment in bodily characteristics. The external colors which most animals possess serve in the main as a protection for the individuals themselves. The animal may thus be protected from its enemy through the close resemblance of its body to its surroundings, in which case the resemblance is spoken of as *protective*; or the resemblance may be *aggressive* in which case the possessor of the coloration is enabled to approach upon its prey unobserved.

The most common coloration phenomena in animals are;

1. Resemblance or "camouflage." This, as stated above, may be either protective or aggressive.
2. Flash Colors. These are colors which are ordinarily hidden and exposed intermittently in flight. They are sometimes spoken of as directive coloration.
3. Warning Coloration. Animals which come under this heading are usually possessed of some bad quality which makes them undesirable as food.
4. Mimicry. This is a superficial resemblance which some animals exhibit to other animals, thereby securing concealment, protection, or some other advantage.

LABORATORY EXERCISE

Upon the record sheets furnished enter the data called for. Remember that in the laboratory it is impossible to exhibit the animals in their natural surroundings and it will therefore be necessary to try to picture them in your imagination as they occur in their environment.

Summary

1. Distinguish between mimicry and protective resemblance.
2. Give one or two examples, other than those studied in the laboratory, of animal coloration under each of the four headings.

EXERCISE 33

DEMONSTRATION OF THE FUNCTIONS OF SOME OF THE PRINCIPAL PARTS OF THE NERVOUS SYSTEM OF THE FROG

References. Needham, General Biology pp. 460-468; Holmes, Biology of the Frog.

Material and Apparatus Needed. Living frogs, dissecting instruments, aquarium, weak acetic acid, small camel's hair brush, induction coil and dry cell battery, prepared dissections of frogs to show the brain and spinal cord.

This exercise is largely a demonstration by the instructor. The student will take notes and make sketches to illustrate the various steps in the experiment. This experiment, though crude, illustrates the functions of the principal parts of the nervous system of the frog. Cruel as this exercise may seem it must be noted here that the first operation of removing the cerebral hemispheres deprives the frog of all consciousness—hence the succeeding operations are not "felt" by the animal.

LABORATORY EXERCISE

1. The Uninjured Frog. Note its activity, manner of jumping, swimming, response to such stimuli as the tilting of the support on which it rests, etc. The student should first become familiar with the living normal frog, so as to be able to judge the changes produced in its actions by the loss of parts of the nervous system.

2. The Frog With the Cerebral Hemispheres Removed. The cerebral hemispheres are removed by making a transverse incision into the skull just back of the tympanic membranes.

Note that the frog has lost its want of volitional activity. Test its power for correlated movement by throwing it into water and making it swim; by tilting the object on which it rests; by making it jump. Try to determine whether it can see and hear. A frog in this condition may be kept alive for weeks or months but the food must be placed in its mouth; otherwise the frog would starve even if plenty of food were available. Why?

3. The Frog That has also Lost Its Cerebellum and Mid-brain. After removing the cerebellum and mid-brain try the same experiments (as under 2), noting especially the effect of this loss upon the coordination of its movements.

4. With the Spinal Cord Severed at its Junction with the Medulla. Observe how the severance of the brain from the cord

has affected the tone of the body as whole. Hang a brainless frog up by its head for convenience in manipulation and test its body at various points for reflex responses to stimulation of the skin. A small brush dipped in dilute acid, or an electric current, may be used to touch the skin.

To demonstrate the correlation mechanism within the nerve centers that remain, stimulate one side of the frog in the flank with the acid, or electric current, and notice the foot of the same side lifted and rubbed against the spot as if to wipe it off. Then stimulate the flank again in like manner, but hold the foot of that side by the toes to keep it from repeating the act. After one or more attempts to use this foot, the foot of the other side will be lifted and swung around to the spot stimulated. This illustrates cross reflexes.

5. With the Spinal Cord Destroyed. The spinal cord may be destroyed by thrusting a wire down the vertebral column and twisting it, thus breaking up the reflex arcs.

After the spinal cord has been destroyed test again for responses by stimulating the frog with dilute acid or the electric current.

6. Stimulation of the Sciatic Nerve. Expose the great sciatic nerve which appears as a coarse white thread lying between the muscles of the inner side of the thigh. Stimulate this nerve directly to produce muscular response. Then trace this nerve to its forking at the knee, and stimulate each of its main branches separately to see the specifically different responses resulting.

7. *Make a drawing*, properly labeled, of the brain and spinal cord of the frog and indicate where the cuts were made in the foregoing experiments.

8. *Compare* the brain of the frog with brain of a higher vertebrate, such as the rabbit or pigeon. *Make drawings*, properly labeled, and tell wherein the brains differ.

Summary

1. What is a reflex arc?
2. In what phase of the experiment was it demonstrated?
3. Give 5 examples of reflex actions in human beings.
4. Of the examples cited which were reflex from birth, and which have become so through practice.

EXERCISE 34

THE INSTINCTS OF THE TENT CATERPILLER

References, Needham, General Biology, pp. 527-529; Slingerland and Crosby. Manual of Fruit Insects, pp. 112-117.

Material and Apparatus Needed: Hand lens or simple microscope, riker mounts containing all stages of the complete life history of the tent caterpillar, twig or branch of tree showing the egg mass and nest.

This is a study on instincts. Instinct is an "inherited tendency to perform a specific action in a specific way when the appropriate situation occurs." The tent caterpillar, in its life cycle, passes through a series of marked changes of form and in each it is fully equipped for doing the necessary things in the right manner. There is no reasoning or previous experience, its actions are guided entirely by nstinct.

i

EXERCISE

A. Field Trip. If convenient observations should first be made in the field upon the living insects to note the natural habitat of the caterpillars, the location of the egg masses and the location and structure of the "tent."

B. Laboratory Exercise. Study the different stages of the tent caterpillar in the riker mounts and the twig which shows the position of the egg mass and the nest.

Make drawings of the following:

1. Twig showing position of egg mass and nest.
2. An egg cluster as seen from the side.
3. A cross-section of an egg mass.
4. Side-view of the caterpillar.
5. Pupa and cocoon.
6. Male and female moth.

Make a list of all the instincts which the life history of the caterpillar and moth illustrate.

Summary

1. Write out the life history of the tent caterpillar.
2. What type of metamorphosis is illustrated?
3. What is the economic importance of the tent caterpillar?
4. How may they be controlled?

EXERCISE 35

LEARNING BY TRIAL AND ERROR IN CHICKS

References. Needham, General Biology pp. 479-484.

Material and Apparatus Needed. Healthy young chickens, a week to ten days old; food and water for the chickens; a labyrinth made on the plan shown in figure 4 below; record tabulation sheets.

This study consists in observations on the details of the method of a chick in learning the route through the labyrinth from one end to the other. The chick does not learn things by the reasoning method but by repeated haphazard trials it stumbles upon the right course. Every time the act is repeated the subsequent preformances become easier until the chick has learned by the trial and error method.

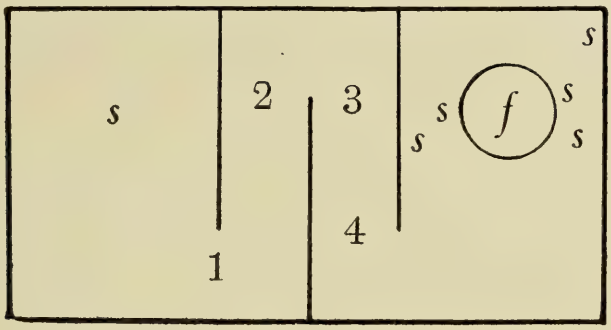


Fig. 4

Diagram of a simple box labyrinth, s = chicks, f = food, 1, 2, 3, 4 = points of record in the passageway.

LABORATORY EXERCISE

Not more than eight or ten observers should gather around one labyrinth.

1. Place the chicks as indicated in figure 4, several of them around a plate of food in one end of the box, and one chick (the subject of the experiment) alone and without food in the other end. The group will feed and chirp contentedly, and the other one, moved by the sound of their social converse and by his gregarious instincts, will (if not too well fed) try to get to the others.

Observe in detail his methods. Let one person be time keeper, and let the others record impartially all the efforts of the chick. Mark the chicken that is to be the first subject of the experiment in some way (or note its personal characteristics) so that the same one may be taken again for repetition of the trial. *Record* all its acts and the time it takes to find the way to its mates. Return it to the starting point and record again; and repeat until the chicken has made *ten* trials. Record on the tabulation sheet the results of the successive trials.

2. *Repeat* with a second and third chicken.

Summary

1. What conclusions are you able to draw from this laboratory experiment?
2. Upon what conditions does this method of learning rest?

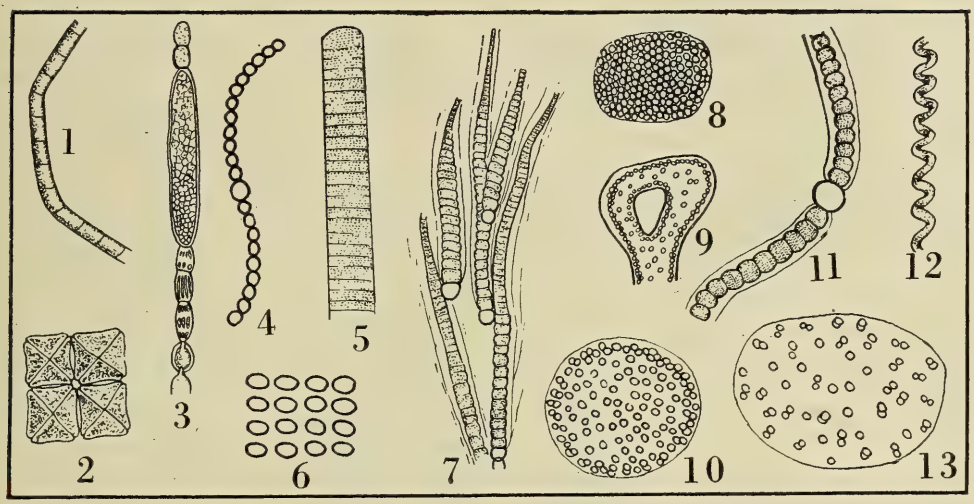
GENERA OF PLANCTON ORGANISMS

The following pages contain figures and very short descriptions of the more common genera of plancton organisms. A number of forms, especially green algae, are included which are not truly plancton organisms but they so commonly occur in ponds and streams that it seemed advisable to include them. In order to make identification as simple and non-technical as possible for the beginner it seems advisable to let the student learn to recognize the different forms by comparisons with the figures and the short descriptions which are given. For a more complete treatise on the subject, with keys, figures and descriptions, the student is referred to Ward and Whipple, Fresh Water Biology, and other works.

In each of the groups an asterisk has been placed before the genera which probably will be most commonly encountered.

The plates are from Johannsen and Lloyd, Genera of Plancton Organisms of the Cayuga Lake Basin, and are used with their permission.

BLUE-GREEN ALGAE



1, Phormidium. 2, Tetrapedia, 3, Aphanizomenon. 4, Anabæna. 5, Oscillatoria. 6, Merismopedia. 7, Rivularia. 8, 9, Microcystis. 10, Cœlosphærium. 11, Nostoc. 12, Spirulina, 13, Apanocapsa.

BLUE-GREEN ALGAE

The blue-green algae are characterized by a bluish-green color; they are either free floating or they live in masses of gelatine; reproduction is by simple division.

1. **Phormidium.** Many-celled filaments, straight or bent, surrounded by a slimy sheath.

2. **Tetrapedia.** Cells flat, quadrangular, occurring either singly or in colonies.

3. **Aphanizomenon.** Many short, straight, filaments aggregated in bundles, so as to form a feathery mass.

*4. **Anabaena.** Single filaments, the cells not imbedded in gelatine.

*5. **Oscillatoria.** Single filaments, composed of many short cells; living specimens often exhibit waving or oscillating movements.

6. **Merismopedia.** Spherical or oblong cells arranged in plate-like colonies. Often the cells adhere together in groups of fours.

*7. **Rivularia.** Many filaments found within a globular gelatinous mass. The filaments taper considerably toward one or both ends.

8. 9. **Microcystis.** Cells spherical, very small, united in great numbers to form small solid colonies.

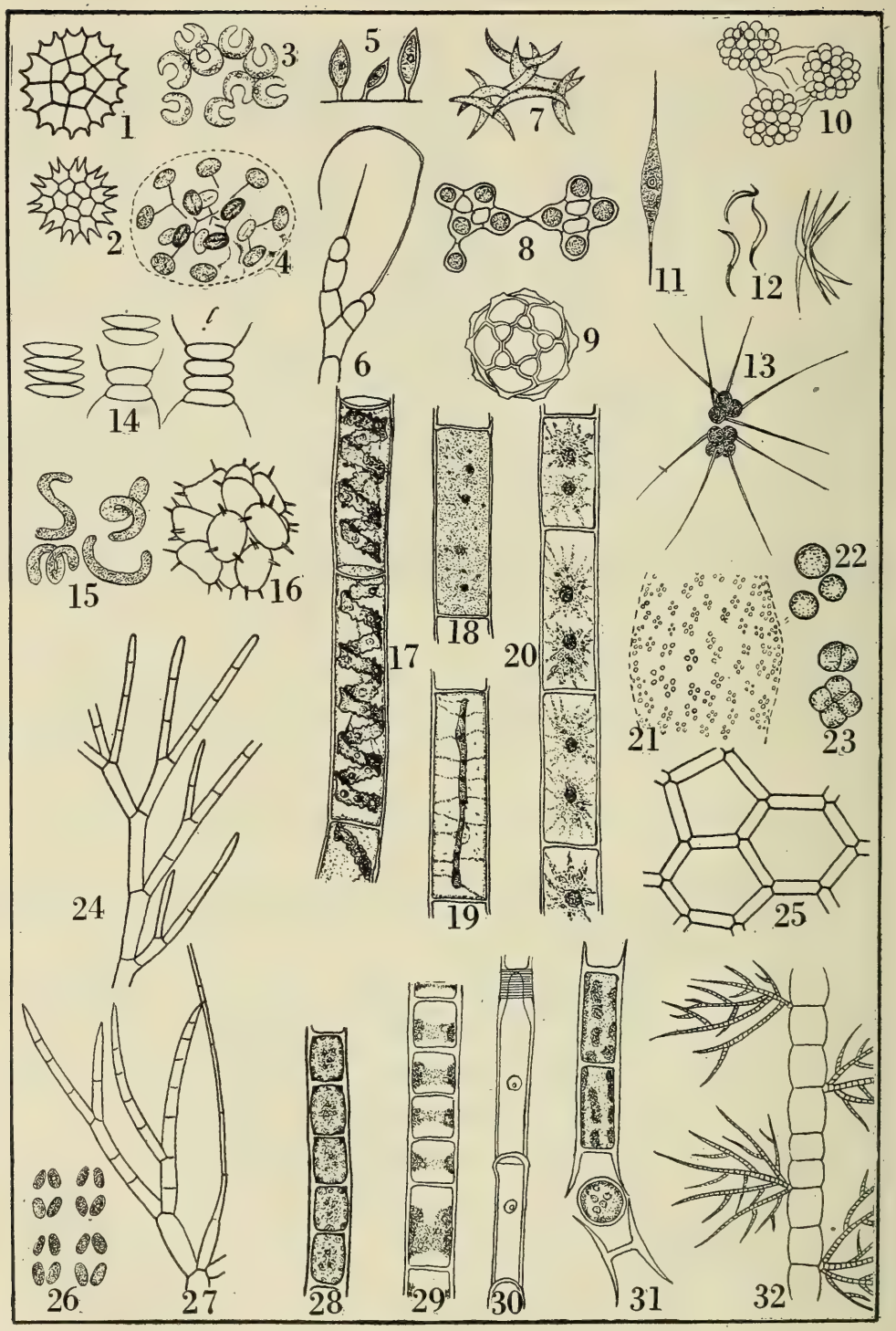
10. **Coelosphaerium.** Spherical or oblong cells, closely arranged to form a hollow spherical colony.

*11. **Nostoc.** Many twisted or contorted filaments aggregated in a spherical colony. The filaments are imbedded in gelatine.

12. **Spirulina.** Single celled, spiral-shaped filaments.

13. **Aphanocapsa.** Many small globose cells scattered within a gelatinous mass.

GREEN ALGAE



1, 2 Pediastrum. 3, Kirchneriella. 4, Dictyosphærium. 5, Characium. 6, Bulbochæte. 7, Selenastrum. 8, 9, Cœlastrum. 10, Botryococcus. 11, 12, Ankistrodesmus. 13, Richteriella. 14, Scenedesmus. 15, Ophiocytium. 16, Sorastrum. 17, Spirogyra. 18, 19, Mougeotia. 20, Zygnema. 21, Tetraspora. 22, 23, Pleurococcus. 24, Cladophora. 25, Hydrodictyon. 26, Crucigenia. 27, Chætophora. 28, Microspora. 29, Ulothrix. 30, Oedogonium. 31, Tribonema. 32, Draparnaldia.

GREEN ALGAE

The green algae are characterized by the green color. They are either unicellular, clustered, unbranched filamentous or branched filamentous.

1, 2. **Pediastrum.** Cells composed of a single layer, forming a plate, whose marginal cells possess one or two pointed projections.

3. **Kirchneriella.** Crescent-shaped cells occurring in clusters.

4. **Dictyosphaerium.** Spherical or oblong cells imbedded in gelatine.

5. **Characium.** Single cells attached to some object; shape variable.

6. **Bulbochaete.** Branched filamentous plant; the end cells, and often others, bearing long colorless hair-like projections which are swollen at the base.

7. **Selenastrum.** Small, crescent-shaped cells without pyrenoids.

8, 9. **Coelastrum.** Spherical cells arranged in clusters.

10. **Botryococcus.** Cells in grape-like clusters, imbedded in gelatine.

11, 12. **Ankistrodesmus.** Single or loosely clustered cells, needlelike, often variously curved.

13. **Richteriella.** Small cells occurring in colonies of four, eight, sixteen or more cells, the outer cells bearing long bristles.

*14. **Scenedesmus.** Oval or pointed cells, usually occurring in groups of four, placed side by side, the end cells often with spines.

15. **Ophiocytium.** Single cells, variously shaped, end susually with spine.

16. **Sorastrum.** Cells kidney or heart shaped, clustered together in a solid mass, the cells bearing short spines.

*17. **Spirogyra.** Long filaments composed of many elongate cells which contain one, two or more spiral chloroplasts.

*18, 19. **Mougeotia.** Long filaments composed of many elongate cells; chloroplast an axial plate, with several pyrenoids.

*20. **Zygnema.** Long filaments composed of many elongate cells; chloroplasts consist of two radiating or star-shaped bodies for each cell.

21. **Tetraspora.** Very small cells arranged in fours, imbedded in gelatin.

*22, 23. **Pleurococcus.** Small spherical cells, single or in groups, when grouped together the cells are somewhat angulate. Occurs on bark of trees, bricks etc.

*24. **Cladophora.** Plants large, branched, cells with many pyrenoids.

25. **Hydrodictyon.** Elongate cells joined together so as to form a coarse net.

26. **Crucigenia.** Very small, spherical or elongated cells grouped in fours, forming a flat plate of 16 or more cells.

27. **Chaetophora.** Fine branched filaments imbedded in a gelatinous substance and usually ending in a colorless bristle. Much smaller than Cladophora.

28. **Microspora.** Filaments composed of short cells. Chromatophore granular or netted, without pyrenoids.

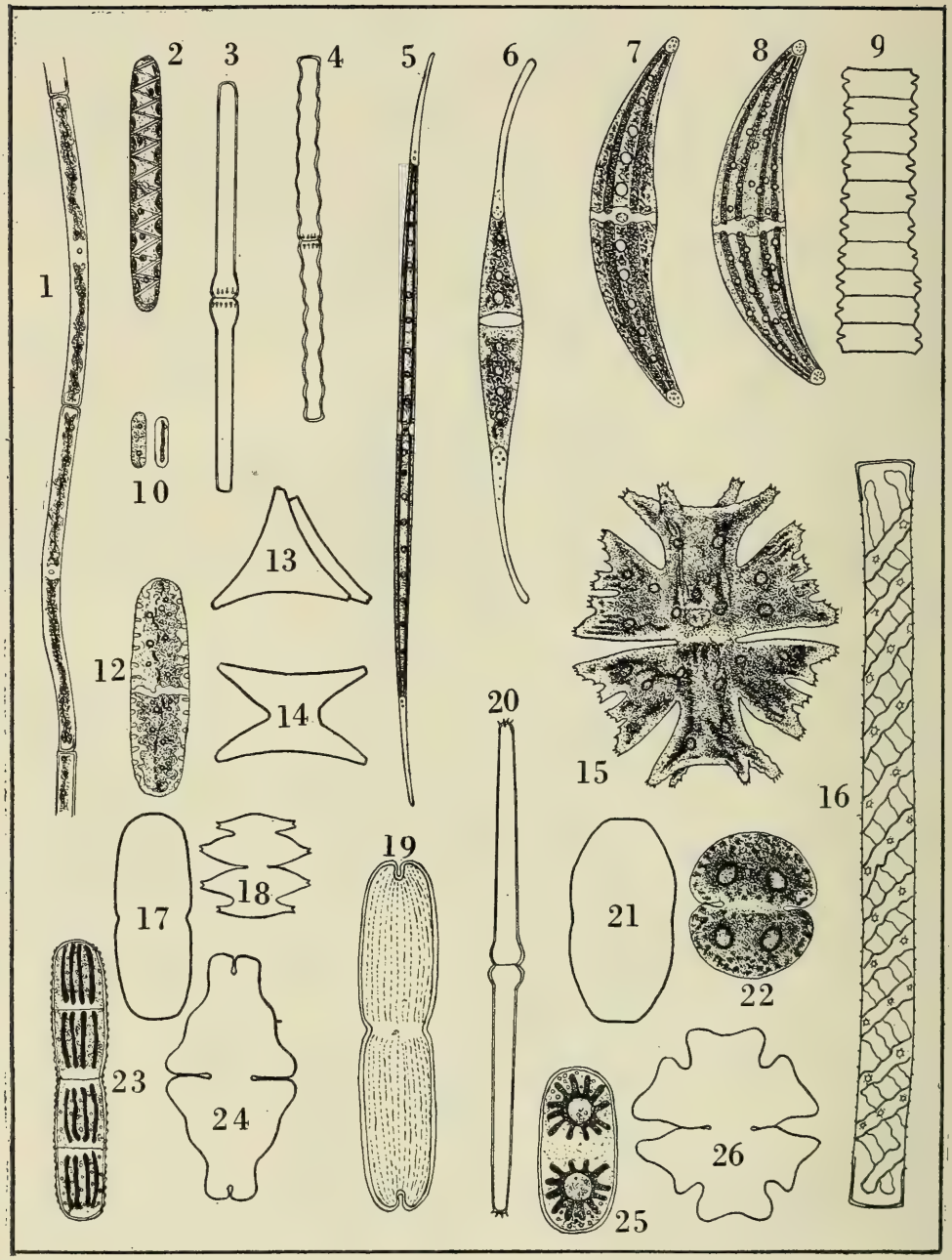
*29. **Ulothrix.** Filaments composed of cells which are hardly longer than wide, chromatophore forming a parietal band with one or more pyrenoids.

*30. **Oedogonium.** Filaments composed of long cells, chromatophore with several pyrenoids; membranes often with transverse striations at end of a cell.

31. **Tribonema.** Unbranched light green filaments, two or more parietal chromatophores, no pyrenoids.

32. **Draparnaldia.** Main filaments large, bearing lateral tufts of finer branches. Terminal cells usually ending in a long hair.

DESMIDIACEAE



1, Gonatozygon. 2, Spirotænia, 3, 4, Docidium. 5, 6, 7, 8, Closterium. 9, Desmidium. 10, Mesotænium. 12, Netrium. 13, Staurastrum (end view). 14, Staurastrum (side view) 15, Micrasterias. 16, Genicularia. 17, Penium. 18, Micrasterias. 19, Tetmemorus. 20, Pleurotænium. 21, 22, Cosmarium. 23, Penium. 24, Euastrum. 25, Cylindrocystis. 26, Euastrum.

DESMIDIACEAE

The desmids are green, unicellular plants, sometimes united into filaments; cells made up of two symmetrical halves; chromatophore contains one or more pyrenoids.

1. **Gonatozygon.** Long cells covered with minute spines; chromatophore a central plate in which occur the pyrenoids.

2. **Spirotaenia.** Cells oblong, ends rounded, containing one or more spiral chromatophores.

3, 4. **Docidium.** Elongate cylindrical cells constricted in the middle; chromatophores are longitudinal radial plates.

*5, 6, 7, 8. **Closterium.** Crescent-shaped cells, tapering toward each extremity; two chromatophores in each cell; at each end a large vacuole with moving granules.

9. **Desmidium.** Short cells united to form long twisted filaments; each cell constricted in the middle; end view of cell triangular or quadrangular.

10. **Mesotaenium.** Very small oblong oval cells; chromatophore a single axial plate containing one or more pyrenoids.

12. **Netrium.** Oblong cells; two radial flat chromatophores with ridged or scalloped margins.

13, 14. **Staurastrum.** End view of cells triangular, quadrangular, or radiate; side view shaped somewhat like an hour-glass.

15. **Micrasterias.** Large disc-shaped cells, deeply constricted in the middle, each half of the cell again divided in 3 or 5 lobes, the tips usually bearing spines.

16. **Genicularia.** Elongate cylindrical cells covered with fine spines; chromatophores consisting of several parietal spiral bands.

17. **Penium.** Elongate cells with rounded or truncate ends, sometimes slightly constricted in the middle; a large pyrenoid in each half of the cell around which the chromatophores are radially placed.

18. **Same as 15.**

19. **Tetmemorus.** Elongate cylindrical cells with a shallow constriction in the middle and a narrow incision at each end; a single axial chromatophore with a single row of pyrenoids.

20. **Pleurotaenium.** Elongate cylindrical cells, swollen before the middle constriction; chromatophore a radial plate with a row of pyrenoids.

*21, 22. **Cosmarium.** Circular or elliptical compressed cells with a narrow, deep middle constriction; each half with a chromatophore which radiates from one or more pyrenoids.

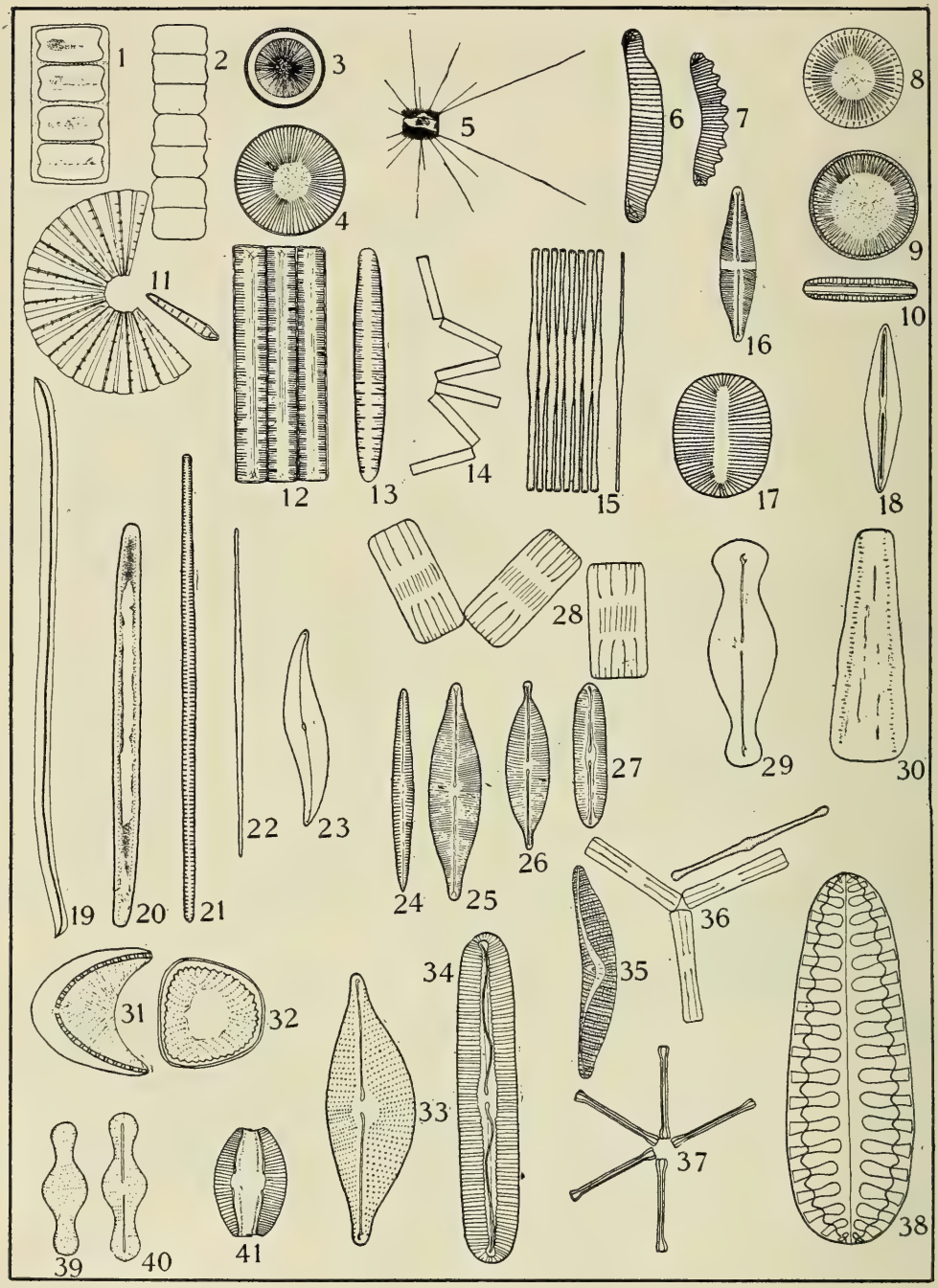
23. **Same as 17.**

24. **Euastrum.** Compressed oblong or elliptical cells with a deep middle incision and variously undulating or incised margins; chromatophore axial; pyrenoid large.

25. **Cylindrocystis.** Oblong cells with rounded ends; two star-shaped chromatophores, radiating from a central pyrenoid.

26. **Same as 24.**

DIATOMS



1, 2, 3, 4, Melosira. 5. Stephanodiscus. 6, 7, Eunotia. 8, Stephanodiscus. 9, 10, Cyclotella. 11, Meridion. 12, 13, 14, Diatoma. 15, Fragilaria. 16, Stauroneis. 17, Cocconeis. 18, Frustulia. 19, 20, Nitzchia. 21, 22, Synedra. 23, Pleurosigma. 24, 25, 26, 27, Navicula. 28, Tabellaria. 29, 30, Gomphonema. 31, 32, Campylodiscus. 33, Cymbella. 34, Pinnularia. 35, Epithemia. 36, Tabellaria. 37, Asterionella. 38, Surirella. 39, 40, Achnanthidium. 41, Amphora.

BACILLARIACEAE (DIATOMS)

Yellowish colored unicellular plants, sometimes united in chains; membrane silicified, with minute cross striations or other definite markings. Cells composed of two parts or valves, the side where the edges of the valves overlap is called the *girdle side* and the outer surface the *valve side.*

1, 2, 3, 4. **Melosira.** Short discoid cells, circular in crosssection, united into filaments; entire valve uniformly marked.

5, 8. **Stephanodiscus.** Cells single, valves circular, with raidal rows of dots; around margin a circle of spines of varying lengths; ends of girdle view wavy.

6, 7. **Eunotia.** Single cell, more or less curved, with transverse punctate striations, median line (raphe) absent, ends with nodules.

9, 10. **Cyclotella.** Single cells, disc-shaped, without spines; valves circular, with a smooth or punctate central area and radiating striations on the outer margin; girdle view with wavy ends.

11. **Meridion.** Wedge-shaped cells united to form fan-shaped or circular bands; valves transversely striate.

*12, 13, 14. **Diatoma.** Cells rectangular in girdle view, oblong oval in valve view, transversely striate; cells mostly attached in zig-zag chains.

*15. **Fragilaria.** Cells long and slender, valve side wider in middle and attenuate toward the ends, without transverse ribs; cells united into long ribbons.

16. **Stauroneis.** Single cells, lance-shaped, valve side with broad central nodule which extends to near margin of valves; cross striations of fine dots.

17. **Cocconeis.** Valve view of cells oval, raphe straight, middle nodule present but no end nodules.

18. **Frustulia.** Similar to **Stauroneis,** but the central nodule not so broad.

19, 20. **Nitzchia.** Long slender cells, rachis lateral, with a keel at one edge, cells rhomboidal in cross section.

*21, 22. **Synedra.** Cells single, very slender, often attached at one end, forming fan-like stalked clusters.

23. **Pleurosigma.** Single cells, S-shaped, central and end nodules present.

*24, 25, 26, 27. **Navicula.** Cells more or less lance-shaped, central nodule small, cross striations composed of find dots.

*28, 36 **Tabellaria.** Girdle view of cells rectangular, with two or more longitudinal lines from the end toward the center, valve view slender, thickened in the middle and at the ends; mostly united into zig-zag chains.

*29, 30. **Gomphonema.** Single cells, girdle view wedge-shaped, valve view with undulating edges.

31, 32. **Campylodiscus.** Single cells, large, saddle-shaped in valve view.

33. **Cymbella.** Valve view asymmetrical, girdle view oval or elliptical.

34. **Pinnularia.** Oblong cells with end nodules, turned toward one side.

35. **Epithemia.** Single lopsided cells, transverse markings coarse and converging toward the middle.

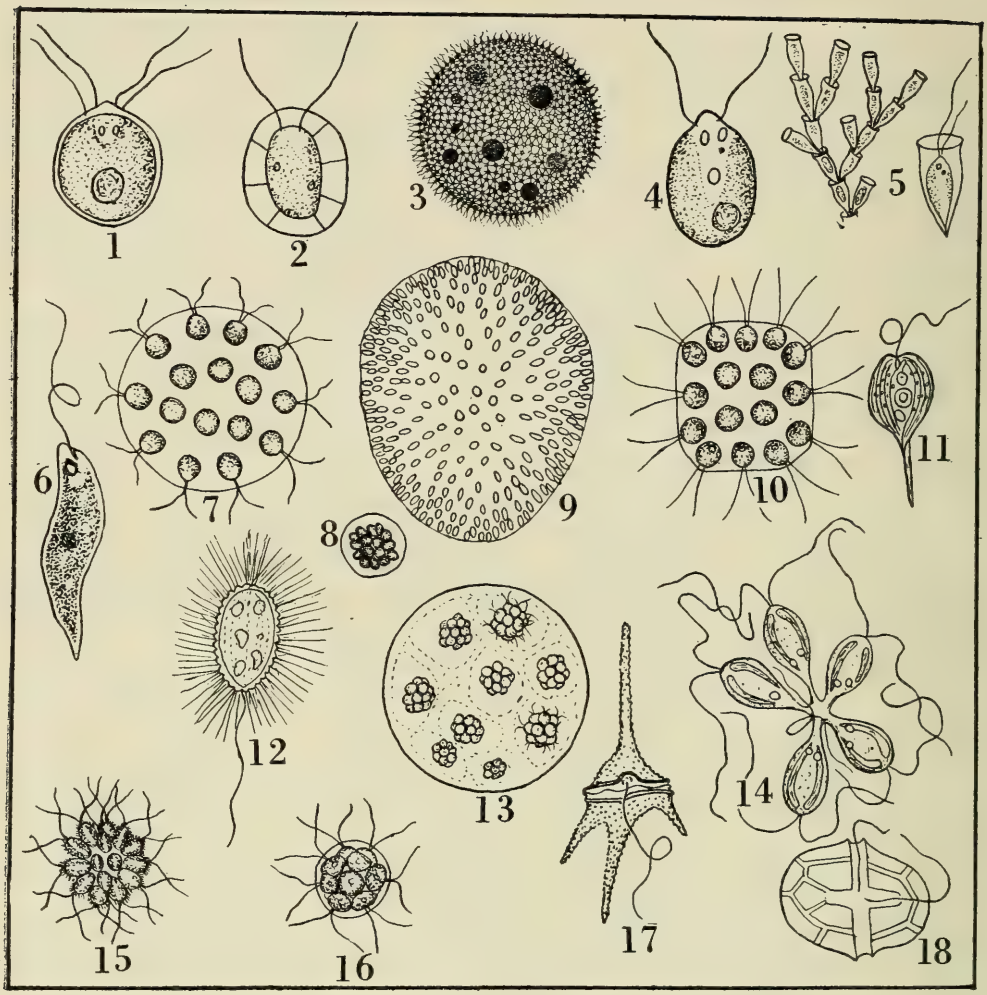
*37. **Asterionella.** Linear cells, enlarged at both ends, united at one end to form a wheel or star.

38. **Surirella.** Large single cells with looped striations.

39, 40. **Achnanthidium.** Single cells with a swelling in middle and ends.

41. **Amphora.** Single cells, valve view convex, girdle view elongate oval.

FLAGELLATA



1, Carteria. 2, Sphærella. 3, Volvox. 4, Chlamydomonas. 5, Dinobryon. 6, Euglena. 7, Eudorina. 8, Eudorina (young colony). 9, Uroglena. 10, Gonium. 11, Phacus. 12, Mallomonas. 13, Pandorina. 14, Uvella. 15, Synura. 16, Pandorina. 17, Ceratium. 18, Peridinium.

FLAGELLATA

The Flagellates are characterized by the presence of one or more long, flexible, whip-like processes (flagella) commonly occurring at one end of the body. They are either unicellular or colonial.

1. **Carteria.** Nearly spherical single cells bearing four flagella.

2. **Sphaerella.** Elliptical single cells bearing two flagella; the membrane is widely separated from the chromatophore but connected to it by fine protoplasmic strands.

*3. **Volvox.** A large number of small cells united into a large spherical colony; each cell bearing two short flagella or cilia.

*4. **Chlamydomonas.** Single elliptical or spherical cells bearing two flagella; chromatophore single, hollow, parietal.

5. **Dinobryon.** Beaker-shaped cells united into dichotymously branched colonies; cells bearing one long and one short flagellum.

*6. **Euglena.** Spindle-shaped single cells, usually green, bearing one flagellum; a reddish eye-spot at base of flagellum.

*7. **Eudorina.** Spherical colonies of eight, sixteen or thirty-two cells evenly distributed near the surface of the gelatinous mass; cells bearing two flagella.

8. **Eudorina.** Young colony.

9. **Uroglena.** Very many small cells united into a spherical, gelatinous colony; cells bearing two unequal flagella or cilia.

10. **Gonium.** Four to sixteen spherical cells united into a plate-like colony; each cell with two flagella.

11. **Phacus.** Round to pear-shaped single cells with a longitudinally striated surface, a single flagellum present; cells bearing a caudal spine or process.

12. **Mallomonas.** Single elongate cells with amber colored chromatophores, and a shell of overlapping plates bearing long spines; a single flagellum present.

13. **Pandorina.** Eight or sixteen slightly elongate cells closely packed together within a gelatinous mass; cells bearing two flagella.

14. **Uvella.** Four or five elongate cells, each with two chromatophores and two flagella.

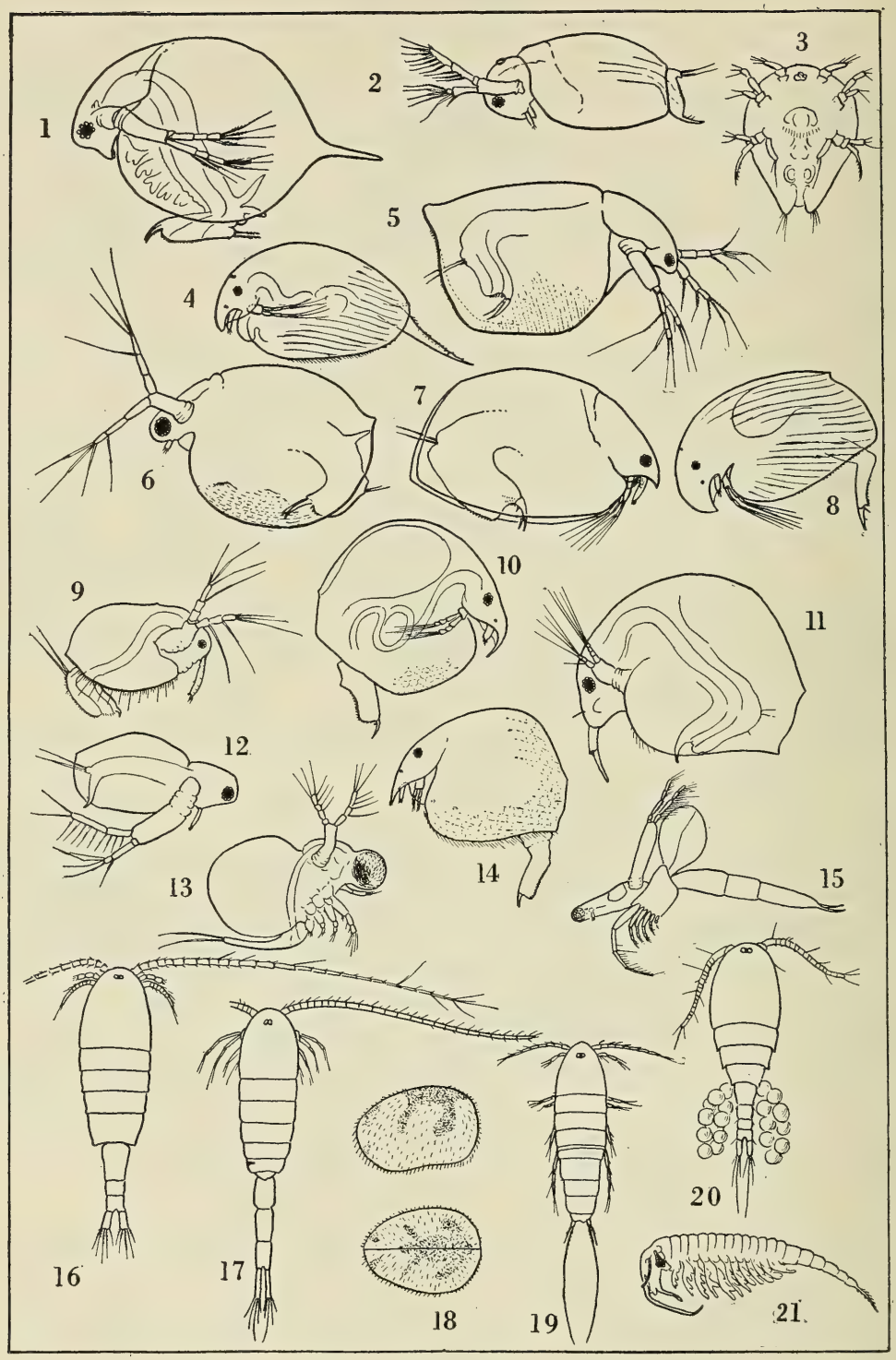
*15. **Synura.** Many elongate cells held loosely together, each with a thin membrane which often is spiny; two unequal flagella present.

16. **Pandorina.** Same as 13, single colony enlarged.

*17. **Ceratium.** A single cell inclosed in a membranous shell with long spine-like processes; a single flagellum present.

18. **Peridinium.** A single cell enclosed in a membranous polygonal shell without spine-like processes.

CRUSTACEA



1, Daphnia. 2, Sida. 3, Nauplius. 4, Camptocerus. 5, Simocephalus. 6, Ceriodaphnia. 7, Eurycerus. 8, Acroperus. 9, Macrothrix. 10, Chydorus. 11, Bosmina. 12, Diaphanosoma. 13, Polyphemus. 14, Alonella. 15, Leptodora. 16, Diaptomus. 17, Limnocalanus. 18, Cypridopsis. 19, Canthocamptus. 20, Cyclops. 21, Eubranchipus.

CRUSTACEA

CLAODOCERA, COPEPODA, OSTRAEODA AND PHYLOPODA

*1. **Daphnia.** Upper branch of antenna four-segmented, lower branch three-segmented; no tranvserse suture on neck; shell with polygonal marks and with a posterior spine.

2. **Sida.** Upper branch of antenna three-segmented, with many setae, lower branch two-segmented; a transverse suture on neck.

*3. **Nauplius.** An immatiure stage of Cyclops etc, bearing 3 pairs of appendages.

*4. **Camptocerus.** Antennae short; a crest or keel on head and back; post-abdomen very long and slender.

5. **Simocephalus.** Two pairs of long antennae; shells somewhat quadrate, marked with transverse lines.

6. **Ceriodaphnia.** Size small, head small, eyes larger; antennae long.

7. **Eurycerus.** Size large; post-abdomen very large, with more than 100 saw-like teeth on dorsal margin.

8. **Acroperus.** A crest on head and back; shells obliquely striated.

9. **Macrothrix.** Crest on dorsum; antennae long; shells with long movable spines on ventral margin.

10. **Chydorus.** Body nearly spherical; antennae short and thick; post-abdomen short.

*11. **Bosminia.** Antennules long and fixed to head so as to suggest a long beak; shells truncate behind, the lower angle with a spine.

12. **Diaphanosoma.** Antennae very large, about as long as body, upper branch three-segmented, lower branch two-segmented.

13. **Polyphemus.** Body and feet not covered by shell; four pairs of feet, head large; a long caudal process (on ventral side of body).

14. **Alonella.** Rostrum long, slender, recurved; shells striated or reticulated, truncate behind.

15. **Leptodora.** Size very large; body and feet not covered by a shell; six pairs of feet; antennae very large; a dorsal brood sac.

*16. **Diaptomus.** Outer portion (endopodites) of first swimming feet composed of two segments, of third and fourth swimming feet of three segments; antennae as long as body; posterior body region short; tails (furca) short.

17. **Limnocalarus.** Outer portion (endopodites) of all swimming feet composed of three segments; antennae as long as body; posterior body region long; tails (furca) long.

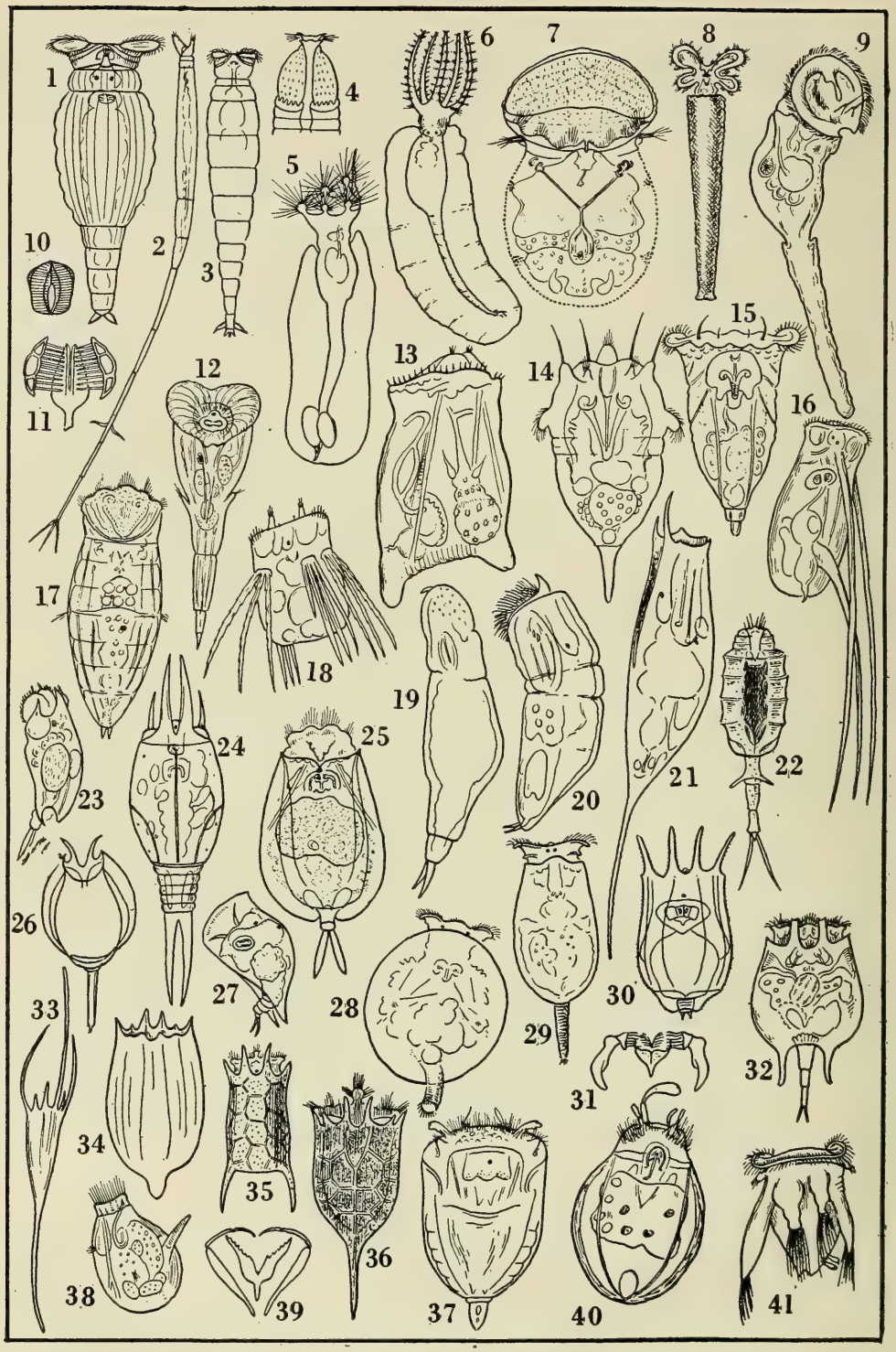
18. **Cypridopsis.** Body completely enclosed in a bivalver shell which is marked dorsally and laterally with three dark bands.

*19. **Canthocamptus.** Antennae short, of eight segments; last abdominal segment usually with spine-like processes.

*20. **Cyclops.** Antennae shorter than cephalothorax, with not more than seventeen segments; female with two egg sacs.

*21. **Eubranchipus.** (Fairy shrimp). Elongate body not covered by a shell, with eleven pairs of legs.

ROTIFERA



1, Philodina. 2, 3, Rotifer. 4, Adineta. 5, Floscularia. 6, Stephanoceros. 7, Apsilus. 8, Melicerta. 9, Conochilus. 10, Ramate jaws. 11, Malleo-ramate jaws. 12, Microcodon. 13, Asplanchna. 14, 15 Synchæta. 16, Triarthra. 17, Hydatina. 18, Polyarthra. 19, Diglena. 20, Diurella. 21, Rattulus. 22, Dinocharis, 23, 24, Salpina. 25, Euchlanis. 26, Monostyla. 27, Colurus. 28, 29, Pterodina. 30, Brachionus. 31, Malleate jaws. 32, Noteus. 33, 34, Notholca. 35, 36, Anuraea. 37, Plœsoma. 38, Gastropus. 39, Forcipate jaws. 40, Anapus. 41, Pedalion.

ROTIFERA

The rotifers are characterized by the ciliated area at or near the anterior end of the body. These cilia serve as locomotory organs or to bring food to the mouth.

*1. **Philodina.** Two wheel-like discs of cilia (corona); two eyes in the neck, directly over the brain.

*2, 3. **Rotifer.** Two discs of cilia; two eyes in dorsal proboscis.

4. **Adineta.** Corona a flat disc with cilia on the ventral side.

5. **Floscularia.** Corona lobed; cilia not in whorls, scattered, or in groups.

6. **Stephanocerus.** Corona drawn into 5 long pointed arms or spines which bear short cilia.

7. **Apsilus.** Short sac-like body; corona a large sac without cilia.

8. **Melicerta.** Corona with four lobes; living in tubes, attached.

9. **Conochilus.** Corona flat; free swimming clusters or colonies.

12. **Microcodon.** Corona somewhat heart-shaped; body ending in a long slender foot.

*13. **Asplanchna.** Body sac-like, without foot; intestine ending blindly.

*14, 15. **Synchaeta.** Corona as broad as broadest part of body, with 2 or 4 long bristles; at the sides of the corona two large ciliated lobes (auricles) which may be retracted.

16. **Triarthra.** Body with three long spine-like appendages.

17. **Hydatina.** Body ending in two short toes; corona as broad as body, composed of a double wreath of cilia.

18. **Polyarthra.** Body with 12 blade-shaped appendages, with serrate edges, in four groups.

19. **Diglena.** Body slender; two toes; corona narrower than head; two eyes.

20. **Diurella.** Body quite short, ending in two toes.

*21. **Rattulus.** Body elongate, ending in one long toe.

22. **Dinocharis.** Head retractile; foot bearing two spines dorsally; foot and toes together nearly or quite twice as long as the body.

23, 24. **Salpina.** Armor with spines either anteriorly or posteriorly, or both.

25. **Euchlanis.** Armor composed of two plates; foot pointed, bearing two long toes.

26. **Monostyla.** Body armored, with one long rod-shaped toe.

27. **Colurus.** Head bearing an arched shield, in side view appearing like a hook; foot ending in two short toes.

28, 29. **Pterodina.** Corona surrounded by two wreaths of cilia; foot long, ringed and ending in a bunch of cilia.

30. **Brachionus.** Body armored; spines or teeth in front; foot ending in two short toes.

32. **Noteus.** Body stout, armed with spines; foot three-jointed; two toes.

*33, 34. **Notholca.** Armored, anteriorly with 6 spines, posteriorly ending in a long slender spine or else ending in a blunt projection; dorsum of armor with longitudinal striations.

*35, 36. **Anuraea.** Armored, anteriorly with 6 spines, posteriorly ending in one or two spines; dorsum of armor marked off into polygonal areas.

37. **Ploesoma.** Armor marked with grooves; foot with two short toes.

*38. **Gastropus.** Armor flask-shaped; small foot projecting from ventral surface; foot ringed, ending in one or two toes.

40. **Anapus.** Armored; head with long finger-like processes; foot absent.

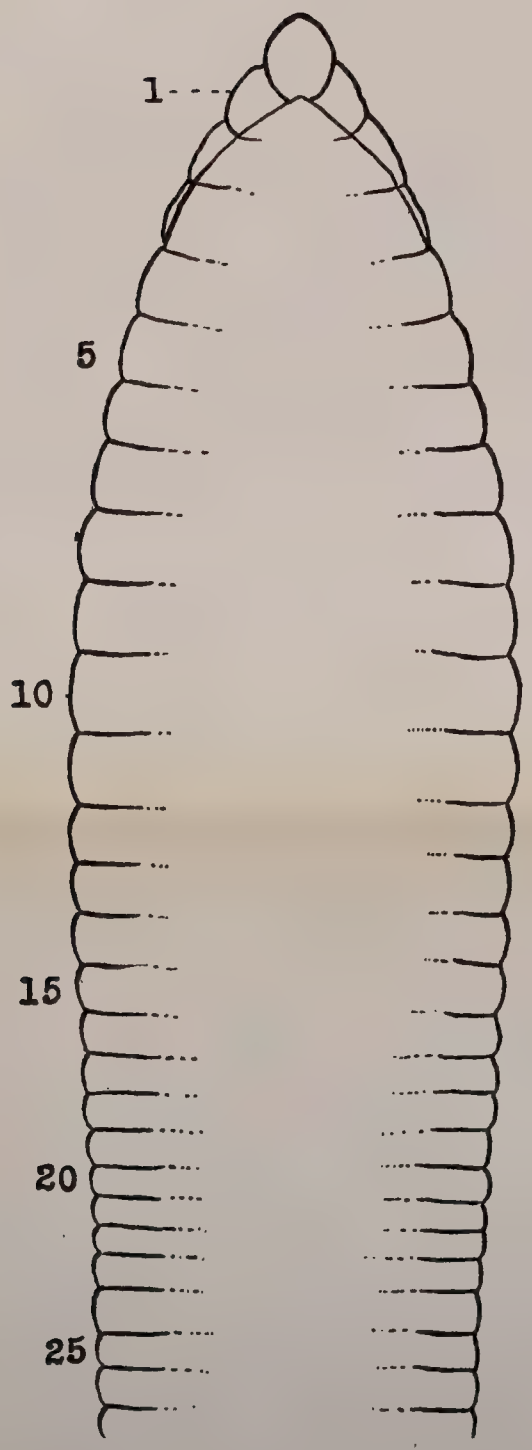
41. **Pedalion.** Unarmored; with six branching, limb-like appendages.

EXERCISE 2

OBSERVATIONS ON COMMON INSECT-GALLS

Common name of Plant and Gall[1]	Part of P ant Affected[2]	Position on that part[3]	THE GALL			THE GALL-MAKER				Other tenants[10] of the Gall and Misc. Remarks
			Type[4]	Aggregation[5]	Special Features[6]	Name[7]	Solitary or Gregarious	Stage Found[8]	Mouth Parts[9]	

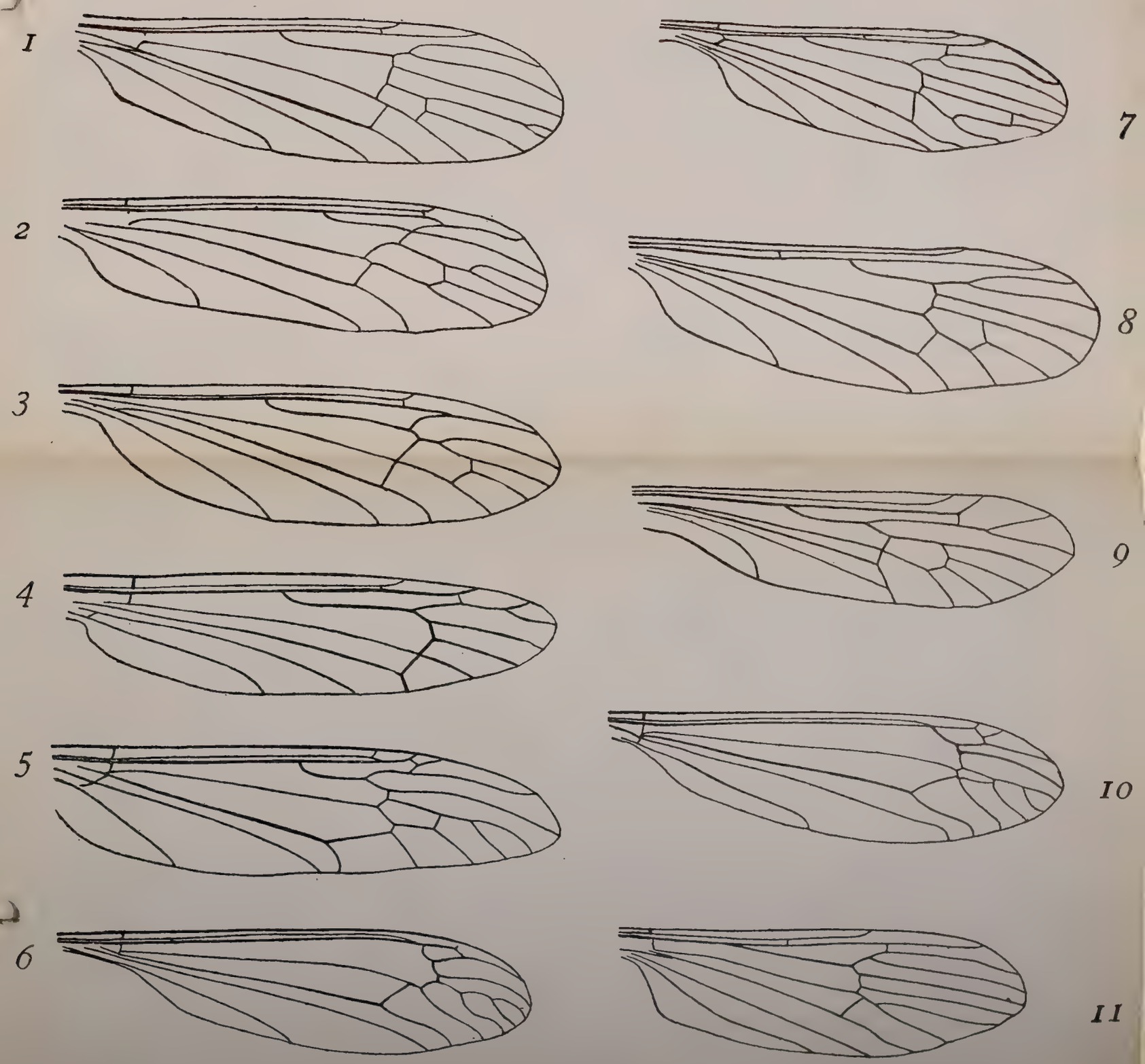
[1]*Ex.*, "Cone gall of willow." [2]Leaf, stem, root, twig, flower, bud, etc. [3]Upper or lower surface, midrib or membrane or margin or stalk of leaf, axial or lateral in stem and root, etc. [4]See table on page 13. [5]Solitary clustered or compound. [6]Shape and fit of cavity, color and armature of surface, repellants against foraging animals, exit passages for gall makers, etc. [7]Consult key on pages 14 and 15. Larva, pupa or adult. [8]Biting, if it has distinct horizontally moving jaws; piercing and sucking, if the beak is jointed: rasping and sucking, if it has mouth hooks. [10]Parasites, hyperparasites, and guests.


1
5
10
15
20
25

EXERCISE 17

EXERCISE 20

DIPTERA—TIPULIDÆ (CRANEFLIES)



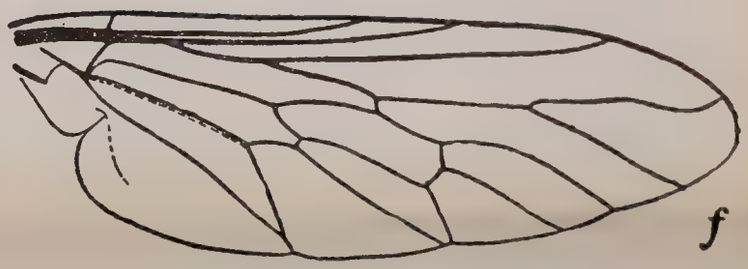
EXERCISE 20

DIPTERA (VARIOUS FAMILIES OF FLIES)

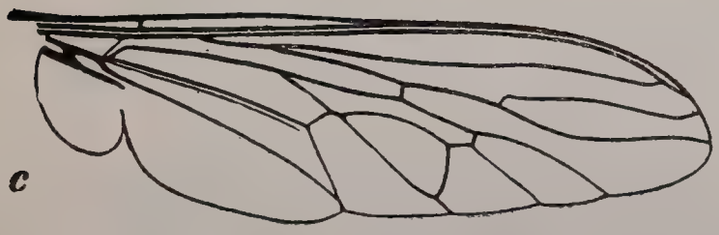
a

e

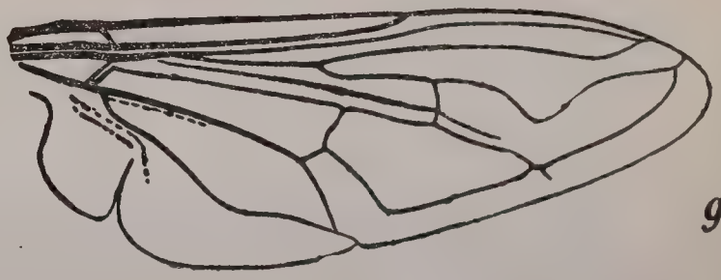
b



f

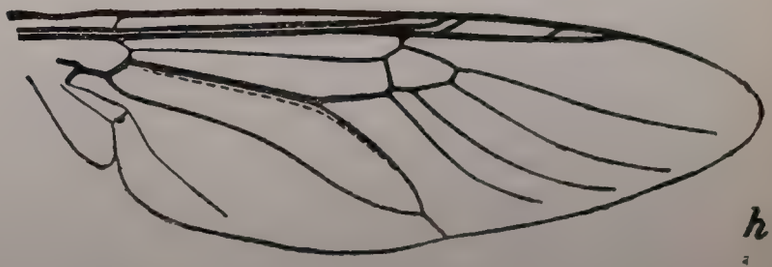


c



g

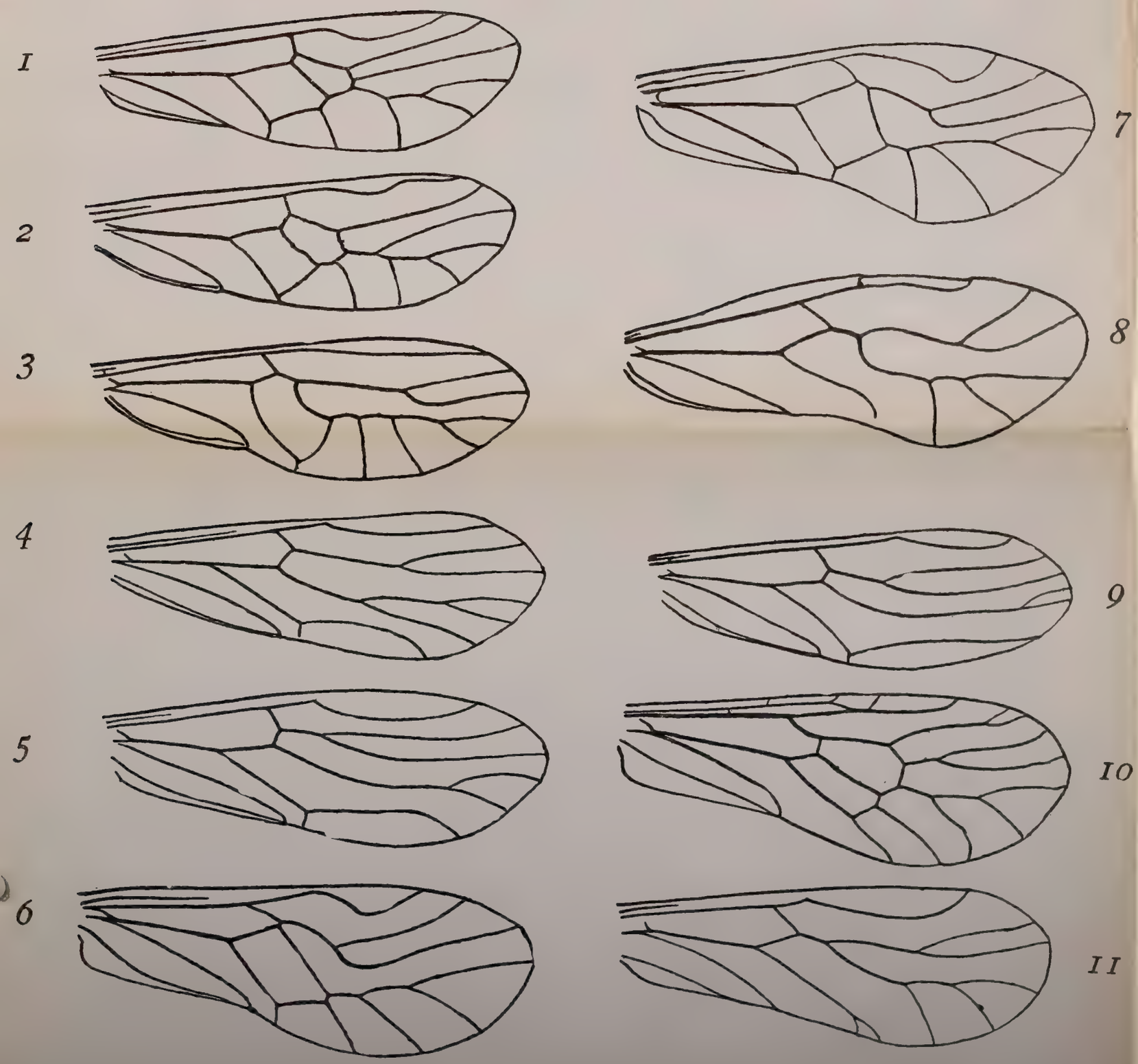
d



h

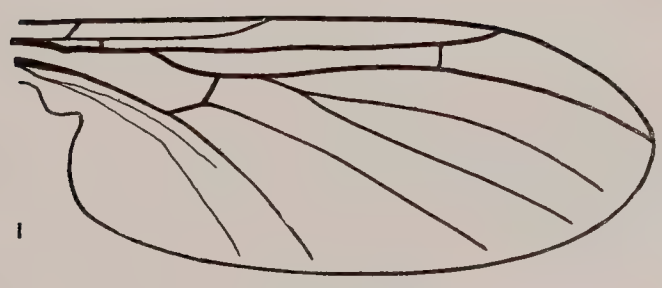
EXERCISE 20

PSOCIDÆ (BOOKLICE)



EXERCISE 20

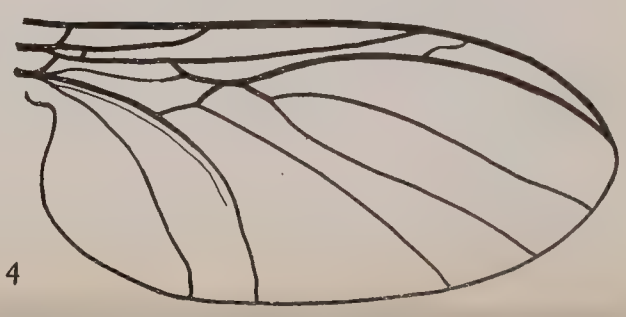
DIPTERA-MYCETPHILIDÆ (FUNGUS GNATS)



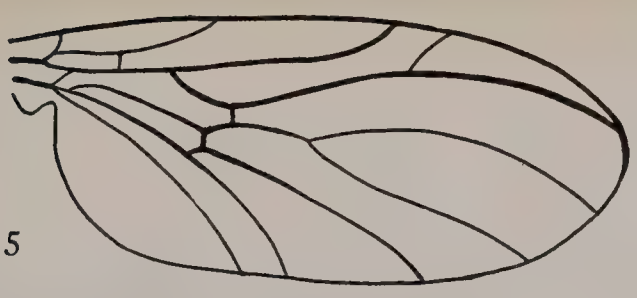
1

2

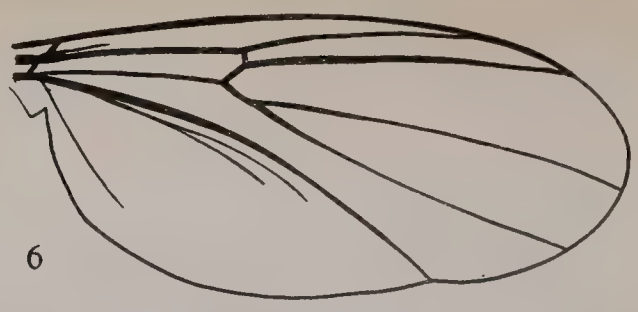
3



4

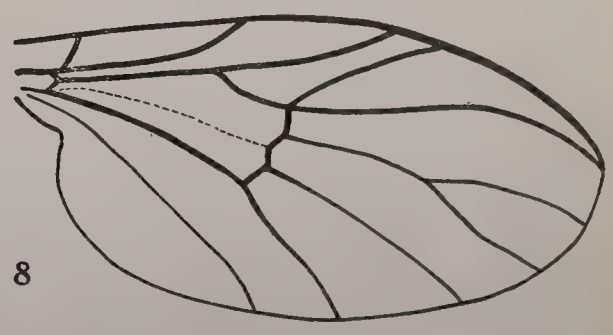


5

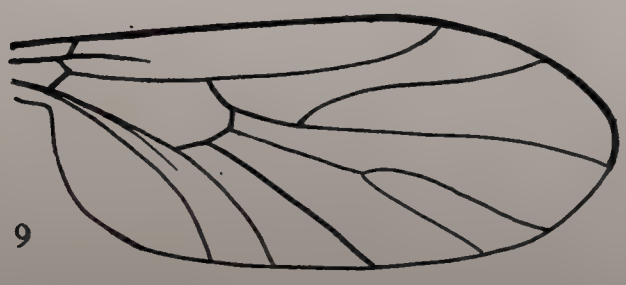


6

7



8



9

10

TABLE OF MALACOSTRACAN APPENDAGES

KINDS OF APPENDAGES

Seg.	in Cambarus	in Gammarus	in Asellus	in Squilla
1				
2				
3		*md*		
4		*mx*		
5		*mx*		
6		*mxp*		
7				
8				
9				
10				
11				
12				
13				
14	*r in* ♀			
15			*o in* ♀	
16				
17			*gill*	
18			*gill*	
19				
20		o	o	o

Bracket together the segments that are consolidated upon the dorsal side.
When different in the two sexes divide the space with a diagonal line and write characters of male and female in separately.

FUNCTIONS OF APPENDAGES

	Swimming	Walking	Jumping	Fighting	Grasping	Chewing and manipulating food	Respiratory	Tactile	Other functions*	Rudimentary	Problematic	
Cambarus			o				7-12		*14 and 15 in* ♂	*14 in* ♀		
Gammarus							8-12					
Asellus									*14 to 16 in* ♂ *14 and 16 in* ♀	*15 in* ♀	*19*	
Squilla			o									

**Specify function. Indicate segments by number only (1 to 20), as in preceding table.*
Specify characters of male and female separately, where they differ.

EXERCISE 22

ONTOGENY

A. Comparison of the tadpole stages of the frog with the adult.

In the following table, note on the dotted line *by letter* (see list below) the characters indicative of the group.

I. Organs and parts peculiar to the young tadpole stage and wanting in the adult.

.....

II. Organs and parts functional in the young tadpole stage and vestigial in the adult.

.....

III. Organs and parts developed in both but better in the adult stage.

.....

IV. Organs and parts rudimentary or absent in the young, functional only in the adult.

.....

a	Notochord	*n*	Liver
b	Sucker pits	*o*	Ossified skeleton
c	Lips with teeth	*p*	Gills
d	Horny teeth in jaws	*q*	Cartilaginous skeleton
e	Mucous glands of skin	*r*	Lungs
f	True teeth in upper jaw	*s*	Sex organs
g	Eustachian tube	*t*	Vocal organs
h	Tympanum	*u*	Tail
i	Pronephric duct	*v*	Four aortic arches
j	Spiral intestine	*w*	Heart
k	Fin	*x*	Eye
l	Kidneys	*y*	Tongue
m	Two chambered heart	*z*	Sensory cells in lateral line

B. In parallel columns compare the following embryonic stages of the frog with the adult form of animals lower in the series (*i. e.*) with protozoa, coelenterates, worms, etc.

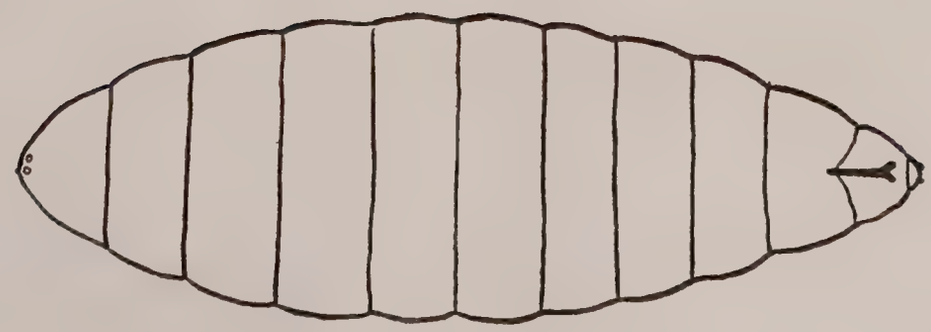
Lower Forms	Frog
	One-celled egg
	Eight-cell stage
	Sixteen cell stage
	Thirty-two cell stage
	Morula stage
	Blastula stage
	Gastrula stage
	Young embryo

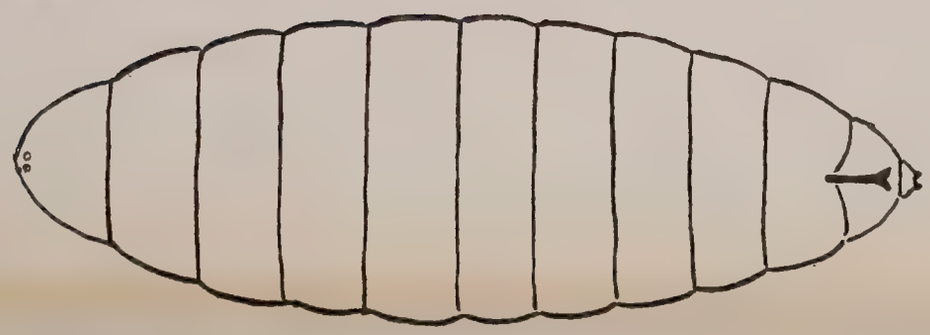
Exercise 26

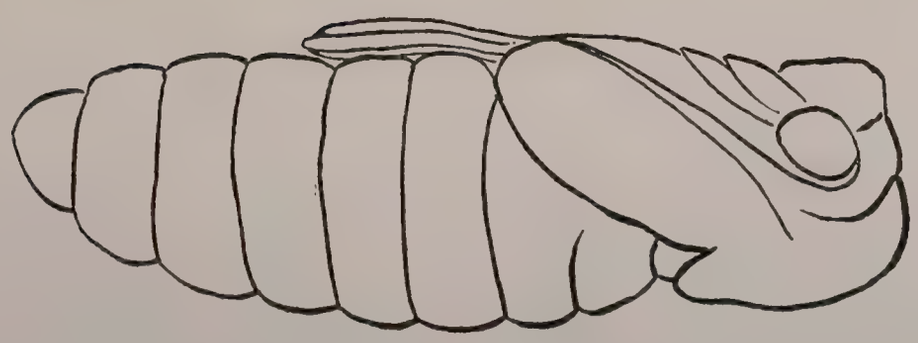
EXTERNAL METAMORPHOSIS IN INSECTS

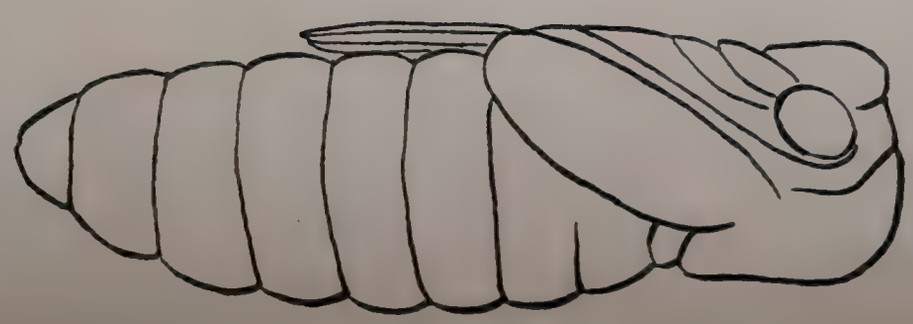
Name and Order	Larva or Nymph							Adult					
	Ratios[1]	Mouth Parts[2]	Wings[3]	Legs[4]	Peculiar Parts[5]	Lives Where	Eats What	Ratios[1]	Mouth Parts[2]	Legs[4]	Peculiar Parts[5]	Lives Where	Eats What
Grasshopper Orthoptera						Meadows	Herbivorous					Meadows	Herbivorous
Stone fly Plecoptera						Aquatic	Mainly Carnivorous					Aerial	Most eat nothing
May fly Ephemerida						Aquatic	Herbivorous					Aerial	Nothing
Damsel fly Odonata						Aquatic	Carnivorous					Aerial	Carnivorous
Dragon fly Odonata						Aquatic	Carnivorous					Aerial	Carnivorous
Water bug Hemiptera						Aquatic	Carnivorous					Aquatic	Carnivorous
Cadis fly Trichoptera						Aquatic	Herbivorous					Aerial	Nothing
Butterfly Lepidoptera						Upon its host plant	Herbivorous					Aerial	Nectar Some do not feed
May beetle Coleoptera						In the soil	Roots					In trees	Herbivorous
Weevil Coleoptera													
Crane fly Diptera						In earth or Aquatic	Herbivorous					Aerial	Nothing
Fly Diptera												Aerial	Organic solutions

[1]Relative lengths of head, thorax and abdomen expressed in the ratios $1 : x : y$; the head being taken as 1.
[2]Adapted for biting, sucking, or atrophied.
[3]Externally or internally developing.
[4]Relative development.
[5]Found in this larva (or adult) only.









EXERCISE 29

WOODLAND PLANT SOCIETY

A study in the local and seasonal adjustment of the commoner plants of the Renwick Woods, Ithaca, N. Y.

Checking List;

Group 1—Trees — *Height in Feet*

1. Elm ....
2. Maple ....
3. Butternut ....
4. Swamp Oak ....
5. Ash ....
6. Sycamore ....
7. Willow ....
8. ....
9. ....

Group 2—Shrubs

1. Spice-bush ....
2. Elder ....
3. Raspberry ....
4. Currant ....
5. Viburnum ....
6. Dogwood ....
7. ....
8. ....

Group 3—Vines — *Height in Feet* — *Climbing by means of*

1. Wild Grape ....
2. Poison ivy ....
3. Virginia creeper ....
4. Moonseed ....
5. Clematis ....
6. Nightshade bittersweet ....
7. ....

Group 4. Tall late herbs spreading by underground branches — *Height in in.*

1. Aster ....
2. Goldenrod ....
3. Sunflower ....
4. Polygonum ....
5. Mint (*Blephila*) ....
6. Wood nettle ....
7. Sensitive fern ....
8. ....

Group 5—Rosette-forming tall herbs

1. Meadowrue ....
2. Buttercup ....
3. Geum ....
4. Dock ....
5. ....

Group 6.—Ground-cover creeping herbs

1. Violet ....
2. Ground ivy ....
3. Moneywort ....
4. Forget-me-not ....

Group 7.—Coarse monocots with deep root stalks — *Height in in.*

1. Skunk cabbage ....
2. Veratrum ....

Group 8.—Slender bulbous monocots

1. Onion ....
2. Adder's tongue ....

Group 9.—Bulbous crucifers

1. Bitter cress ....
2. Pepperroot ....

Group 10.—Annual herbs

1. Touch-me-not ....
2. Giant ragweed ....

Group 11.—Biennial herbs

1. Cow parsnip ....
3. Poison hemlock ....

Group 12.—Miscellaneous

1. Stinging nettle ....
2. Bedstraw ....
3. Grasses ....
4. Sedges ....
5. Mosses ....
6. Fungi ....

Work Program

I. Learn to recognize poison ivy, and then avoid it, unless you are immune.

II. In the checking list before the name place a:—

* to indicate those that are vernal plants—those whose vegetative activity is at its height in early spring.

‡ to indicate those found chiefly in the openings of the forest cover—those that require most sun light.

w to indicate those found in the lower places, nearest the water.

l to indicate those woody plants that are commonly found rooting in fallen logs.

III. Make a general diagram of a vertical section of the woods (including one low wet spot) showing stratification of crowns at four levels, and of roots in the soil below. Indicate height and depth of strata and name on the diagram two of the dominant plants of each stratum.

IV. Make simple diagrams to indicate:—

1. The underground spread and copse-forming habit of elder or viburnum.
2. The spread of the red raspberry by means of stolons.
3. The growth habit and asexual mode of increase in one representative each of groups 4, 6 and 9.
4. The form of one representative each of groups 5, 7, 8 and 10. In all these draw a line at the soil level, and indicate height and depth.

Exercise 30

POLLEN PRODUCTION

Name	Sex[1]	Form of flower cluster[2]	No. stamens per flower	No. pistils per flower	No. pollen grains per stamen	No. ovules[3] per carpel	Ratio of pollen grains[4] to ovules.
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							

1. Male, female, or bisexual; 2. catkin, panicle, loose cluster, head, solitary etc. 3. May be obtained from some work on Systematic Botany; 4. Expressed in the ratio X:1.

EXERCISE 31

III. **Illustrations of Flash Colors.**

Name	Color	Exposed to view how	Exposed to view when	Folded away how	Possible use
Flicker					
Junco					
Roadside grasshopper					
Underwing moth					

IV. **Illustrations of Mimicry.**

Name	Coloration	Mimicks What	Whose Defense is what
Viceroy butterfly			
Syrphus fly			

EXERCISE 31

Examples from the local Fauna of the principal types of Animal Coloration

I. **Illustrations of Resemblance.**

Name	Coloration[1]	Type[2]	Details of Resemblance
Sandpiper			
Backswimmer			
Frog			
Plover			
Least Bittern			
Treehopper			
Leaf insect			
Deadleaf butterfly			
Katydid			
Walking stick			
Water flea			

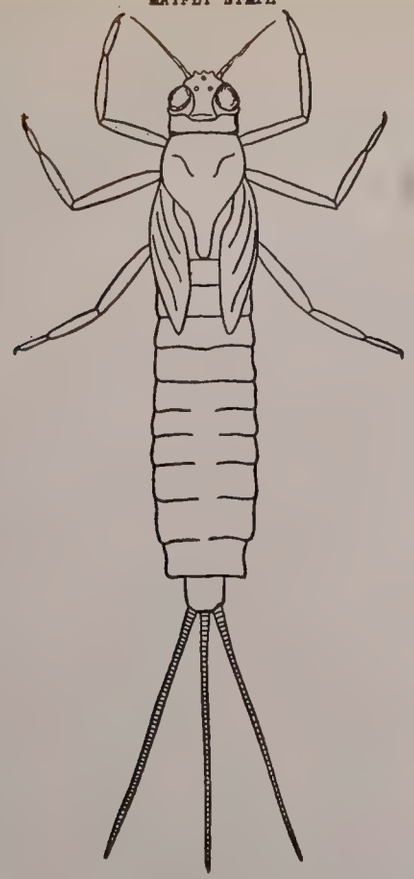
1. Protective or aggressive 2. General or specific

II. **Illustrations of Warning Coloration.**

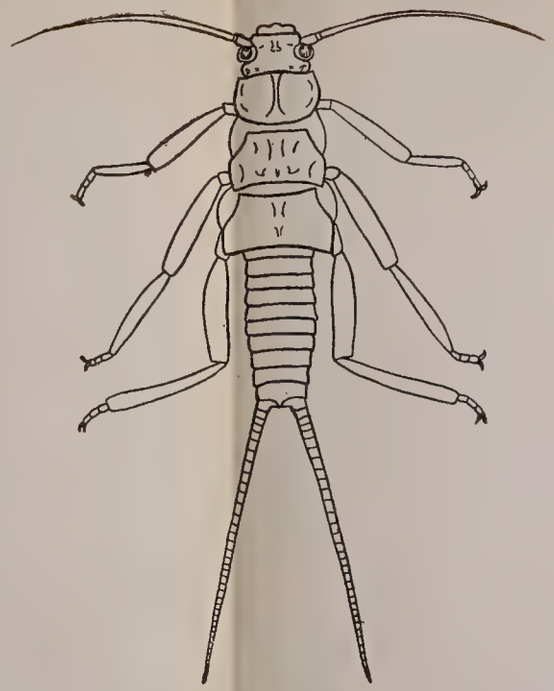
Name	Colors	Pattern	Disagreeable Quality Advertised
Bumblebee			
Ant			
Skunk			
Hornet			
Potato Beetle			
Monarch butterfly			
Bee			
Owl beetle			

EXERCISE 30

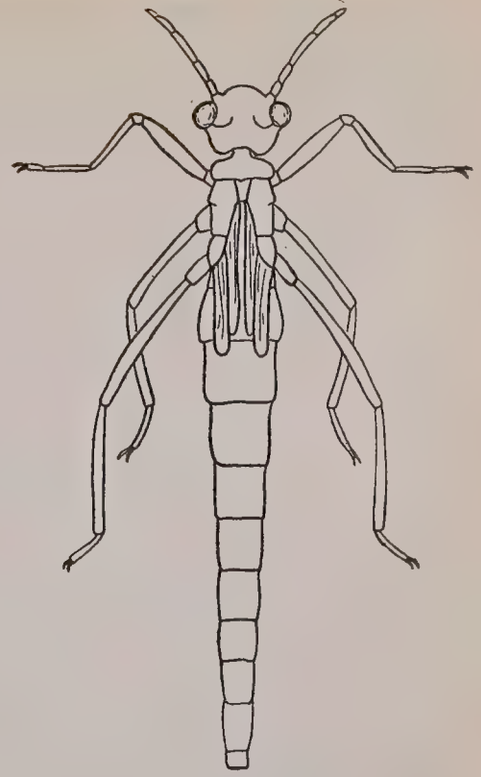
MAYFLY NYMPH

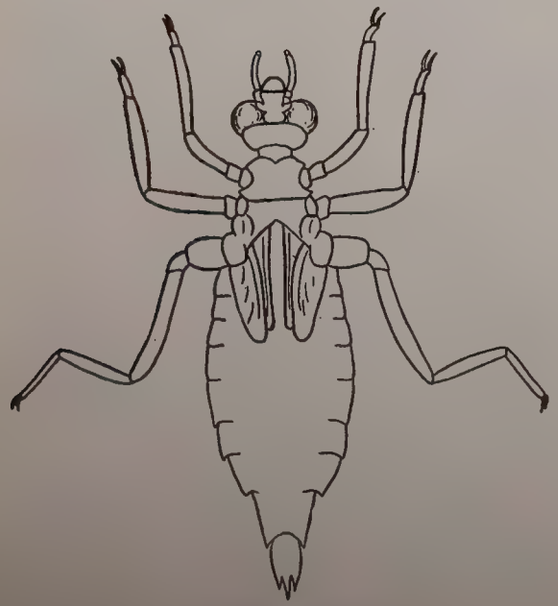


STONEFLY NYMPH

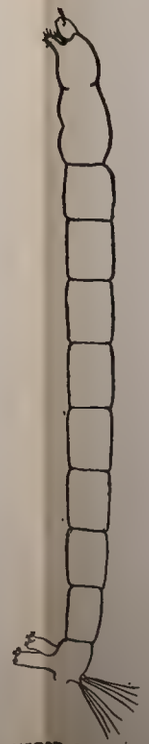


DAMSELFLY NYMPH





DRAGONFLY NYMPH



MIDGE LARVA

CADDIS WORM

EXERCISE 34

RECORD OF EXPERIMENTS ON TRIAL AND ERROR

FIRST CHICKEN

Trial	Spells of peeping	Walks with change of direction	Peerings through walls	Flights	Returns from			Time
					1	2	3	
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

SECOND CHICKEN

1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

THIRD CHICKEN

1								
2								
3								
4								
5								
6								
7								
8								
9								
10								