LABORATORY EXERCISES

TO ACCOMPANY

WAGGONER'S MODERN BIOLOGY

BY

MARY ALLISON BENNETT, B.S.

DEPARTMENT OF BIOLOGY
WESTERN ILLINOIS STATE TEACHERS COLLEGE

D. C. HEATH AND COMPANY

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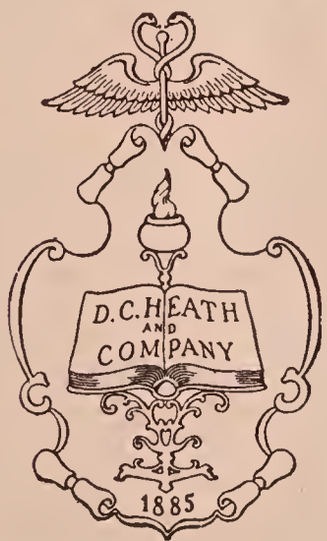

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PREFACE

This set of laboratory exercises is intended to form an integral part of a year's course in elementary biology. It is especially prepared to accompany and to supplement Waggoner's *Modern Biology: Its Human Aspects*, and as such can be used to the greatest advantage. The exercises are so arranged that they can be employed almost equally well in the laboratory which has little equipment and in one which is complete in every respect. While the demonstration method of presentation is suggested as being the most economical of supplies and probably the most effective in results, the directions are so planned that in most cases the individual method of study may be used when so desired. Throughout the course, the availability of the material to be employed has been kept in mind. In the majority of the exercises where live specimens are to be preferred, it should be possible to obtain them at the season of year for which they are suggested. To facilitate the use of the exercises, notations are inserted to call attention to the need of advance preparation of materials. It is advised that much of the work be done in the field, either by the class as a whole or by individuals. However, under conditions which make field work inexpedient, the majority of the exercises are suitable for indoor use. Throughout the book the attempt has been made to conform to the recommendations of the Commission on the Reorganization of Secondary Education appointed by the National Education Association (Bulletin No. 26, 1920).

The suggested laboratory exercises are ones which have been in use or have grown out of work done in the high school department of the Western Illinois State Teachers College during an extended period of years. The author wishes to acknowledge

her indebtedness to Dr. H. D. Waggoner, head of the Biology Department of this school, for his large contribution to the subject matter of this book, his unfailing advice, and his criticism of its contents and of the actual use of the exercises preceding their compilation in their present form.

Mary A. Bennett

Macomb, Illinois
June, 1926

DIRECTIONS TO THE INSTRUCTOR

The exercises in this book are so planned that they may be adapted to various forms of presentation, to schools whose laboratory equipment is complete or meager, and to the varying conditions of climate and of community life where the guide is to be used. In general, it is advised that the work be done in the field when it is so suggested; that the demonstration method of presentation be employed in the majority of the exercises (see Downing, *Teaching Science in the Schools*, Chapter VIII, University of Chicago Press, 1925); and that the textbook and these laboratory exercises be regarded as supplementary to each other.

Early in the year the instructor should carefully note what materials are required for the exercises which he plans to use. He should then make provision for them by the collection and preservation of such material and by placing early orders with supply companies when additional material is needed. Notations are made at appropriate points in the Manual to remind the instructor of such material as must be prepared immediately before it is used.

It is advised that where microscopic studies are to be made by students of secondary schools, the manipulation of the microscope and the preparation of slides should both be cared for by the instructor. The use of a projection microscope will greatly facilitate such studies and will add much to the efficiency of instruction.

If studies of the internal anatomy of animals are desired, the use of specimens previously dissected and prepared by the instructor or of museum dissections (which are permanently mounted and may be obtained from supply houses) is recommended. The use of such preparations obviates the current objections

to dissection and the waste of material through frequent failures of pupils to make successful dissections.

The pupil's notebook work should be done carefully so that it shall lead to correct concepts and clearly defined results. It should be accurate but at the same time economical of the pupil's time. It should never become an end in itself or a means of marking time. In general the drawings should show only what can be seen and should be done mainly in outline. Shading should be discouraged. The use of a hard lead pencil for drawing is advisable. *All structures referred to in the accompanying exercise should be labeled in the required drawings.* These labels are to be written or printed neatly at the side of the picture, parallel to the bottom of the page. They should be connected with the structure indicated by a straight solid or dotted line. (As an example, see Waggoner, Fig. 12.) Drawings are frequently suggested by the author but others may be asked for by the instructor. In some exercises the drawings may be the only notebook work required, but where written work seems to be desirable, it should be done in ink and should be clear, concise, and accurate. Incorrect spelling and poor English should not be tolerated.

Finally, more exercises are provided than can well be used in a single year's course in elementary biology. Therefore a number are indicated as supplementary and may be substituted for or used in addition to the others. It is advised that if Waggoner's *Modern Biology* is used as a text, all exercises not indicated as supplementary shall be utilized so far as it is practicable. As additional individual problems, parts of Exercise 85 should be assigned.

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LABORATORY EXERCISES

TO ACCOMPANY

WAGGONER'S MODERN BIOLOGY

EXERCISE 1

GRASSES

I. Field Study. Make a collection of grasses, both wild and cultivated. (Corn and the small grains are grasses.) Each specimen should consist of an entire plant. (This collection may be made either as individual or as class work.)

II. Laboratory Study.

1. Identify as many as possible of the different specimens of grasses which have been collected. Attach a label to each.

2. *Structure. a. Roots.* Note the characteristics of the roots of each. Observe especially those of the blue grass and timothy. *b. Stems (Culms).* Note the form and size of the stems of each. Determine which are hollow and which are filled with pith. Note the *nodes*, or joints, and the *internodes*, or the parts which are included between the joints. *c. Leaves.* Remove a leaf from the stem. Note the free part or *blade.* What is the arrangement of its veins? Note the *sheath*, the part which clasps the stem. What is the arrangement of the leaves with relation to one another? *d. Flowers.* Note the flowers. (See Waggoner, Fig. 12.) Where are the flowers borne?

EXERCISE 2

THE CORN PLANT

I. Roots. What are the nature and extent of the roots?

1. Find the *vertical* roots, which arise at or near the base of the stalk and penetrate to the deeper layers of soil.

2. Find the *lateral* roots, which arise from the base of the plant and, after descending a short way, extend out almost horizontally for twenty inches or more.

3. Next note the *brace* roots, which appear from the nodes of the stalk just above the ground. What is the use of the brace roots? What is the time of their appearance?

II. Stem. What is the form of the stem? Note the *nodes* and *internodes.* What is the nature of the surface of the stem? Study a cross section. How does the outer part differ from the inner? How does this arrangement affect the rigidity of the stalk? Observe the numerous small fibers in the inner part or *pith* of the stem. These fibers are the *fibrovascular bundles.*

III. Leaves. Note the arrangement, the size, and the number of the leaves. Where are the leaves attached to the stem? The lower part of the leaf is the *sheath;* the free upper part is the *blade.* Note the scale-like appendage at the division of the sheath and the blade. Note the *midrib* of the blade. How are the veins arranged with relation to the midrib?

IV. Flowers. (See Waggoner, Fig. 4.)

1. *The Tassel.* Where is the tassel? What are the chaffy structures on its branches? What do these produce?

2. *The Immature Ear.* Remove the husks. Note their arrangement and structure. The corn kernels are formed from the flowers which are borne on the cob. What is the relation of the "silks" to the kernels?

V. Make a drawing of a complete stalk of corn.

(NOTE — Begin preparations for the growth of corn and bean seedlings in order to allow at least 15 days for this before the seedlings are to be used. See Exercise 11.)

EXERCISE 3

THE SIMPLE FLOWER

Use the radish or mustard blossom or that of a single geranium for this study. Use a hand lens freely in this exercise.

I. Where is the flower borne on the plant? Is it borne in a cluster or singly? What are its shape, size, and color?

II. Structure. What differences in the flower and the bud are evident? The stem of the flower, the *peduncle*, may have an enlarged end, the *receptacle*, to which the circles of parts are attached. (In some cases one or more green structures, somewhat leaf-like in form, may be attached to the peduncle near the flowers. These are *bracts*.)

1. The outside circle of parts situated upon the receptacle is the *calyx*. Each of these parts is a *sepal*. Note the number, shape, and color of the sepals. What is the function of the calyx?

2. Next to the calyx is a circle of parts known as the *corolla*. Each of its parts is a *petal*. Note the number, shape, and color of each. Compare with the sepals. What is the function of the corolla?

3. The next circle of parts is the circle of *stamens*. Note the number, the structure, and the arrangement of these. Each stamen is made up of the stalk, or *filament*, and of the enlarged tip, or *anther*. Observe the anther closely. What does it contain? This yellow powder is *pollen*. What is its use?

4. The central structure of the flower is the *pistil*. What is its shape? Its position? The enlarged base is the *ovary*, the tip is the *stigma*, and the connecting part is the *style*. Do you find a substance adhering to the stigma? What is it? What is *pollination?* Cut off the ovary. Does it contain more than one cavity? Crush the ovary. What is the nature of its contents? The tiny objects are *ovules*. What is their relation to seed development? What is the function of the stigma? The style? The ovary?

III. Why is a flower an important structure? Which of the parts observed are the essential parts of the flower? Draw a flower, showing the parts.

EXERCISE 4 (Supplementary)

TYPES OF SIMPLE FLOWERS

Use simple flowers, such as the snapdragon, petunia, morning-glory, sweet pea, and phlox. At least six different flowers should be used in this exercise.

I. Note whether the flowers are borne singly or in clusters. If borne in a cluster, what are the characteristics of the cluster?

II. Compare the floral parts of each flower with those of the simple flower which was first studied. Note any peculiar adaptation of parts or any specialization of structures which may be present. Determine if possible what relation, if any, each specialized structure bears to pollination.

EXERCISE 5 (Supplementary)

A COMPOSITE FLOWER

Use a sunflower, a cosmos, or some similar type of composite flower.

I. Compare this " flower " with the simple flowers previously studied, in regard to its size, its position on the plant, etc. Note the parts which appear to resemble the floral parts of a simple flower. Remove some of the petal-like structures and some of the parts nearer the center. Examine the base of each. Note, on an older specimen, into what these parts may develop. What is each of these parts? What then is the entire " flower " of this plant?

II. The inner parts are *disk florets*. The outer are *ray florets*. Study each, determining what floral parts are present. The sepal-like structures outside the florets are the *bracts*. The circle of the bracts is the *involucre*. What is the function of the involucre?

III. Which disk florets blossom first? Where do the stamens first mature? When do the pistils mature? Explain the significance of these differences relative to pollination.

EXERCISE 6

POLLINATION, PART I

This exercise may not only serve the purpose for which it is intended, but also be the means, incidentally, of making a collection of insects for the insect study which occurs later in the year. (See Exercises 67 to 72.) The insect specimens which are so collected may be preserved in formalin. (See Appendix.)

I. Field Study. The class may be divided into small groups, and each of these should be supplied with small bottles or cans and, if possible, with an insect net. Each group may visit a number of different flowering plants and one member of each group may act as its reporter. Collect any insects (six-legged animals) which are on or in the neighborhood of these plants. Make a careful note of the kind of place in which each was found. Bring to the laboratory the insects which you collect and specimens of the plants in the vicinity of which each insect was found. (To kill the insects, put them in a covered jar containing some cotton saturated with gasoline or chloroform.)

II. Laboratory Study.

1. *Insects.* Note the number of the main body divisions of the insects collected, the number of wings, and the number of legs. Look at the mouth parts of a bee, a butterfly, a fly, and a grasshopper. What is the character of each? Why do insects visit flowers?

2. *Flowers.* Note those which were collected. Is pollen present? Examine some grains of pollen which have been mounted under a microscope. What characteristics of the pollen make it possible for these grains to be distributed by insects? Draw several grains of pollen. Indicate from which plant each is obtained.

(NOTE — Collect and preserve several dozen locusts (grasshoppers) for use in Exercise 67).

EXERCISE 7

POLLINATION, PART II

I. Field Study. Work in small groups, each group choosing one of the following problems for study.

1. *Problem 1.* Observe and record the number, time, and length of visits of any bees to a single flower or to a cluster of flowers.

2. *Problem 2.* Follow a bee in its visits from flower to flower. Record the time and the length of each visit which it makes.

II. Conference. Each group may report its observations. Each member of the class may record the results in tabulated form, as follows:

PROBLEM 1

GROUP	VISITS OF BEES		
	Number	*Time*	*Length*
1 2 3			
TOTAL			
AVERAGE.....			

PROBLEM 2

GROUP	VISITS OF BEES		
	Number of flowers	*Time*	*Length*
1 2 3			
TOTAL			
AVERAGE...			

Each one may also make a copy of the tabulations of the group to which he belonged.

III. From your observations and from the results of the observations of the class as a whole, what do you conclude to be the relation of insects, especially that of bees, to the pollination of flowers?

EXERCISE 8

FRUITS

I. Bean. Note the shape, the color, the markings, and the texture of a green bean pod. From what part of the plant has this pod developed? What floral parts are represented in the specimen? (Have a flower for comparison, if possible.) Where are the calyx and corolla? Cut away one side of the pod so as to expose the seeds. Is the ovary simple or compound? Where are the seeds attached? What is the " string " of the bean pod? How does the food get to the seed from the parent plant? Break off a bean and note the scar. This is called the *hilum*. What causes its presence? As the bean ripens, what becomes of the food in the pod? Name several plants which bear the same type of fruit which we find in the bean. Draw an external and an internal view of the pod. Label all the parts.

II. Apple. What floral structures are represented in the apple? Cut the apple midway between the blossom and stem ends. Note the position of the seeds and the markings and nature of the core and pulp. What is the arrangement of the seeds? Is this ovary simple or compound? Of what use may the pulp be to the wild apple? Draw the interior view. Label the parts.

III. Cocklebur. From what part of the flower did the outer prickly covering develop? Open the bur. Determine what other floral parts are represented. Is the ovary compound or simple? How many seeds do you find? (See Waggoner, Fig. 23.)

IV. Study a number of other fruits such as the tomato, the peach, the pumpkin, the wheat kernel, the cranberry, the lemon or

orange, and the capsule of the morning-glory. In each determine what floral parts are represented.

V. What is a fruit? Pulpy fruits often remain hard and inedible until ripe. Why is this of advantage to the plant? Name several fruits that have not been mentioned in this exercise.

EXERCISE 9

SEED DISPERSAL

This exercise may be assigned as individual work or may be used as the basis for a field trip of the entire class.

I. Collect seeds which are disseminated by wind, by animals, and, if possible, by water and by mechanical means.

II. List these in tabulated form, indicating the characteristics of each seed and the means of the dispersal of each.

Name of seed	Adaptations for dispersal	Agent of dispersal

III. Make a chart on which specimens illustrative of each type of dissemination are mounted and labeled. (The chart may be made as individual or class work.)

IV. Remove the seeds of a single ragweed, pigweed, or some other weed which bears an abundance of seed. (If the ragweed is used, save the seeds for Exercise 61.) Count or estimate approximately the total number of seeds which have been borne by the plant. (If the seeds are very numerous, a small quantity may be measured or weighed and the seeds which compose it may be counted. Following this, the entire quantity may be measured or weighed. The total number of seeds may then be determined with considerable accuracy by multiplying the number of seeds in the small quantity

by the number of times that this quantity is contained in the total quantity.) What does the number of seeds borne by a single plant indicate with regard to the necessity of seed dispersal?

(NOTE — Put corn and bean seeds to soak 24 hours preceding their use in Exercise 10. Make a collection of algæ for Exercise 34.)

EXERCISE 10

THE SEEDS OF THE CORN AND BEAN

Provide a sufficient supply of corn kernels and bean seeds so that each pupil may have at least two specimens of each. Soak half of the supply of each for one or two days previous to using.

I. Structure of the Bean Seed.

1. *The Dry Seed.* Note the size, the shape, and the color. Make a comparison of the length, the breadth, and the thickness of the seed. What is the nature of its covering? Note the position of the scar or *hilum.* What is its cause? Note the hole at the end of the hilum, the *micropyle.* What is the function of the micropyle?

2. *The Soaked Seed.* Compare with the dry bean in size, in smoothness, and in the texture of its covering. Remove the coat. From what part of the ovule did it develop? Note the structure just within the micropyle. This is the *hypocotyl.* Its extreme tip is the *radicle.* The two halves are the *cotyledons.* Examine the cotyledons. Were both attached to the hypocotyl? Examine the one which you find attached. Note the tiny structure which lies between the cotyledons at the end of the hypocotyl. This is the *plumule.* (Use a lens.) Into what does the plumule develop? Note the relation of its parts to one another.

3. The entire structure within the coats of the bean constitutes the *embryo,* or young plant. Make a drawing of the bean as it appears when opened. Show all its parts.

II. Structure of Corn Kernel.

1. *Dry Kernel.* Note the shape, the color, and the markings. Compare the ends of the kernel. What is the cause of the " dent "? Note the oval area on one side.

2. *Soaked Kernel.* Compare the soaked kernel with the dry kernel in size and in general appearance. Note the change in the "dent." Explain. Cut the kernel lengthwise and, using a lens, note the spongy, shield-shaped portion within. This is the *scutellum* or *cotyledon.* On the cut surface of the spongy portion two tiny points appear — the *plumule,* pointing toward the "dent" end, and the *radicle,* pointing toward the sharp end. Note the *sheaths* which cover each point. The scutellum, the plumule, the radicle, and the sheaths constitute the *embryo.* The structure which almost surrounds the embryo is the *endosperm.* Note the origin of the horny and the starchy portions of the endosperm. What is the origin of the endosperm? Of what use is it to the growing plant? Make drawings of longitudinal and cross sections.

III. What is a seed?

EXERCISE 11

CORN AND BEAN SEEDLINGS

Begin preparations for this exercise 15 days before the seedlings are to be used. Make five plantings of corn and five of beans, allowing three days to elapse between each planting. Use seeds of the same variety as those which were used in the previous exercise. Provide boxes of sand for this purpose. So place these boxes that sufficient heat and moisture may be supplied and frequent observations may be possible. Appoint individuals or committees to assist in or to assume full responsibility for one or more plantings and the care of each. When ready for the final exercise, remove the seedlings from the sand and prepare exhibits of the various stages of growth. This may be done by placing one specimen from each stage upon a large card in the order of development.

I. Development of Bean Seedling. You will make five drawings. Place the first four on one page and allow a full page for No. 5. Label drawings, showing from what seed structure each part is developed. Study the questions below before making the drawings.

1. *Stage 1.* Note the break in the coat. What has caused this? (Stage 1 should show the radicle from $\frac{1}{2}$ to $\frac{3}{4}$ inches in length.)

2. *Stage 2.* How has the radicle changed? What new structures are present?

3. *Stage 3.* Explain the use of the arch of the hypocotyl.

4. *Stage 4.* Describe the changes which have occurred in this specimen since it was planted.

5. *Stage 5.* Note that sand adheres to the roots above the tips. (This is due to the presence of root hairs. Exercise 18.) What is the cause of the shrinkage of the cotyledons?

II. Development of Corn Seedling. Arrange and make your drawings as in Part I of this exercise.

1. *Stage 1.* What is the first structure to emerge? Examine the interior and note any changes. (Stage 1 should show the radicle one half to one inch long.)

2. *Stage 2.* (In the drawing the plumule should point toward the top of the page.) Examine the sheath of the plumule. Open it and note its contents.

3. *Stage 3.* Note the beginnings of the root system. Examine the endosperm.

4. *Stage 4.* Do the parts above the ground develop as rapidly as the roots?

5. *Stage 5.* Note the change in the endosperm. What is the cause of this? How will the young plant get a new supply of food?

III. What is germination? When does the germination of a seed begin?

(NOTE — Put peas to soak. See Exercises 12 and 16.)

EXERCISE 12

CONDITIONS FAVORING THE GERMINATION OF SEEDS

Plan a number of simple experiments by means of which it may be determined what conditions of moisture, temperature, and air are favorable to the germination of seeds. The following exercises

are suggestive but they may be modified or others substituted for them if expedient.

I. Temperature. In three separate boxes of moist sand plant seeds of the same kind. Place one box in a cool place (50° F.), one in a very warm place (120° F.), and the third in a moderately warm place (70° or 80° F.). Be sure that the preparation of the boxes and the care given them are the same in all particulars. (To provide equal moisture in the sand more water will be required for the boxes in the warm place than for those in the cool.) Observe from day to day. In which case are the best results obtained so far as the proportion of seeds germinating and the rapidity of germination are concerned?

II. Moisture. Plant seeds of the same kind in each of three dishes of sand. Be sure that all the conditions are the same, except that in one case no water shall be added; in another, the sand shall be sufficiently wet for water to be evident above the surface; and in the third, the sand shall be only moderately moist. Observe the results as in Part 1.

III. Air. Fill two small glass bottles with soaked peas. Cover one bottle in such a way that there can be no exchange of the air inside with that outside. Leave the other uncovered. Observe the results. Explain.

EXERCISE 13

TESTS FOR NUTRIENTS

I. Test for Starch. Place the same amount of water in each of two test tubes. To one add a little thin starch paste, and to each, a few drops of iodine solution. Note the result. The tubes are alike except in one particular. What is it? To what must the difference in results be attributed? What, then, is a test for starch as shown by this experiment?

II. Test for Glucose. Add the same amount of water to each of two test tubes. To one add glucose. Now add Fehling's solu-

tion to each and boil. In what way do the contents of the two tubes differ? What causes the difference in results? What, then, is a test for the presence of glucose? (Some other sugars also reduce Fehling's solution but glucose is the one most commonly found in connection with plant and animal life.)

III. Test for Cane Sugar. Prepare two test tubes with a solution of cane sugar and water. Add some Fehling's solution to one. Boil. What is the result? Is this a test for cane sugar? Explain. Add a drop of dilute hydrochloric acid to the other test tube which contains sugar solution. Boil. Then, while its contents are still hot, add to the test tube some Fehling's solution. What is the result? What change did the acid cause with regard to the cane sugar? What is a test for cane sugar?

IV. Test for Oil. Place a drop of oil on paper. Warm the paper. What is the result? What then is a test for oil? (Oil may also be extracted with ether and obtained in a practically pure state. This is another test for oil.)

V. Test for Protein. Add some of the white of egg (a protein substance) to a test tube of water. Boil. What is the result? Add some strong nitric acid to a similar preparation of egg albumin. Warm this. What is the result? Pour off the acid which is in this tube. Rinse with water to remove the nitric acid. Then add some ammonia. What is the result? What are two tests for protein?

EXERCISE 14

NUTRIENTS STORED IN A SEED

I. The Corn Kernel.

1. Cut a soaked corn kernel through the center so that the embryo is exposed. Place the cut surface in iodine. Locate the starchy portion. How are you able to do this? Locate the yellowish portion. This is richer in protein. Is all of the protein in the embryo? Why can you not see the protein which is present in the endosperm?

2. The instructor has scraped off and mounted some of the endosperm under the microscope. Examine it under both low and high power. What is the shape of the grains which you see? Are there markings on these grains? When a drop of iodine is placed at the edge of the cover glass, note the result. What, then, are these grains? Is any yellowish substance present? What is it?

II. The Bean. Study some of the material which is scraped from the cotyledon of the bean seed and mounted under the microscope. Is much protein present here? When starch is as abundant as it is in the bean, why should the bean be looked upon as one of the protein foods?

III. The Potato. Study a very thin slice of an Irish potato mounted under the microscope. Note the markings on the starch grains of the potato. Note that these grains are borne within cell walls. (See Waggoner, Page 35.)

IV. How could you, under any circumstances, distinguish the starch which comes from corn, beans, or the Irish potato? In what parts of a plant may food be stored? What are the uses of the food which is so stored?

V. Make drawings of the different types of starch grains which you have seen.

VI. Arrange an exhibit of plants which illustrate various types of food storage. Attach to each a label bearing the name of the plant. Each member of the class may then determine in what way food is stored in each plant and may list in a tabulated form as follows:

Name of plant	Storage of Food			
	In Stem	*In Root*	*In Leaves*	*Fruits*

EXERCISE 15

THE ACTION OF ENZYMES — PTYALIN UPON STARCH

What is an enzyme? (See Waggoner, Page 67.)

I. Label three test tubes *A*, *B*, and *C*. Place in each of them 5 cc. of water. Add 1 cc. of a well boiled starch paste to each. (See Appendix for directions for the paste.) Heat test tube *A* to the boiling point. As quickly as possible, add about 1 cc. of saliva to this tube and to test tube *B*. Keep the test tubes *B* and *C* for a few minutes at about blood heat. This may be done by warming them over a flame and holding them in the palm of the hand. Divide the contents of test tube *A* into two equal portions. Do the same with the test tubes *B* and *C*.

II. Test one of the portions from test tube *C* for starch. Observe and explain the results. Test the other portion of tube *C* for a simple sugar. (The test for glucose is the test for simple or reducing sugars.) What results do you observe? Explain.

III. Test one portion of test tube *B* for starch and, with Fehling's solution, test the other for sugar. Note the results. What apparently has become of the starch? Why was this tube kept warm? Explain what has happened.

IV. What is the enzyme in saliva? What is its effect upon starch? What happens to the flavor of an unsweetened cracker or a bite of bread when chewed slowly? How does the action of the enzyme upon starch help to explain the way in which the starch stored in grain becomes available for use in the growth of the plant during germination? Think of other cases in which such action occurs in plants.

V. Test one of the portions of paste from test tube *A* for starch. Test the other for sugar with Fehling's solution. What do the results show as to the effect of boiling upon ptyalin? Determine the effect of heat in general upon enzymes. (See Waggoner, Page 69.)

EXERCISE 16

RESPIRATION

Place a half cup of soaked peas in a wide-mouthed eight ounce bottle. In another, place the same amount of dry peas. Cork both bottles tightly. Then allow them to stand in the room for forty-eight hours. At the end of this period test the air in each bottle for *carbon dioxide.* What is the result? Test for oxygen. (See Appendix.) What is the result? What is the origin of the carbon dioxide which you find in one bottle? What became of the oxygen in the same bottle? What change has been taking place in the peas in this bottle? For what purpose is oxygen needed in this process. What is respiration? (See Waggoner, Page 69.) Of what use is it to a plant?

(NOTE—Prepare seeds for growth of root hairs. See Exercise 18.)

EXERCISE 17

ROOTS

The collection of the roots to be used in this exercise may be made by individuals or by the class as a whole.

I. Field Study. Collect roots of the following types:

1. *Soil roots.* *a. Fibrous,* the grasses. *b. Storage,* the sweet potato or dahlia. *c. Woody,* shrubs and trees. *d. Tap,* the ragweed, carrot, parsnip, etc.
2. *Air roots.* The trumpet vine (*Tecoma radicans*).
3. *Water roots.* The duck weed, or other common floating water plants.

II. Laboratory Study. Arrange an exhibit of the roots which are collected. Attach a label bearing the name to each. List and state briefly the characteristics of each. This may be done in a tabulated form as follows.

Name of Plant	Roots			Length of Life
	Where formed	*Kind*	*Characteristics*	
(*Example*) Carrot	Soil	Tap	Fleshy with few fine, fibrous branch roots.	Biennial

III. Do you find nodes and internodes in any of the roots? What are the functions of roots?

EXERCISE 18

ROOT HAIRS

Prepare the material for this exercise three or four days previous to the time when it is to be used. In Petri dishes place well moistened filter paper. Upon this paper place a number of radish, lettuce, and oat seeds. Cover and keep in a warm room under a bell jar. (This is to prevent drying.) The specimens can be used for the preliminary study without opening the Petri dishes.

I. Examine the roots which have appeared from the seeds kept in the moist air of the Petri dish. What is the color of the roots? What other characteristics do you observe? From what part of the seeds do the roots appear? Study one of the roots which has been mounted under low power. Note the *root cap*. What is its nature? Can you see cells in the root? Note the downy growth which nearly covers these roots. This growth is made up of *root hairs*. What do you observe with regard to the number of the root hairs? Their size? Where are the root hairs located with reference to the root-tip? What is their relation to the surface cells? Cómpare in nature and in length the root hairs which are nearest the tip with those which are farther away. By examining the condition of the root hairs farthest from the root-tip, determine what finally becomes of the root hairs. Where in the root does

growth take place? Locate the "*zone of root hairs*" with reference to the tip. (See Waggoner, Figs. 43, 45, and 46.) Why is it of great advantage to the plant that the root should grow at this point rather than farther back from the tip? Why does soil adhere to young roots?

Make a drawing of one of the roots. Show the "zone of root hairs."

II. Soil water is taken into the plant through the root hairs. (The process of osmosis by which this transfer takes place will be discussed later. See Exercise 23.) The walls of the root hairs are thin. What is the advantage of this fact? Why does a plant wilt when it is transplanted? Why do we usually take up soil with a plant which is to be transplanted? During plant growth, how does the position of the "zone of root hairs" change in relation to the layers of soil? Of what advantage to the plant is this change?

EXERCISE 19

TRANSPLANTING SHRUBS AND TREES

With your observations of root hairs in the laboratory and your study of the text (see Waggoner, Page 87) as a basis, make plans for transplanting some wild shrubs or trees from a neighboring woodland to your school grounds. Then, if possible, put your plans into operation. Note carefully the soil and drainage conditions of the school grounds and select only those plants which grow naturally under similar conditions. Why are these precautions taken? In selecting the location for planting, take into consideration the size which the plant may later attain, the purpose which it is to serve in the school grounds — shade, decorative effect, shelter and food for birds, etc. — and any previous planting which has been made.

Write to the American Tree Association, 1214 Sixteenth Street N. W., Washington, D. C., sending two cents return postage, and receive information regarding the planting of trees and their registration with the Association.

EXERCISE 20

CELL STRUCTURE

I. Plant cells. Examine a bit of banana pulp which has been mounted under the microscope. Note the tiny oval structures. These are cells. Can you distinguish them with the naked eye? Why? Of what is the flesh of the banana composed? Stain the cells by adding a drop of iodine. What is the effect? What does this indicate with regard to these grains? Do you find a cell wall? A nucleus? Make drawings of several cells showing the parts which are visible to you.

II. Animal Cells. Examine some cells from the inside of the cheek which have been mounted under the microscope. (These may be obtained by gently scraping the cheek lining with the finger nail.) What is the color of these? Is there a definite cell wall present? Do you find any starch grains? How do these cells differ from those of the banana? What is the transparent granular substance of which the cell is composed? Note whether there is a tiny, apparently more solid, portion near the center of each cell. If so you are seeing the *nucleus*. The protoplasm outside the nucleus is the *cytoplasm*. Draw several of the cheek cells. Show the parts which were observed in each. (See Waggoner, Fig. 51.)

III. What marked characteristic of plant cells is not found in animal cells? What is a cell?

EXERCISE 21

CELL DIVISION — MITOSIS

For this exercise use models, or lantern or microscopic slides. Refer to the diagram (Waggoner, Fig. 52).

I. The Resting Stage. Locate the following structures: the *cell wall* (or membrane), the *cytoplasm*, the *nucleus*. In the nucleus, locate the *chromatin* particles. (In the models, you may

also note the *centrosomes* in the cytoplasm near the nucleus. In higher plants centrosomes do not appear.)

II. Mitosis. Cells multiply by a process known as cell division or *mitosis*. Study the models or slides provided for the purpose of illustrating the various stages of this process.

1. What is the first change in the nucleus? What happens soon to the ribbon-like chromatin strand? The segments of this strand are called *chromosomes*.

2. Where do chromosomes tend to arrange themselves? What happens at the same time to the membrane surrounding the nucleus?

3. When the chromosomes have become arranged in the center of the cell, observe the divisions in each. What structure appears at either side of the chromosomes? Describe this *spindle*. What successive changes occur in the location of the chromosomes?

4. What becomes of the chromosomes when they have reached the poles, the points from which the spindle fibers radiate? What change is taking place during this process in the cell wall (or membrane)?

5. How many chromosomes will each daughter cell have as compared with the number in the original cell? Why? Of what importance is this fact?

(NOTE — Place cuttings of geraniums or some other house plant in water. See Exercise 28.)

EXERCISE 22

DIFFUSION

Fill a tall, narrow glass jar with clear water. Into this drop a few large solid crystals of potassium permanganate. Allow this jar to remain undisturbed in a quiet place of uniform temperature for two or three days. Observe frequently. Note the distribution of the permanganate as indicated by the density of color. Where is the permanganate most abundant? Where is it least so? In what direction has it been possible for the molecules of the dis-

solved substance to move most easily? Why will these molecules tend to become uniformly distributed after a time? (See Waggoner, Fig. 53.) To some extent the distribution of the potassium permanganate has been due to *diffusion*, but it is probable that other influences also have affected it. What have these been? Define diffusion.

EXERCISE 23

OSMOSIS

For this experiment, a small tube similar to a thistle tube can be made easily by heating a test tube in the center by means of a Bunsen flame. When the glass is soft, the central portion of the tube may be drawn out to the desired size. The larger end of the small thistle tube thus produced may then be covered with the membrane from the inside of an eggshell. This apparatus serves well to illustrate osmosis. If an ordinary thistle tube is used, it is more practicable to use as a membrane the wall of the bladder or the outer wall of the intestine of a freshly killed beef or hog. The covering of fresh sausages, thoroughly cleaned, is also satisfactory. Animal parchment paper, such as is used in the chemical laboratory, will serve the same purpose. (Diffusion shells, used in dialysis, may be employed if available.)

I. With a rubber band fasten the membrane tightly over the thistle tube. Place in the thistle tube a solution which has been made by dissolving some glucose in water. Lower this thistle tube into a beaker of pure water. (Arrange the whole as in the diagram, see Waggoner, Fig. 54.) Mark on the tube the level of the solution which is within. Note at intervals any changes which may occur in the level of this solution. After two hours, test the water which is in the beaker for glucose. What is the result?

II. What causes the change in the level of the solution in the tube? What does diffusion have to do with the change in the composition of the water in the beaker? What factor enters into the process in this experiment that was not present in the experiment on diffusion? How do root hairs take in soil water?

III. The membranes of plant cells are *semipermeable.* (See Waggoner, Page 104.) They prevent the concentrated contents from passing outward and thus are largely responsible for the condition known as *turgor.* (See Waggoner, Page 104.) Wash a slice of fresh red beet in cold water. What is the color of the water following this process? Has the beet lost any of its firmness? Place the beet in water and heat it. What do you now observe with regard to the color of the water? Does the character of the beet change? If so, how? What has been the effect of the heat upon the character of the protoplasmic membrane within the cell walls?

EXERCISE 24

SOILS

I. Field Study. Provide yourselves with a trowel and a few dishes or large-mouthed bottles.

1. Visit some small stream which flows down a gradually decreasing slope into a pool. Observe the arrangement of the soil particles which have been deposited after being carried by the water of the stream. As the current slackens, which particles, with relation to size, have been dropped first? Which last? Why? Do you find any sediment still clouding the water of the pool? That is, is it still " muddy "? Take this water to the laboratory for further study.

2. Examine some blue grass sod. What is the relation of the roots to the soil? What causes the formation of " sod "? What does the decay of the dead grass roots have to do with the addition of organic matter to the soil? By what other means may organic matter be added to the surface soil? Take a sample of soil containing organic matter.

II. Laboratory Study. Study each sample of soil which the instructor has mounted under the low power of a microscope. Make a drawing of particles of each sample. From your observations, discuss the composition of soil.

EXERCISE 25

BUDS AND BRANCHES

This work may be done either in the field or in the laboratory.

I. Apple Branch.

1. Examine the leafless branch of an apple tree. (A similar branch of a hickory or a tulip tree may be substituted if desired.) Locate the largest buds. Note the other buds. Locate the leaf scars. Note the size and shape of each. What is the general arrangement of the leaf scars on the branch? What is the position of the buds with reference to the leaf scars? Into what does a bud develop? A bud is formed in the axil of practically every leaf. Why do many of the twigs of a tree die?

2. *Terminal Bud.* Remove from the terminal bud those scales which protect the undeveloped branch within. Note the scale scars which remain. Look along the branches for old scars of a similar nature. When were these scars formed? What do they indicate regarding the age of the specimen which you are studying? What is the effect upon the lateral buds if the terminal bud is removed? In the field, find branches upon which the terminal buds have been destroyed. What effect does topping usually have upon the shape of a tree?

3. *Structure of Stem.* What is the nature of the surface, the color, and the texture of the bark? Separate the bark from the wood beneath. The layer which lies between the two is the growth layer or *cambium.*

II. Lilac Twig. Note the character, the size, and the arrangement of the buds of the lilac. Examine a bud to determine the arrangement of the bud scales. Compare the bud with that of the apple. Cut lengthwise through the center of the lilac bud. Determine what undeveloped parts of the next year's stem are present. (See Waggoner, Page 121.)

III. What is a bud? Where are buds formed? When are they formed?

EXERCISE 26

THE INTERNAL STRUCTURE OF A STEM

I. Sunflower or Pumpkin Stem. (Dicotyledonous Stems)

1. Note on a portion of the stem the regular succession of *nodes* and *internodes.*

2. Cut thin cross sections through the internodes. Using a lens when necessary, examine carefully. If present, study the *pith* in the central region. Note its character. Find the circle of rather oval or wedge-shaped structures which are situated about the central region. These are the *fibrovascular bundles.* (The narrow regions of tissue between these bundles give rise in perennial plants to the primary *medullary* rays. See Waggoner, Page 124.) Outside of the circle of the fibrovascular bundles are the tissues which, taken together, make up the cortex. The outer skin-like layer is the epidermis.

3. *Fibrovascular Bundle.* Examine a fibrovascular bundle under the lens. The inner part is the *xylem;* the outer, the *phloëm.* Between the two is the region of the *cambium.* Remove from a longitudinal section one of the fibrovascular bundles. Examine it. Test its strength.

4. Draw a cross section of the stem which was studied.

II. Indian Corn. (Monocotyledonous Stem)

1. Examine a thin transverse section. How do the fibrovascular bundles differ in position from those of the sun-flower or pumpkin?

2. Remove the epidermis and cortex of an Indian corn stem. Remove one of the fibrovascular bundles from the pith. Test its strength. What is the nature of the pith?

III. What are the uses of the fibrovascular bundles? Of the bark? Why does a *girdled* tree die? What purposes do stems serve?

EXERCISE 27

A BLOCK OF OAK WOOD

Obtain blocks of wood — oak, if possible — and cut so as to show cross, longitudinal, radial, and tangential sections. (See Waggoner, Fig. 67.)

I. Examine a block. What was the position of the block in the log? Determine where the center of the log must have been with relation to this block. From a study of the figure in the text (see Waggoner, Page 129) determine what is meant by a *cross* or *transverse*, a *longitudinal*, a *radial*, and a *tangential* section. Locate such sections with reference to the block which you have.

II. Cross or Transverse Section. What are the position and the appearance of the medullary rays? Do all of these reach the center? How many sizes of rays do you find? What is the number of the circles of large pores? Where and when were these formed? When were the circles of compact wood formed? What is an *annual ring?* What is the approximate age of your specimen? Note whether the color of the wood is uniform. What causes the *heartwood* to be darker than the *sapwood?* (See Waggoner, Page 128.) What is the number of the annual rings in the sapwood?

III. Radial Section. What are the appearance and the location of the rays in the radial section? Of the annual rings? Of the heart and sapwoods? Why is the heartwood more durable than sapwood? How is *quarter-sawed* oak cut? (See Waggoner, Page 130.)

IV. Tangential Section. What is the appearance of the rays? Of the annual rings? What are the darker areas on this surface? Select an annual ring that is seen in all three sections and trace out the appearance in each.

V. Make a drawing of the block which you have examined.

EXERCISE 28

VEGETATIVE PROPAGATION OF PLANTS

The members of the class may bring specimens to be used in this exercise. Cuttings of some house plant such as a geranium should have been placed in water about two weeks previously.

I. The Runner. Note one of the slender branches which is sent out from the main plant of the strawberry or common cinquefoil (the " five finger "). Observe the position of the tip of such a runner. Does the runner have nodes? Does it have leaves? What is likely to occur where such a runner touches the ground? The runner is called a *stolon*. Name other plants which may be propagated by some similar method.

II. The Underground Stem.

1. Study the " quack grass " (couch, quitch, or quick grass — *Agropyron repens*). Dig up an entire plant. Where are the roots? Examine the underground stem. How does it differ from the roots? Note its branching and find nodes if nodes are present. What is the function of this underground stem? Why is the plant hard to kill out? Such an underground stem is called a *rootstock* or *rhizome*.

2. Examine the tuber of an Irish potato. What is its shape? Its markings? Its covering? Where was it attached to the parent plant? Where are the " eyes " most numerous? What are the " eyes "? What is the arrangement of the " eyes "? What portion of the plant is represented in the tuber of the Irish potato? What is the function of the tuber? Of what use to the plant is the food which is stored in the tuber? What part of a potato do we plant in order to grow other potatoes? Why can we divide a tuber and grow several " hills " from it? Why is the seed of potatoes almost never used? Draw a tuber.

III. Cuttings of geraniums or other house plants which have been " rooted " may be examined. Note the position of the roots on the stem. Draw.

IV. In the propagation of plants, what are the advantages of the use of vegetative means as compared with the use of seeds?

EXERCISE 29

THE EXTERNAL STRUCTURE OF A LEAF

I. Preliminary Laboratory Study. Examine a simple leaf, identifying the following structures: *stipules* (if present), *petiole*, *blade*, *veins*. Define each. (Refer to the text, if necessary. See Waggoner, Fig. 78.) Note the thickness of the leaf as compared with its length and breadth. Note the color. What is the relation of the petiole to the veins and the branching of the veins? Draw the leaf.

II. Field Study. Examine each of the following (or similar types), observing the position on the branch, the bud in the *axil* (the angle between the stem and the petiole of the leaf), and the form of each leaf: the apple or peach, the rose, walnut, hickory, box elder or ash, and the horse-chestnut. Determine which leaves are simple and which are compound.

III. Laboratory Study. Use for this purpose the leaf of a geranium, live-for-ever, or Wandering Jew. Peel off the under surface layer — the *epidermis* — of the leaf. Examine with a lens. Study when mounted under the low and the high power of the compound microscope. Note the walls of the epidermal cells. Note the oval objects. These are *stomates*. Of how many cells is a stomate composed? These are *guard cells*. What is their position with reference to one another? Note the openings between them. What purpose is served by the stomates? Why is the washing of leaves by rain or artificial means of value to the plant? Is there chlorophyll in the epidermis? In the guard cells? What is the function of chlorophyll? Draw some of this epidermis, showing epidermal cells and stomates.

IV. What is a leaf? Why is it an expanded structure? Why does it need air and sunlight? What would happen to a plant if it were kept stripped of its leaves? Why?

EXERCISE 30

LEAF ARRANGEMENT

I. (Specimens may be studied in the field or may be brought into the laboratory.) Examine the branch of a maple tree. How many leaves do you find at each node? What is their arrangement with reference to each other? Examine the leaves of an apple tree. How does the arrangement differ from that of the maple leaves? (These are the more common forms of arrangement.) Find a plant in which three or more leaves appear at a single node.

II. Observe the leaf arrangement of common shrubs, trees, and herbs. Tabulate as follows:

Name of plant	Arrangement	
	Number of leaves at node	*Opposite, alternate, or whorled*

III. Note the leaf arrangement in each of the plants observed which makes possible the exposure to sunlight of the largest extent of leaf surface. Note especially the "rosette" arrangement of the leaves of the dandelion and the common plantain. Note also some common vines such as the climbing roses, the ivy, the morning glory, and the grape vine.

IV. What is the function of a leaf? Of what advantage are the various arrangements of leaves? Why is it important that leaves be exposed to sunlight?

EXERCISE 31

THE INTERNAL STRUCTURE OF A LEAF

Study prepared cross sections of leaves under a hand lens or the low power of a microscope. (If these are not available, study the diagram in the text. See Waggoner, Page 145.)

I. Note the dark-covered oval areas which are scattered through the section, and determine the relation of these to the fibrovascular bundles of the petioles and veins. Of what are these bundles composed? Next note the upper and lower layers of cells. These constitute the *epidermis*. The outer walls of the epidermal cells are covered with *cuticle*. Below the epidermis note the layers of thin-walled, elongated cells which are closely joined together. This is the *palisade tissue*. Note the *chloroplasts*, the numerous green bodies in these cells. Below the palisade tissue note the region of thin-walled cells and numerous air spaces. This is the *spongy tissue*. In the lower epidermis note the *stomates*.

II. Make a drawing of the cross section, labeling each of the structures shown.

EXERCISE 32

PHOTOSYNTHESIS

I. 1. Place a green water plant (green alga or " water moss ") in a jar or beaker of water. Fill a test tube with water and invert the test tube and a funnel over the plant. (See Waggoner, Fig. 86.) Into what does any gas pass which arises from the plant? Place the apparatus in the sunlight and observe. Note the bubbles which appear. From what do they come? Now shade the plant and observe any changes which occur.

2. Place the plant in the light and leave it for several hours. Then test the gas in the test tube for carbon dioxide and for oxygen. (See Appendix.) Use the lime water test first. Why? Which is present, carbon dioxide or oxygen? What is its origin? Where did the chemical elements come from which were used in the process of photosynthesis?

II. Early in the morning, carefully cover one half of the leaf of a growing plant with tin foil. After allowing the plant to stand in the sunlight for several hours remove the tin foil. Carefully warm over a flame some 95% alcohol, the ordinary commercial form, and place the leaf in the alcohol so that the chlorophyll may be dissolved out of it. Next test the leaf for starch. Do you find starch in both the part which was covered and that which was not? Explain. Under what conditions is starch manufactured? What is photosynthesis? Compare respiration and photosynthesis. (See Waggoner, Fig. 88.)

III. Temporary Storage of Starch in Leaves. In the latter part of the afternoon, dissolve out the chlorophyll of a leaf of a geranium plant with alcohol. Then test the leaf for starch. Repeat in the early morning with another leaf from the same plant. Compare the results. Explain any differences in the amounts of starch found in each case.

EXERCISE 33

TRANSPIRATION

For this experiment use a rather small but vigorous potted geranium. The plant should be one with a single stem.

I. Water the plant well. Cover the pot with heavy paraffined paper or with sheet rubber — the inner tube of an automobile tire may be used — and secure this covering tightly about the geranium stem. Place the pot under a bell jar. (See Waggoner, Figs. 89 and 90.) Observe frequently. What soon appears on the inner surface of the bell jar? What is its origin? What purpose does the paper or rubber covering of the pot serve? The cool bell jar?

II. Weigh the potted plant after the covering is placed over the pot. Repeat at intervals of an hour throughout the day. Record the results. What must be the cause of any change in weight which occurs? What is transpiration?

(Note — Make preparations for Exercise 35 several days before the materials are needed for class use.)

EXERCISE 34

ALGÆ

The algæ for this exercise should be collected before cold weather begins or obtained from some biological supply house.

I. Spirogyra (Green Algæ).

1. In what kind of location does spirogyra grow? What have you observed about its abundance? When in the year is this abundance greatest? What is the appearance of this alga to the naked eye? Its color? To the presence of what substance is this color to be attributed?

2. Study a few strands of spirogyra which have been mounted under the low power and others which have been mounted under the high power of the microscope. Of what is a single filament of spirogyra composed? What is the shape of one of the cells of which the filament is composed? (See Waggoner, Fig. 98.) Where do you find the chlorophyll in the cell? How many bands do you see? Describe their position in the cell.

II. Protococcus. Where is this alga found? Explain why it is more abundant on the north than on the other sides of tree trunks. Study some of the Protococcus which has been mounted under the microscope. What is the color? How many cells seem to be joined together? Make a series of drawings showing different groups of the cells of the Protococcus.

EXERCISE 35

BREAD MOLD — MUCOR

After moistening pieces of bread in water, place them in dishes which have close fitting covers. To be certain that mold spores will be present, shake a duster over the bread before covering. Keep the dishes in a warm room for two or three days.

I. Note the appearance from day to day of the mold which grows upon the moist bread. This mold is probably Mucor or a nearly related type. What is its appearance to the naked eye?

What is the color of the young growth? What is the color of the older parts? What is the cause of this color? Where are the black objects? How does the fluffy white mass change as it becomes old? Note the odor. Why are organic materials which are closed up liable to mold readily?

II. Study some of the mold which has been mounted under the microscope. Each thread is a *hypha*. The whole network of *hyphæ* is the *mycelium*. (Examine with a lens; then examine under low power.) What is the nature of the hyphæ? Are they divided into cells? Are they branched? Compare the hyphæ (rhizoids) which are beneath the surface of the bread with those which are above.

III. Examine the fruiting body under high power. This is a *sporangium*. Compare the color of the old and young *sporangia*. Why are the older ones so dark? Note the abundance and size of the spores which are present. Where are they produced? Examine a spore case. Estimate the number of spores in a sporangium and the number of sporangia on a growth of mold.

IV. Draw a mold plant. Show the hyphæ, rhizoids, and sporangia. Draw a mature sporangium as you see it under high power, and also several separate spores. (See Waggoner, Figs. 103 and 104.)

EXERCISE 36

WOOD-DESTROYING FUNGI

Much of this exercise should be worked out on a field trip by the class. If a class trip is impracticable, the work may be done by individuals. Specimens may be collected on such a trip which can be used for further study in the laboratory. (All the work may be done in the laboratory if the weather prevents field work. In this case, specimens collected earlier in the year can be used.)

I. Field Study.

1. Observe various trees upon which the shelf-like fungous growths appear. Where upon the trees are these growths located?

What part of the fungi are the shelf-like structures? Do you find any mycelium? Where? What is the nature of the wood where it is present?

2. Note the shape, the size, the structure, and the attachment of the fruiting body. Where are the spores produced? Do you find spores? What is their nature? Their abundance? How are they scattered? How do the spores find entrance into trees? What becomes of most of the spores? What is the value to the fungus of the abundance of these spores?

3. If possible, observe trees which show treatment for wounds. Why should wounds in valuable trees be protected? How may this be done? How are wounds healed? Note several which have healed. What is the danger of leaving a stub of a branch on a tree? When removing branches, what precautions should be observed? (See Waggoner, Page 179.) What is meant by " heart rot "? What does a fruiting body upon an apparently healthy tree indicate?

II. Laboratory Study. With a lens study some of the wood in which the mycelium is present. Note the character of the mycelium. Also study a tiny portion of a fruiting body which has been mounted under the low power of a microscope. Make drawings showing what you see.

EXERCISE 37

WHEAT RUST

Specimens of the various stages of wheat rust (black stem rust) should be collected in summer. (These may be found in late summer upon volunteer oats, wheat stubble, or rye straw or obtained from a biological supply company.)

I. The Red Rust Stage. Study wheat plants showing the *red rust* stage. What part of the plant is affected? Examine the red structures with a lens. What causes the red color? What is the age of the wheat plants upon which this stage occurs? (See Waggoner, Figs. 113 and 114.) Make drawings as directed by the instructor.

II. The Black Rust Stage. Study wheat plants showing the *black rust* stage. What part of the plant is affected by this stage? With a lens determine what causes the color of the black areas. Compare the age of the wheat plant affected by black rust with that of the wheat affected by red rust. (See Waggoner, Figs. 113 and 114.) Make drawings as directed by the instructor.

III. The Cluster Cup Stage on the Barberry. Study leaves of the common barberry which are affected by the cluster cup stage. What is the appearance of the spots upon these leaves? On which side of a leaf do you find these spots? Study under a lens. What is the relation of this stage to the other stages? Why is the complete eradication of the common barberry advised by the United States Department of Agriculture? (See Waggoner, Fig. 115.) Make drawings as directed by the instructor.

IV. The Distinction between the Common and the Japanese Barberry. Compare specimens of the common barberry with the Japanese barberry as to size and form of leaves, character of thorns, and arrangement of fruits. (See *The Black Stem Rust and the Barberry,* E. C. Stakman, Pub. of U. S. Dept. of Agriculture, No. 796, Page 18, or the *Yearbook of the U. S. Dept. of Agriculture,* 1918, Page 77 ff.) Draw specimens of each. The common barberry is the one which acts as a host to wheat rust. The Japanese barberry is a useful shrub which has no relation to this disease of wheat and which should never be confused with the common barberry. (See Waggoner, Fig. 116.)

V. Find out if possible what has been done in your state towards the eradication of the common barberry. Inquire of your county agricultural advisor or of others interested in the growing of wheat and oats.

VI. Design a poster which may be effective in calling attention to the need of the eradication of the common barberry.

(Note — Prepare the yeast mixture for Exercise 40 the day preceding that on which it is to be used.)

EXERCISE 38 (Supplementary)

OAT SMUT

Use specimens collected during the summer. (Obtain these when the oats are heading.)

I. Examine oat plants which are affected by oat smut. Where is the smut found? When does it appear? What part of the plant is affected by it? In what way does it injure the plant? How is oat smut spread? Why is the prevention of a recurrence of this smut a comparatively simple matter? (See Waggoner, Page 189 and Fig. 117.)

II. Study some of the spores which have been mounted under the microscope. Note their size, color, and shape. Draw several spores. Draw a spikelet of the infected oats.

EXERCISE 39 (Supplementary)

POTATO SCAB

The pupils may bring specimens which show this disease.

I. Examine a potato tuber which is affected by the *scab*. What injury does this scab do to the potato? Cut sections through the potato. How deep are the diseased spots? Is the interior affected? Is there any evidence that other organisms may have had a part in the resulting injuries? Do you find spores? How is the disease transmitted and how can this transmission be prevented? (See Waggoner, Page 191.)

II. Draw an exterior view of a *scabby* potato and also a section of a potato showing the nature of the scab injury in the interior.

EXERCISE 40

YEAST — STRUCTURE AND REPRODUCTION

I. Place a cake of dry yeast in water and allow to stand over night. Study the resulting mixture. Note the odor and appear-

ance. What causes the murky appearance? What else is present in the yeast cake and hence in this mixture? What is the use of this starch?

II. Structure. Study a drop of the mixture which has been mounted under high power. Note the size, shape, and color of the yeast plants. Observe their structure. (See Waggoner, Fig. 122.) Is protoplasm present? What is its nature? Note the large semi-transparent object within the cell. This is a *vacuole.* Make a drawing of a yeast plant showing its structures.

III. Reproduction. What is the explanation of the several types of cell clusters? What becomes of the small *"buds"?* (Discussion by instructor or reference to text, Page 194.) What other form of reproduction may occur in yeasts? (Discussion.) Show by a series of drawings the manner in which yeast multiplies by budding.

EXERCISE 41

YEAST — FERMENTATION

Use the yeast mixture which was prepared for the preceding exercise or a similar one.

Number five fermentation or test tubes. In each, place 5 cc. of this mixture. To No. 1, add nothing; to No. 2, glucose; to No. 3, cane sugar; to No. 4, starch; and to No. 5, glucose. Boil No. 5. Fill each with water and allow to stand in a warm room. At the end of several hours observe the results. Note the amount of gas in No. 2. The amount of gas present indicates the amount of growth of the yeast plants. This gas may be tested for the presence of O and CO_2. What is the gas? What is its source? Smell the contents. What else besides CO_2 is present? What has caused these changes in the contents of this tube? The process is known as *alcoholic fermentation.* Compare the amount of fermentation in the other tubes with that found in No. 2. (Compare with Waggoner, Fig. 125.) What substances ferment? What is the effect of heat upon fermentation? Explain. What bearing does

this fact have upon the canning of fruit? What relation does the yeast plant have to bread raising? Why does cider become "hard"?

EXERCISE 42

"COLDS" *VERSUS* GOOD HEALTH

The outline suggested below may be used as the basis of a study of some of the health conditions during the winter months. It will probably require observations covering a period of from six to eight weeks.

I. Problems.

1. Determine how many members of your class have had no "colds" or other troubles of the respiratory tract since the opening of school. Of those who have been so affected, how many have lost time from school? The U. S. Public Health Service, in investigating the occurrence of colds, discovered that during a period of six months only ten per cent of a large group of people had no colds and that the average annual rate was three and seven-tenths colds per year. Suppose you keep a record of such conditions in your class. To do this, you may keep a daily chart for a period of six weeks. Plan such a chart.

The following is suggestive:

Date	Duration of "colds" or other diseases of the respiratory tract		Causes	Treatments used
	Confinement to home (days)	*Remaining period of affection (days)*		

2. From local and state newspapers make a collection of clippings which refer to health conditions during the period in which

the health charts are being kept. If possible find some reference in your text which bears upon each. Paste the clippings upon binder paper such as is used in your laboratory note book. At the side of each clipping copy the reference from the text book and give the page on which it is found.

3. *A.* Make a collection of advertisements of " patent medicines " for colds and respiratory troubles as you find them in newspapers, periodicals, etc., and of labels and wrappings from bottles containing such nostrums. Sort these clippings and labels into the following groups:

a. So-called " cure-alls."

b. Advertisements in which no statements of a definite nature are made.

c. Advertisements which contain definite statements regarding specific diseases.

d. Advertisements advising not only the use of the nostrum but also some other treatment such as massage or the assistance of a physician. Mount these labels and clippings in the same way as you did those referring to health conditions. If Volumes I and II of *Nostrums and Quackery*, published by the American Medical Association, are available, find references to as many as possible of the nostrums for which you have advertisements. Make a note of the findings regarding such nostrums.

B. Make a comparison of well known periodicals and of newspapers with regard to the number and types of " patent medicines " advertising in each. Determine what factors are responsible for the differences which you discover.

C. Secure a copy of the " Pure Food and Drugs Act " and copy those clauses in it which refer to the regulation of the labeling of nostrums. Likewise copy those parts of the " Postal Fraud Act " which regulate in any way the use of the mail for such purposes as the advertisement of nostrums. Examine your labels and copies of advertisements to find whether either of these acts may have influenced their content in any way. (Copies of these acts may be obtained by addressing the Superintendent of Documents,

Government Printing Office, Washington, D. C. The "Pure Food and Drugs Act," 8th revision (1922), costs five cents; the "Postal Fraud Act," to be found in "Postal Laws and Regulations of the U. S.," one dollar.)

D. Why do "styles" in "patent medicines" change from year to year? If all the statements made by the manufacturers of "patent medicines" were true, why should there be so many colds and other diseases? What is your conclusion as to the real reason for the manufacture of so many nostrums?

II. Summaries and Conclusions.

1. At the end of the period used for this project, summarize the individual records of the class as follows: (Committees of pupils may do this work if so desired.)

Date	No. of pupils affected by "colds" and other respiratory diseases	
	Confined to home	*Not confined to home*
Total . . .		

Each pupil may copy this table. What is the average number of days of complete disability (confinement to the home) per pupil? Of partial disability? Estimate the equivalent of the former in money value by determining the wages which might have been earned in an equal period of time in some occupation engaged in by boys and girls of your age.

2. List the supposed causes to which may be attributed the colds, etc., of the various pupils. Rearrange in a series according to frequency. From your study of the text you have found that without the presence of germs such diseases as colds could not

occur, and that when the body resistance is low these germs secure a foothold most easily. Which of the " causes " that you have listed may have in some way lowered your body resistance? Which of them could have been avoided? What is essential to the maintenance of a high degree of body resistance? Compare your statement of conditions with those conditions under which the athlete lives while in " training."

3. List the treatments which were used as you did the " causes." Which of these treatments are in line with the most advanced scientific ideas regarding disease? Underline them. From your study of " patent medicines " would you expect the patient who uses them to recover because of them or *in spite of them?* Why is the advice of a thoroughly trained physician desirable if drugs are to be used in the treatment of disease?

4. Review the statements regarding disease which you have found in your text. Either summarize briefly those which you are willing to accept and which you expect to apply in your own case or write a short paper on the topic, " How I can help myself to be a healthy individual."

III. Arrange all the material which you have collected or written in connection with this project in an orderly manner and bind it into booklet form. Appropriate covers may be designed for the booklet if so desired.

EXERCISE 43

BACTERIA — STRUCTURE

I. Note the murky or cloudy appearance of water in which some substance has been decaying. To what is this appearance to be attributed? Examine a drop of the water which has been mounted under a high power of the microscope. Can you see any tiny objects, either moving or quiet? Describe any which you may see.

II. Method of Staining Bacteria.

1. Place a drop of water which contains the decaying substance upon a clean cover glass. Allow this to dry. Then pass the cover

glass rapidly through a Bunsen flame three times. This flame will kill and " fix " the bacteria. Next place a drop of gentian violet stain upon the cover glass. (A concentrated solution of purple aniline dye and denatured alcohol has been used as a stain with satisfactory results.) Let the cover glass stand for a few minutes. Then wash by allowing gently flowing water to pass over the cover glass. After this place the cover glass, bacteria side down, upon a clean slide.

2. Repeat the process, using a scraping from the teeth which is mixed with a drop of water.

III. The instructor will mount the prepared slides under the high power of the microscope. When this has been done you may study them. How many shapes of bacteria do you find in each case? Do these vary in size? Compare the dimensions of the bacteria to the diameter of a hair which has been placed under the cover glass. Why are the bacteria seen more easily in the stained slides than in the unstained ones? Make drawings of the various types and sizes of bacteria which you see. (See Waggoner, Figs. 127 and 128.)

IV. What are evidences of the presence of bacteria in any substance?

EXERCISE 44

INTERRELATIONS OF THE ORGANISMS OF A HAY INFUSION

I. Preparation. Use timothy hay (dried) and water from a pond. Cut the hay into small pieces and allow a handful of it to soak for a few days in a quart of the pond water. Keep the infusion in a warm room.

II. Study of Organisms in the Infusion. Study samples of the water which have been mounted under the microscope. Do this two or three times each week. Note the character of any living organisms which may be visible. Note the changes which take

place with reference to the kinds of organisms which are present in the water. Make drawings of the organisms observed each time. Date each set of drawings.

(NOTE — This infusion may be kept as a basis for work later in the year. See Exercises 62 and 63.)

EXERCISE 45

THE GROWTH OF BACTERIA

I. Sterilization of Utensils. Prepare a number of test tubes, a glass funnel, a flask, and fifteen Petri dishes. To do this, wash the glassware clean and sterilize it in a hot air sterilizer held at a temperature of 170° C. (340° F.) for one hour. (A common gas oven serves well for a hot air sterilizer. A large double cooker or steamer may be employed if hot water is to be used for sterilization. (See Waggoner, Page 213.)

II. Preparation of a Culture Medium. To prepare a medium for the culture of bacteria, dissolve 15 gm. of agar-agar which has been cut into small pieces in 1000 cc. of water. Then add to this 5 gm. of extract of beef. Boil for one-half an hour. The mixture should be slightly alkaline. To make it so, add just enough baking soda to cause red litmus paper to turn blue. Filter the medium into a flask through cotton placed in the funnel. Pour about 10 cc. of the medium into each of the prepared test tubes. (This should fill them about two inches deep.) Insert a stopper of cotton in each and steam for one-half hour in a common steamer such as that referred to above. Repeat this steaming twice at intervals of twenty-four hours.

III. Relation of Dust to Growth of Bacteria. Number the sterile Petri dishes from one to fifteen. In a *quiet* room, pour the medium from the test tubes into the Petri dishes. Avoid all unnecessary handling. No. 1 is to be kept as a *check* or *control*. Why? For one minute each, expose the medium in the following Petri dishes to the air: No. 2, in a quiet class room; No. 3, in the same

room immediately following sweeping; No. 4, in a quiet laboratory; No. 5, in the same laboratory after sweeping; No. 6, in the corridor when unoccupied; No. 7, in the same corridor during the passing of classes; No. 8, outside the window of an upper story; No. 9, on a doorstep. Brush the hair over No. 10; cough over No. 11; sneeze over No. 12; lay the fingers on the agar of No. 13; after washing the hands thoroughly, repeat with No. 14; shake a wrap over No. 15. Allow these Petri dishes to remain in an oven held at 85° F. to 95° F. or in a warm room. Examine after two or three days. Whitish patches which develop upon the agar medium are colonies of bacteria. How do the sizes and general appearance of the colonies in the various dishes compare? Explain the results. Record in a tabulated form as follows:

No. of dish	Place or condition of exposure	No. of colonies resulting	Explanation of results

What is your conclusion as to the relation of dust and bacteria? Explain the necessity for care in the preparation of the materials and glassware which were used in this exercise.

EXERCISE 46

PRESERVATIVES AND DISINFECTANTS

Prepare some clear beef bouillon, a hay infusion, or some other liquid that clouds as a result of bacterial action. Number two sets of test tubes from one to ten each. Fill each tube one-third full of the medium. Another tube should be filled in the same manner and kept as a "control."

I. Preservatives. Add the following substances to the first set of test tubes:

To No. 1, $\frac{1}{3}$ cc. of salt; to No. 2, 3 cc. of salt; to No. 3, 1 cc. of sugar; to No. 4, 4 cc. of sugar; to No. 5, 4 cc. of vinegar; to No. 6, 2 cc. of powdered boric acid; to No. 7, 1 drop of commercial formalin; to No. 8, 4 drops of commercial formalin. Keep the tubes in a warm room for two days. At the end of this period, observe the odor and appearance of the contents of each tube. What indicates bacterial action? Compare the bacterial action in each to that in the "control" tube. Which substances added to the medium have been most effective in preventing bacterial action? Which are required in large amounts? Which are harmless? Which are dangerous? Where is each used? What is a preservative?

II. Disinfectants. To the second set of test tubes add the following chemicals:

To No. 1, one drop of five per cent mercuric chloride solution; to No. 2, 6 drops of the same mercuric chloride solution; to No. 3, 1 drop of five per cent carbolic acid solution; to No. 4, 6 drops of the same carbolic acid solution; to No. 5, 1 drop of tincture of iodine; to No. 6, 6 drops of tincture of iodine; to No. 7, $\frac{1}{8}$ cc. of slaked lime solution; to No. 8, 1 cc. of slaked lime; to No. 9, 1 drop of four per cent chloride of lime solution; to No. 10, 5 drops of the same chloride of lime solution. Set the tubes aside in a warm place for two days. Then observe the bacterial growth in each. Compare the tubes with the "control" and with one another. Which is the clearest? Does the amount of a disinfectant need to be considered? Which of these disinfectants are widely used? Discuss the use of each. Define "disinfectant." How does a disinfectant differ from a preservative?

EXERCISE 47

THE EFFECT OF HEAT UPON BACTERIA

Make an infusion by steeping some chopped timothy hay in water. Allow this to cool and then add to it some faucet water in which the hay was previously washed. The solution should then be filtered until it is clear.

I. Fill each of eight test tubes one-third full of the solution. Allow No. 1 to stand in an oven at 90° F. (about 32° C.), No. 2, in a room at about 65° F., and No. 3, in a refrigerator at about 45° F. Let the three tubes remain under these conditions for 48 hours or until No. 1 becomes cloudy. Close Nos. 4, 5, 6, 7, and 8 with cotton plugs. Place No. 4 in water held at 60° C. for 5 minutes; No. 5 in water held at 70° C. for five minutes; No. 6 in water at 80° C. for five minutes; No. 7 in water held at 90° C. for five minutes; and No. 8 in boiling water for five minutes. Then allow these five to stand in the oven at 90° F. (about 32° C.). What general difference do you observe in these eight tubes after forty-eight hours? What does a cloudy appearance indicate? What is the use of the hay? Why was the cool wash water added in the beginning? Why were the tubes of the last group closed with cotton? (If no oven and refrigerator are available for this experiment, approximate results may be obtained in winter by placing the tubes in the furnace room and in a cold room.

II. What do the first three tubes show in regard to the effect of heat upon the growth of bacteria? Which clouded first? Why? Explain the differences observed in the last group of tubes. What is the effect of high temperature upon bacteria? Why do substances decay more rapidly in warm than in cooler weather? In warm weather, why does food keep better in the ice chest than out of it? Why does surface water become stagnant in warm weather?

EXERCISE 48

ORGANIC MATTER IN WATER

I. Procure samples of distilled, faucet, well, cistern, pond, and dirty surface water, placing each in a separate bottle. Fill each bottle one-half full and label it. Shake the bottles before studying their contents. Note any odor which is present. Explain the presence of such odors, if possible. Cork the bottles and place in an oven held at 90° F. (or in a furnace room) for two or more days. At the end of this period examine the samples again. Note the

color, odor, and general appearance. Explain the differences which you find in any sample after it has stood in the oven, as compared with its former characteristics.

II. Place 4 cc. of distilled water in each of two clean test tubes. To one add a small amount of organic matter. Next add a drop of potassium permanganate solution to each tube. (This may be made by adding a crystal of potassium permanganate to sufficient water to make a bright purple solution.) Gently heat the tubes. Note any change in color. How did the contents of the two tubes differ before adding the solution? What then has caused the difference in results? State clearly the test for organic matter as shown by this experiment.

III. Test each of the samples in Part I for organic matter. In which is the most present? Has this organic matter any relation to the odor and appearance of the sample? Is there any relation between the amount of organic matter and the results which you observed after allowing the samples to stand for two days? Is organic matter itself likely to be very injurious to those who drink the water which contains it? What does its presence indicate as to the source of the water which contains it? Why then is water containing organic matter objectionable?

IV. What is organic matter? What is its source?

EXERCISE 49

THE REMOVAL OF SEDIMENT IN DRINKING WATER

I. Settling. Allow water from five sources — a well, a cistern, a faucet, a pond, and a muddy pool — to stand over night in well cleaned deep glass vessels. At the end of this period, compare the amounts of sediment. Is the water in all the vessels equally clear? Explain the differences which you observe. What is the nature of the sediment in each? Examine some which has been mounted under a microscope.

II. Filtration. Prepare three filters as follows:

No. 1. Place filter paper in a glass funnel.

No. 2. Place fine sand three inches thick in a funnel. (Stop the opening with cotton.)

No. 3. Place powdered bone charcoal in a funnel as in No. 2.

Filter muddy water through each of these. Is there any difference in the results? Which is the best method, judging from the filtered specimens? Add some coloring to the water or use colored cistern water, and repeat the filtering. Is the coloring removed in any case?

III. Chemical Removal of Sediment. Add a little alum solution to each of several samples of muddy pond or creek water. Allow to stand for some time. Note the results. Filter through filter paper. Again note the results. What is the use of the alum?

IV. Does settling water free it from all impurities? Does it help? Why? Is this method used in your city water system? Is any one of the above filtration methods in use in this system? If so, how does it help? Is alum added to the water in your city? Will the settling, filtration, and addition of alum remove all danger from the use of the water? Explain. What else is needed in addition to the removal of the sediment in the water?

EXERCISE 50

THE CITY WATER SUPPLY

A class trip to the city water system may be made if the system is one which provides for the purification of water from a lake, a river, or other stream.

I. The Reservoir. What is the source of the water which finds its way into the reservoir? Is there evidence of the presence of any springs which may furnish a part of the water? Does the appearance of the water undergo any change while in the reservoir? Does the change occur slowly or rapidly? Note living plants or

animals which may be in or about the water. If sediment is present in the water, what is its nature? What is the source of this sediment? Does water readily become clear? What are possible sources of pollution? Could the untreated water which is in the reservoir be used with safety? Explain. At what season of the year is the danger from the use of such water greatest? Why?

II. The Settling Basins. How does the water get into these basins? What is their purpose? Note their size and structure. Examine the water which they contain. Note its character and appearance. What chemicals are used to purify this water? How are they added to the water? What is the use of each? Note especially the effect of the alum, if used. Does it remain in the water which is to be pumped through the city? What evidence is there that the chloride of lime or liquid chlorine is effective?

III. From the standpoint of health, of what value to a city is a water system like the one you are studying? Write a brief paper upon this topic.

EXERCISE 51

A SURVEY OF UNSANITARY CONDITIONS

I. Field Work. Choose for this survey town blocks or other definite areas which appear to be below a desirable standard so far as sanitary conditions are concerned. The class may work in groups or as a whole. All observations are, of necessity, to be made from streets, alleys, or other public highways. Each member of the class may prepare a plan of the area studied. Show on it the location and size of all buildings, alleys, passageways, etc. locate on it all stables, cesspools, outbuildings, garbage cans, piles of garbage, tin cans, and other rubbish, hog pens, rotting vegetables, standing water, etc. Locate any wells or cisterns and note the probable drainage conditions surrounding each.

II. Conference. Discuss each source of danger found. Explain why it endangers the public health. Point out the remedy

in each case as far as it is possible to do. Each member of the class may then write a brief report of the discussion. If it seems advisable, the best of these reports may be published in the school or local newspaper.

EXERCISE 52 (Supplementary)

THE VERTEBRATE SKELETON

Use a skeleton or chart. If neither is available, use the illustrations from text books. Study the skeleton of the human; then, if possible, compare it with that of the fish, the frog, a reptile, a bird, and another mammal, such as the cat or rabbit (hare).

I. Note the general character of each of the parts of the skeleton — the skull, the trunk, and the limbs. What are the uses of the bones in each of these parts?

II. The Skull. What are the character and general form of these bones? How are they joined to one another? Where, on the body, are blows most likely to fall? Of what significance are the shape and character of the skull with regard to such blows? Note the bones of the face, the jaws, and the nose. How are the eyes protected? How is the lower jaw attached to the skull?

III. The Trunk. Note the number, the arrangement, and the position of the ribs. How are the ribs attached to the breastbone? To the backbone? How many vertebræ make up the spinal column? What is the use of the spinal column? Note the projections on the vertebræ. Of what use are they? Where is the spinal cord located? How is it protected? What is the relation of the spinal column to the skull? Note the " cushions " between the vertebræ. Of what value are they? By what means is the spinal column supported at its base?

IV. The Limbs. What is the character of the large bones of the arm and of the leg? Name the three largest bones of each. What is the nature of the shoulder blades? How are they attached to the

trunk? What is the character of the collar-bones? Why are they so easily broken? In the human skeleton study the arch of the foot. Upon what does the weight of the body rest? What is the use of this arrangement? What has happened when the condition known as " flat foot " is present?

V. What purposes, in relation to the body, does the skeleton serve?

VI. If it has been possible to compare the skeletons of two or more different groups of vertebrates, what similarities have you found with regard to the skull? The vertebral column? The limbs (appendages)?

EXERCISE 53

THE ORGANS OF THE CHEST AND ABDOMEN OF THE HUMAN

I. The chief regions of the human body are the *head* and *trunk*. The upper part of the trunk cavity is the *chest*; the lower part is the *abdomen*. (Use the manikin or chart. If neither is available, refer to the diagram in the text. See Waggoner, Fig. 140.) Note the character of the chest walls; the thickness. Compare the walls of the abdomen with those of the chest. How do the internal organs lie in the body cavity with relation to one another? What are the character and shape of the *diaphragm*, the partition which separates the chest and abdomen? What is its position with relation to the body walls? To what is it attached? Specify the location on your own body.

II. The Chest. What organs lie in the chest cavity? What is their relation to one another? To the diaphragm? Note the *gullet*, the *esophagus*, which enters from the throat region. In front of this is the *trachea*, whose branches lead to the lungs. Note the *aorta*, the artery which curves upward and back from the heart. Follow its course.

III. The Abdomen. Note the *liver*, the large organ toward the right and just beneath the diaphragm. Below this, and to the

left, is the *stomach*. Note the *bile duct* which passes from the liver to the *small intestine* just below the stomach. Beneath the stomach and lying against it is the *pancreas*. Trace its duct to the place where it enters the small intestine. Note the coiled small intestine. Find the projection of the front of the upper part of the hip-bone. The junction of the small and *large intestines* occurs near here. Note the *appendix*, just below this junction. What is its nature? From this junction the large part, known as the *ascending colon*, passes upward; then, as the *transverse colon*, it crosses the front part of the abdomen about at the waist line; then, as the *descending colon*, it passes downward to the lower abdominal cavity. Locate on your own body the region of the transverse colon. Note the *kidneys* at the back of the abdominal cavity. What is their shape?

EXERCISE 54

THE THROAT AND NASAL PASSAGES OF MAN

Close the mouth. Explore its interior with the tongue. What is the size of the mouth cavity? Is the roof of the mouth hard all the way back? Open the mouth. By aid of a mirror, observe the character of the mouth lining. Then note the position of the following structures — the *lips*, the *teeth*, the *tongue*, the *hard palate*, and the *soft palate*. Examine your nose. Where does the solid bone begin? What is the nature of its tip? What is a "broken nose"? Locate the nasal passages. What is the nature of their linings? With the aid of a manikin or chart, determine the relation of the air passage and the food passage. (If neither manikin nor chart is available use the diagram in the text; see Waggoner, Figs. 137 and 139.) The cavity back of the mouth, into which the nasal cavity opens, is the *pharynx*. Next note the air passage beyond the pharynx. Study the front part of your neck. In this region can you feel the *larynx*, which is situated at the upper end of the windpipe? What seems to be the nature of its walls? Look at a manikin or chart. Observe the position of the *vocal cords*.

Swallow. Note the sound which occurs. Explain this sound. How does food in its passage to the *gullet*, which lies beyond the pharynx, cross over the opening of the windpipe? Locate the *epiglottis*. How are substances, being swallowed, prevented from entering the nasal cavity? What happens when you laugh just as you swallow?

Note carefully the location of the *tonsils* and the region where enlarged adenoids often develop.

EXERCISE 55

THE CIRCULATION OF MAN

I. On a manikin or a chart locate the heart with reference to the lungs, the ribs, and the breastbone. Think where it is in your own body. Place your hand over the location where the heart touches the chest wall. What are the shape and size of the heart? In the figure in the text (see Waggoner, Figs. 147 and 149) note the divisions of the heart — the *right* and *left auricles* and the *right* and *left ventricles*. Find the relation of the *pulmonary artery* and *pulmonary veins* to heart and lungs, respectively. Locate the *aorta*, the great artery leaving the left ventricle. Trace its course. Find the *caval veins* which return the blood to the right auricle. Note carefully the distribution of blood vessels in the lungs and in the various parts of the digestive system.

II. Note the distribution of veins on your arm and hand. Hold your arm on a level with your shoulder or higher. Again note the veins. Next allow the arm to hang at your side. What difference is there in the appearance of the veins under these three conditions? Explain. Compress some spot on the arm or wrist. What is the result? Rub the forearm toward the fingers. What is the result? What is the position of the veins with regard to the skin? Explain the results of the above experiments. How does the movement of the muscles affect the veins which are near them? How does muscular action aid the circulation of the blood? On the manikin or chart determine the positions of veins and arteries as related

to one another and to the body surface. Locate the pulse in your body, *a.* at the wrist, *b.* just in front of the ear, and *c.* below the angle of the jaw. What is the pulse?

EXERCISE 56

THE EFFECT OF EXERCISE UPON THE PULSE RATE

I. Sit quietly for a time. Locate the pulse in the wrist or in the neck. Count the pulsations. Note the number in one minute. Record and average these as suggested below.

II. Stand erect. Count the pulsations as in Part I. Record. Is it a matter of effort to stand? Locate the main muscles which are involved. What differences are evident between the results in Part I and those in Part II? Explain the cause of these.

III. Rise and extend the arms above the head. Sit. Repeat in an energetic manner for a number of times. While still standing, count the pulsations as in the preceding exercises. Record and average as in Parts I and II. What happens with regard to the breathing rate? What is the effect of exercise upon the heart beat? Explain the differences between the results obtained in this part and those obtained in I and II.

IV. What is the effect of exercise upon the pulse rate? Why does the treatment of a disease of the heart usually call for inactivity on the part of a patient?

Tabular form to be used in recording results:

Number of Pupil	Pulsations per Minute		
	While sitting quietly	*While standing*	*While exercising*
1			
2			
3			
4			
5			
Average....			

EXERCISE 57

THE HUMAN RESPIRATORY ORGANS

Use a manikin or skeleton if possible. If these are not available, use a chart or the diagram in the text.

I. The Nasal Passages. Review the position of the throat and nasal passages and their relation to each other. (See Exercise 54.)

II. The Lungs. What are the position, number, and shape of the lungs? What is their relation to the chest wall? To the diaphragm? Find the position of one of your collar-bones. What is the relation of the apex of the lung to this bone? Find the lower ribs. Note the relative positions of the lungs and the lower ribs. Study the relation of the trachea to the lungs. Note the distribution of its branches to the parts of the lungs. What is the use of the trachea? Where does air enter the lungs? Note the distribution of the blood vessels of the lungs. Why is this significant?

EXERCISE 58

AIR IN THE LUNGS

I. Note and estimate the amount of air which is drawn in and which is exhaled in each breath. Breathe naturally. The air which is inhaled under this condition is *tidal air*. After taking in the tidal air, draw in as much more air as you can. This extra air is *complemental air*. Compare the quantity of the two volumes. After breathing out the tidal air, force out as much more as you can. This last is *reserve air*. Compare the amount of this with the other volumes. *Residual air*, about equal in quantity to the reserve air, remains in the lungs and cannot be forced out.

The diagram in the text (see Waggoner, Fig. 153) represents the relative volumes of air which are used by an adult of average size.

II. What part of the lung capacity is taken up by the tidal air? What portion of the lungs is filled with fresh air in *quiet* breathing?

What is the effect of *deep* breathing upon the amount of fresh air in the lungs? What is the relation of such breathing to vigorous exercise? To singing?

III. Test the complemental air for carbon dioxide by blowing it through clear limewater. Do the same with the reserve air. Compare and explain the results. Compare with results shown in Waggoner, Fig. 154. What do these results indicate with relation to the habit of deep breathing?

EXERCISE 59

THE ACTION OF THE RIBS AND THE DIAPHRAGM IN BREATHING

I. Stand erect and take in several deep breaths. Note the movement of the breastbone. How far and in what direction does it move? Measure the chest before taking a breath. Measure while it is expanded. What is the difference? Note the protrusion of the abdominal walls during breathing. What effect would tight clothing about the waist have upon the ability to breathe deeply?

II. On the skeleton or the illustration in the text (see Waggoner, Fig. 140) note the position of the ribs when they are at rest. Where are the ribs jointed? Take in a deep breath and note the movement of the ribs during its inhalation. Where are the muscles which raise the ribs? How are the ribs attached to the breastbone? What dimension of the chest is increased by raising the ribs? Why does air pass out of the lungs without effort?

III. On the manikin, note the position of the diaphragm when the chest is not expanded. What happens when the diaphragm contracts? Why does it press down upon the abdominal organs? What makes the abdominal walls protrude? Give another reason why the breath passes out of the lungs without effort. Why, also, does the elasticity of the lungs help to explain this lack of effort?

IV. When the chest cavity is increased in size by the raising of the ribs and the contraction of the diaphragm, what causes the outer air to enter this cavity? Explain fully.

EXERCISE 60

INHERITED AND ACQUIRED CHARACTERISTICS

Let each individual make his own lists according to the following directions. Be definite in listing these characteristics. For example — *brown eyes* rather than *color of eyes.*

I. List the influences of your environment which you feel certain have had a marked effect upon your life.

II. List some of your personal characteristics which seem to have been inherited; some which you believe you have acquired; some which seem to be the result both of inheritance and of environment.

III. List some characteristics which you do not have and which you believe that no environmental influence could enable you to acquire.

IV. Look over all the hereditary characteristics which you have mentioned. Check all those which appear frequently in your family.

V. What statements which are made in your text does each of these lists illustrate?

After each indivudal list has been completed, the class may be interested in discussing a number of them. (Among the characteristics which may be included in this study are eye color, color and character of hair, shape of nose, height, weight, peculiar markings, special ability along certain lines, occupational tendencies, and temperament.)

EXERCISE 61

VARIATION

Use materials which were collected for this purpose during the fall months. The points of the great ragweed seeds (see Exercise 9, Part IV) or the notches of elm leaves may be counted. If no preparations have been made in advance for this exercise, the pairs of immature leaves in the buds of lilacs may be counted. (Care must be used in avoiding any confusion of outer bud scales with the leaves which they enclose.)

I. Divide the ragweed seeds or elm leaves among the members of the class. Let each person separate them into piles and place all those having the same number of points or notches in one pile. Mark each pile with a slip of paper bearing this number. How many specimens are present in each pile? Write this on the slip for the pile.

II. When the individual counts are made, total the results for the class. List the resulting numbers in order. What is the least number of points found? How many specimens have this number? What is the highest number found? How many specimens have this number? What number occurred most frequently? Make a graph showing the results.

III. Give other examples of variation which you have observed. (NOTE — See Exercise 74. This may be begun in early spring.)

EXERCISE 62

THE AMŒBA

Study pictures of the amœba found on charts, on lantern slides, and in text book illustrations. Then study specimens present in a drop of water which has been mounted under the microscope.

I. Form. Note the general appearance of the amœba. What do you observe regarding its form? Does this form change?

Make four or five drawings as rapidly as possible to show the changes which occur in its form.

II. Structure. Study the protoplasm of the body. Why is an amœba a difficult animal to see? Note that the outer layer is almost perfectly transparent and free from granules. This is the *ectoplasm*. Compare with this the granular central mass, the *endoplasm*. Find one or more clear spaces. These are *vacuoles*. Watch them closely. The one which disappears is probably the *contractile vacuole*. The others are *food vacuoles*. These sometimes contain foreign bodies which have been taken in for food. Find the *nucleus*. This is a round body which is denser than the rest of the endoplasm and appears to be slightly darker.

III. Movement. As the animal moves, observe the formation of the *false feet* (*pseudopodia*). Do these appear in any regular manner? Watch the flowing movement of the granular part of the amœba. How is this movement related to the formation of the false feet?

IV. Food Getting. Add a little powdered carmine to a drop of water containing amœbæ. Under the high power, note whether any of the particles of carmine are taken in by the amœbæ. Describe the process if you see it. (Powdered carbon may be used instead of carmine.)

EXERCISE 63 (Supplementary)

THE PARAMECIUM

The paramecium, like the amœba, is a one-celled animal, but it is a free-swimming organism which is further advanced in the scale of life than the amœba. It is found in fresh water ponds and streams. In the hay infusion previously prepared, you may find a scum which, when closely examined, is seen to be composed of many minute white objects, barely visible to the naked eye. These are probably *paramecia*. Can you explain the presence of these animals upon the surface of the infusion? Study the paramecia in

a drop of water mounted under the microscope. (NOTE — By mixing a drop of egg white with the drop of water containing the paramecia, the movements of the animals may be retarded so as to facilitate a study of them.)

I. Note the shape. Does it seem to be constant? Note the fine hairlike structures which cover the body and which move rapidly as the animal swims about. These are *cilia.* Note the end which is usually foremost. This is the anterior end. How does this end differ from the posterior end? Upon one side of the body is a groove. This is the *oral groove,* which leads just beyond the center to the *mouth opening.* Beyond this opening is a short funnel-shaped *gullet.* The mouth is on the ventral surface. The body of the animal consists of protoplasm. This is made up of a thick fixed layer, the *ectoplasm,* and a more fluid granular mass, the *endoplasm.* A thin covering, the *pellicle,* consists of non-living material. There are two *contractile vacuoles.* These lie in the dorsal region toward either end. Watch them closely. Note the *radiating canals* which surround each vacuole and empty into it. Note the *food vacuoles* which form at the interior end of the gullet. In what direction do they move from this position? Make a drawing, showing the structures which you have identified. (See Waggoner, Fig. 167.)

If specially prepared stained slides are available, note the large, oval, deeply stained mass near the center. This is the *macronucleus.* In a depression in one side of the macronucleus lies the *micronucleus,* a very small rounded body.

II. Activities of the Paramecium. When a little powdered carmine or (carbon) has been added to the drop of water in which a paramecium is present, note how the carmine grains are driven by the cilia. Watch grains as they pass down the gullet. Determine the process by which food enters the animal. (The grains of carmine will enter with the food.) Watch the animal as it swims. Is the same side of the body always uppermost? Explain.

EXERCISE 64

A FRESH WATER HYDRA

The hydras are found in fresh water ponds and streams. Look for them on the under sides of submerged leaves and stems. Living ones may be brought into the laboratory and kept for observation. Prepared microscopic and lantern slides will facilitate the study of these animals.

I. Observe the living animals which you have in the laboratory. Note their positions in the water. How long is the main part, the body, of the animal? Note the *tentacles* which you find branching out from one end. Compare the length of these with that of the body. Observe any movements of the animals. By what part of the body do they attach themselves to objects? Where are these animals most abundant? Determine the reason for this distribution.

II. Place one of the hydras in a little water in a shallow dish. Examine it with a lens. Note the cylindrical form of the body. Note the basal part by which it attaches itself to objects. At the opposite end find the position of the *mouth*. This is surrounded by the *tentacles*. What are the arrangement and number of the tentacles? Within the body is the digestive cavity. The instructor may introduce a number of small crustaceans, such as Cyclops, into the water. Observe what happens when the hydra comes in contact with one of them. How does a hydra get its food? Draw the hydra as you see it. (See Waggoner, Fig. 175.)

III. Examine a hydra which has been mounted under low power. (The cover glass should be supported so that the animal will not be crushed.) Observe that the body wall, as well as the wall of the tentacles, consists of two layers of cells, the *ectoderm*, or outer layer, and the *endoderm*, or inner layer. A very thin gelatinous layer lies between. The body of the hydra is similar to a hollow, double-walled tube. The tentacles are merely hollow extensions of the tube, somewhat as the fingers of a glove are extensions of the

rest of the glove. In the ectoderm you will observe *nematocysts*, ovoid structures which contain stinging threads. If a hydra is mounted with the cover glass resting directly upon it, a light tap on the cover glass will crush the animal. This will free many of the nematocysts. The threads in some will be discharged and can be examined.

EXERCISE 65

THE EARTHWORM

I. The Living Earthworm. Live earthworms may be brought into the laboratory and kept in a box of the soil in which they were found. Let members of the class remove earthworms from the soil, noting any difficulty which may be encountered in the process. Place a specimen on white paper. Note the direction and manner of its movement. Which is the anterior end? Note the slender dark structure running lengthwise within the body. This shows through the dorsal surface and is the *dorsal blood vessel*. Note its contractions. Try to draw an earthworm backward over the paper. Compare the dorsal and ventral surfaces by rubbing lightly with the finger. Experiment to find out whether the animal is sensitive to sound, light, food, etc. Touch the anterior end. Touch the posterior end. Which is the more sensitive?

II. External Structure. (Preserved specimens may be used, if desired.) Note the general shape of the body. How does its thickness compare with its length? The body is regularly divided into *segments* by grooves extending around it. At the anterior end is the protruding upper lip or *prostomium*. This is not a true segment. Some distance back of the prostomium is a somewhat swollen region, the *clitellum*. (Glands in the clitellum secrete a cocoon which collects both the egg and the sperm cells. Within this structure fertilization and the development of the egg and the young earthworm occur.) In the anterior part of the body there are thirty-seven segments when the clitellum and all the segments anterior to it are counted. How many do you find posterior to the clitellum? The *mouth* is on the ventral surface just behind the

prostomium. The *anus* is at the posterior end of the body. Compare the dorsal and ventral sides of the body. How did you find that they differed in the living specimen? With a lens examine the small bristles which lie along each side of the ventral surface. What is their use? Note carefully the covering of the earthworm. What is its nature? Draw an earthworm, showing its external structures.

III. Internal Structure. (Use prepared museum dissections or specimens previously dissected and pinned out by the instructor. Compare with Waggoner, Fig. 178.)

1. Note how the body cavity, the *cœlom*, is divided by thin walls into chambers which correspond to the segments shown externally.

2. *The Digestive System.* The digestive tube runs straight through the body from the mouth to the anus. The *mouth cavity* is a thin-walled, sac-shaped structure into which the mouth opens. This cavity leads into the *pharynx*, a region with muscular walls. Back of the pharynx is the narrow *esophagus*. Next come the large thin-walled *crop* and, following it, the thick-walled, muscular grinding organ, the *gizzard*. The remainder of the digestive tube is the *intestine*. Make a drawing of the digestive system, labeling its parts.

3. *The Circulatory System.* Along the dorsal surface of the digestive canal is a slender dark tube, the *dorsal blood vessel*. In the anterior region this divides into branches, the "*hearts*," which pass around the digestive system to the *ventral blood vessels*. These "hearts" contract and send the blood into the ventral vessel, where it flows in a posterior direction. The contractions of the dorsal blood vessel send the blood within it in an anterior direction. The dorsal and ventral blood vessels and the "hearts" constitute the main part of the circulatory system. Make a diagram showing the general plan of the circulation.

4. *The Respiratory System.* The exchange of gases necessary in respiration occurs throughout the entire body surface. There are no special organs for this process.

5. *The Excretory System.* A pair of excretory organs, "kidneys" (*nephridia*), are present in the ventral part of the cœlom in each segment, except in a few at either end. The "kidneys" are very minute. They begin in one segment as funnel-shaped structures and continue into the next as looped tubes. In the second segment each tube opens to the outside through the ventral body surface. With a lens you may be able to locate these structures.

6. *The Nervous System.* Beneath the digestive tube on the floor of the body cavity lies the white thread-like nerve cord. An enlargement, a *ganglion*, may be found in each segment. At the anterior end, the nerve cord divides and passes around the pharynx, forming two ganglia on the dorsal side. These ganglia are the so-called "brain" of the earthworm.

7. *The Reproductive System.* The earthworm is hermaphroditic; that is, it has separate male and female sex organs and both are present in each individual. The male organs, which can be easily located, are three pairs of large white masses at the sides of and above the esophagus in segments nine to twelve. The female sex organs, the *ovaries*, are located in the fourteenth segment and, because of their small size, are more difficult to see. The ducts of both the male and female sex organs open to the exterior.

EXERCISE 66 (Supplementary)

THE CRAYFISH

I. The Living Crayfish. Observe a living crayfish which has been placed in an aquarium or pan. By means of what appendages and movements does it make its way through the water? Place the animal on a table. Repeat your observations. Place a ruler or stick near a crayfish. How does it grasp the object? Return the crayfish to the water. When it is quiet, drop some coloring matter, such as ink, in the water near the place where the legs join the body. Note where the colored fluid is drawn in and where it is thrown off. The crayfish breathes by means of

gills. How does this explain what you have seen? Think of experiments which you might try in order to test the taste, smell, hearing, sight, and feeling of this animal. Recall observations which you have previously made regarding the habitat and activities of the crayfish. Watch them whenever the opportunity is afforded you while on field trips, fishing trips, etc.

II. External Structure.

1. The crayfish belongs to the same great group of animals as the insects. In the crayfish we have an example of high specialization. This is shown in the widely varying functions of many separate structures of similar origin. The appendages, which show such specialization, are of similar origin. If they are examined closely, a marked likeness in number and arrangement of segments is found. Structures of similar origin and general plan are known as *homologous structures*. Where is the skeleton of the crayfish? It is called the *exoskeleton*. What is the nature of this covering? How is it formed? How does molting enable this animal to accommodate its covering to its size? The body of the crayfish is divided into the *cephalothorax* and the *abdomen*. How many segments are there in the abdomen? The crayfish's body is divided into twenty-one segments. Locate as many of these as possible. With the exception of the first and last, each segment bears a pair of appendages.

2. *The Cephalothorax.* The cephalothorax is divided by a transverse groove into two regions — the *head* and the *thorax*. The exoskeleton of the dorsal and lateral surfaces of the cephalothorax is known as the *carapace*. Begin your study at the anterior end. Note the sharp beak, the *rostrum*, which lies between the *eye-stalks*. What are the size and position of the eyes and how are they attached? Why are the eyes "stalked"? Behind the eyes are the *antennules*, slender double feelers. At the base of these find the *statocysts*. (These are small, sac-like sensory organs.) Back of the antennules are the *antennæ*. At the base of these are the openings of the excretory organs, the *green glands*. The jaws, the *mandibles*, are next in order. In what direction do they move?

Experiment to find out. The next appendages are the *maxillæ*. What is their function? The remaining appendages of the cephalothorax belong to the thorax proper. Find the three pairs of appendages, the *maxillipeds*, which are next to the maxillæ. What is their function? The five pairs of appendages posterior to the maxillipeds are the legs. Study the legs which bear large claws. How many joints are present in these appendages? In what directions can they move? For what are they adapted? Compare the remainder of the thoracic appendages with these. How many pairs are there? What is the function of each?

3. *Abdomen.* Examine the middle segment of the abdomen. How is it attached to the others? Of what advantage is such an attachment? In what direction can this segment move? Note the appendages which are attached to it. These are called *swimmerets*. How many are there in each segment and what is their use? How many segments have such appendages? Compare all the segments of the abdomen, and compare their appendages as to structure and to use. What is the special function of the last two segments and of the appendage which the next to the last segment bears? The last segment is the *telson*.

4. List all the external structures adapted for locomotion, for food getting, and for the receiving of sensations. Draw the side view of the crayfish. Draw one of the third pair of walking legs and one of the swimmerets.

III. The Internal Structure. Study a prepared dissection of a crayfish in which the dorsal wall of the abdomen and thorax has been removed. Note the *heart*, which is in the median line of the cephalothorax. It lies in a cavity which receives the arterial blood from the gills. This blood enters the heart through three pairs of valves that open inwards. From the heart five blood vessels pass anteriorly and another passes posteriorly to the dorsal part of the abdomen. From the latter a branch is sent out to the ventral region. The circulatory system is an *open* one; for in the body tissues the blood leaves the vessels, and it is returned to the heart through a series of open spaces. Remove the side of the shell just

above the legs. Note the *gills*. Place one of the gills in water. What are its character and shape? How many pairs of gills do you find? To what are they attached? What is their function? How does water enter them? Draw one of the gills which has been placed in water. Note the large *stomach* in the cephalothorax. The stomach connects with the *esophagus*, which in turn leads to the mouth. Just back of the stomach, and on either side, is the reddish *liver*. Note the character and the shape of the intestine. Note the light-colored muscles of the crayfish. What is the function of these muscles? In a specimen from which the contents of the body parts have been removed, note the position of the nerve cord and ganglia. They are similar in arrangement to those of the earthworm. Find some of the ganglia along the cord. Where is the "brain"? The *green glands*, before noted, are excretory in function. They are below the stomach, in the front of the head. (See Waggoner, Fig. 179.)

EXERCISE 67

THE LOCUST (Grasshopper)

If possible, collect live specimens for the preliminary study. Freshly killed or preserved specimens may be used for the remainder of the exercise. (See Exercise 6.)

I. The Living Locust. Observe the way in which the locust climbs a stem and the way in which it jumps. Watch the movements of the mouth parts. What is the general shape of the body? What are the nature and the use of its covering? This covering is the *exoskeleton*. Note the division of the body into the *head*, *thorax*, and *abdomen*. How can you distinguish between the abdomen and the thorax? Look for the breathing pores, *spiracles*, a pair of which is present on each segment of the body posterior to the head. Watch the movements of these spiracles. How many legs has this insect? How many wings?

II. The External Structure.

1. What are the size, the position, and the shape of the *head?* How is the head attached to the body? Is it movable? Note the slender feelers or *antennæ.* What are the number and the location of the antennæ? How many segments are there in each? Locate the *compound eyes.* These are upon the sides of the dorsal region of the head. Locate the three simple eyes, the *ocelli.* Two of these lie between the compound eyes, just anterior to their dorsal part. The other lies in a depression in the median line of the "face." Examine the compound eyes with a lens and note the *facets* of which they are composed. Draw some of them. Study the mouth parts. Locate the *labrum,* or upper lip; the *labium,* or lower lip; the *mandibles,* or jaws, which are just below the labrum; and the *maxillæ,* or little jaws, just below the mandibles. How do the mandibles open? Note the appendages of the mouth parts, the *palpi.* How many are there? What are their location and arrangement? Are the mouth parts adapted for sucking or for biting? Explain. Draw both front and side views of the head.

2. Compare the size of the *thorax* with that of the head. Note its divisions. The anterior segment is the *prothorax,* the middle segment is the *mesothorax,* and the posterior one is the *metathorax.* What are the position and arrangement of the wings? Compare the pairs as to size, texture, and use. Remove them carefully and draw one of each. (Extend the back wing.) What are the position and arrangement of the *legs?* Compare the three pairs as to their size, use, and structure. In each leg the small rounded part nearest to the body is the *coxa.* Next to this is the *trochanter,* a still smaller segment. The third and longest segment is the *femur.* Beyond this is the *tibia.* The remainder of the leg is the *tarsus.* What is the use of the "claws" and of the "spines" on the legs? Draw a hind leg. Draw the thorax from the side.

3. What is the shape of the abdomen? What is its size as compared with the *thorax?* Of how many segments is it composed? In the female specimen, note the end of the abdomen. The four-pointed structure is the *ovipositor.* How is it adapted for depositing the eggs? Find the *spiracles,* the breathing pores. What are

their number and position? Their use? Note under the base of the wings, on the first abdominal segment, a pair of shiny oval membranes, the *tympanums.* What is their use? Draw the abdomen from the side.

III. The Internal Structure. (This study is optional with the instructor.) Study a prepared dissection of a female locust from which the dorsal exoskeleton has been removed. (See Waggoner, Fig. 188.)

1. All along the dorsal surface of the abdomen, just beneath the body wall, lies the delicate *heart,* a tube-like structure.

2. The respiratory organs are a system of air tubes, the *tracheæ,* which ramify throughout the body. They are connected with the outside by their openings, the spiracles. The tracheæ may be seen as glistening white threads and sacs in freshly killed specimens. (See Waggoner, Fig. 189.)

3. A mass of yellow eggs will probably be found in the anterior part of the abdomen. This mass may be separated into right and left parts. From each a tube, the *oviduct,* leads to the ovipositor.

4. After removing the reproductive organs, the digestive system may be studied. The *mouth* leads into a *buccal cavity,* which opens into the *esophagus.* This is followed by the large *crop.* In the crop the dark liquid is produced which the locust ejects from its mouth. The crop extends through most of the thorax. It leads into the *fore-stomach.* Next is the *stomach* proper. From the anterior end of the stomach arise the *gastric cæca,* double cone-shaped pouches. These lie parallel with the digestive tube. The stomach extends posteriorly through the fourth segment of the abdomen and leads into the *intestine.* This becomes smaller toward the posterior end and bends dorsally as it opens into the *rectum.* Make a drawing of the digestive system.

5. The excretory system consists of a large number of fine, thread-like, whitish tubes that arise at the anterior end of the intestine.

6. The nervous system is similar to that of the earthworm. If possible, locate the " brain." This is dorsal to the labrum on the

upper side of the esophagus. Locate the *ventral nerve cord.* This is ventral to the digestive system. Do you find ganglia along the course of this cord? Where?

IV. Name the structures present in a locust which adapt it to its habitat.

V. Examine as many different stages of development in young locusts as possible. Note especially the changes in wings and in size. The type of development found in the locust is known as " incomplete metamorphosis."

EXERCISE 68

THE MAY BEETLE

If desired, some other beetle may be substituted for the May beetle (the so-called " June bug ").

I. The External Structure. Examine the specimen which is provided. Note its shape and color.

1. *The Head.* What is the nature of the eyes? Note the character of the antennæ. Compare with the locust. Compare the mouth parts with those of the locust.

2. *The Thorax.* Are the legs all alike? Explain. What is the use of the barb and the claws? How many wings has the beetle? Compare them in regard to structure, size, shape, and function. Note and explain how the posterior wings are folded.

3. *The Abdomen.* What is its structure? Its shape and size? Compare with the remainder of the body. Find the spiracles.

II. The Stages of Development. Note the shape, the color, and the size of the *larva* (the grub). Compare the head, thorax, and abdomen with those of the adult. Describe the covering of the larva. When does the beetle damage plants — in the adult or in the larval stage? What kind of a poison should be used to destroy this insect? Why? Examine the *pupa* of the same beetle. Compare with the larva. The type of development found in the

beetle is known as " complete metamorphosis." (See Waggoner, Fig. 193.)

III. Compare the beetle with a locust and notice several marked differences. What can you tell of the habits of the beetle from the study which you have made of its various structures?

EXERCISE 69 (Supplementary)

THE SQUASH BUG

If desired, the box elder bug or some other species of bug may be substituted for the squash bug.

I. The External Structure. Examine the specimen provided for you. What are its size, its shape, its color, and its markings?

1. *The Head.* What is the shape of the head? What is the position of the eyes? Examine and describe the antennæ. How do the mouth parts differ from those of the locust? Explain fully. From this study, determine the nature of this insect's food — whether it is solid or liquid. How is the *sucking beak* carried when not in use? What kind of a poison would you use to kill this insect — one applied to the plant upon which it feeds or one applied to the body of the insect? Why?

2. *The Thorax.* What is the nature of the legs? The number of the wings? Compare the texture of the outer and under wings, and the anterior and posterior portions of the outer wings. What does their structure suggest with regard to the use of each pair? Draw one of each pair of wings.

3. What is the character of the abdomen?

II. The Stages of Development. Examine a number of young squash bugs. Arrange them in the order of their development. Note any differences, especially with regard to their wings. (See Waggoner, Fig. 191.)

EXERCISE 70

THE CABBAGE BUTTERFLY

If desired, the Monarch butterfly may be substituted for the cabbage butterfly. Handle the specimens very carefully. (See Waggoner, Fig. 195.)

I. The Adult. Note the position and number of the wings; then carefully remove them and place in a book until you are ready to use them for further study. Note the parts of the body. Compare the covering of the body with that of the insects previously studied. Using a lens, examine the head. What are the number, the position, and the character of the eyes? What is the nature of the antennæ? Compare the antennæ with those of a locust. What is the nature of the covering of the anterior part of the head? Examine the mouth parts. What do these indicate with regard to this butterfly's food habits? How are the mouth parts protected? Uncoil the sucking tube. How long is it? How many pairs of legs do you find? Examine them. What is their position? What does their character suggest regarding their use? Compare them with those of a locust. Compare the two pairs of wings as to shape and markings. What causes their rigidity? Examine with the lens. Then examine a portion of a wing which has been mounted under the low power of the microscope. What is the arrangement of the scales which cover the wings? Their nature? Examine the abdomen. What are its characteristics?

Draw one of each pair of wings, a small portion of a wing showing the scale arrangement, an antenna, and the sucking tube.

II. The Larva. Examine the larva of the butterfly. What is its general nature? Note its color and size. Examine the head, noting especially the mouth parts. How do these compare with those of the adult? How many legs are present? To what are they attached? Are the legs jointed? Note the fleshy *prolegs* which are posterior to the true legs. What is their nature? Their use? What is the food of this "cabbage worm"? Compare it

with the adult in respect to food habits. Draw a side view of the larva.

III. The Pupa. Compare the pupa in shape and size with the adult. What is the nature of the body covering? Do you find tiny holes in some specimens? Probably these are the work of minute parasitic insects. (See Waggoner, Fig. 197.) Draw the pupa.

IV. What characteristics of butterflies have you observed which adapt them to their environment?

EXERCISE 71 (Supplementary)

THE HONEYBEE

I. The Adult. Examine one of the "workers." What is its size? Its general form? What are its body parts? Note its color, its markings, and its body covering. Examine its head under a lens. What are the shape, size, and location of the compound eyes? What are the nature and location of the antennæ? Describe the mouth parts. Draw a "face" view of the head. Study the thorax. What are the number and nature of the wings? Compare them with regard to size and shape. Draw one of each. Study the legs, noting their number, size, and covering. How are they adapted for the work done by the honeybee? What are the shape and structure of the abdomen? Find the "sting." What are its location and use?

II. The Stages of Development. If practicable, study the larval and pupal stages of the honeybee. Compare each with the adult in regard to the head, mouth parts, legs, and body covering. Where are these immature stages of the bee to be found?

EXERCISE 72

THE HOUSE FLY

Some other fly may be substituted for the house fly if desired. If this is done, the house fly should be used for comparative purposes.

I. The Adult. Place the specimen on white paper and study under a lens. What are its size and general form? What parts of the body do you find? Note the body covering. What is its nature? What are the number and character of the legs? Of the wings? Compare the wings with those of a butterfly; with those of a beetle. Examine a head which has been mounted, " face " up, under low power. Note its covering. Examine the compound eyes. What is the character of the mouth parts? Draw the head as you see it. Examine a foot which has been mounted under low power. Draw it, showing the nature of its covering and the parts of which it consists. How is a fly fitted to carry disease germs? What food habits has it which make it a menace to health? (See Waggoner, Figs. 207 and 208.)

II. The Egg. (House fly eggs may be found in manure.) Study one under a lens. What are its size, shape, and color? Draw an egg.

III. The Larva (Maggot). (The larvæ also may be found in manure or in decaying waste matter.) What are its color, size, and shape? Are legs present? What is the food of the house fly's larva? Draw a larva, using the same scale as you did for the egg.

IV. The Pupa. (Find the pupæ in manure or in materials near by.) Study under a lens. Compare with the larva as to shape, size, and color. Do you find mouth parts? Does the house fly eat while in this stage? What developments take place during the pupal stage? Draw a pupa, using the same scale as for the egg.

EXERCISE 73

A SURVEY OF BREEDING PLACES OF FLIES AND MOSQUITOES

I. Field Work. Divide the class into groups, one group each for certain city blocks or areas which adjoin the school. After the assignment of these areas, each group may make a map showing

the location of buildings, fences, alleys, and adjoining streets. On this map may be indicated with symbols the location of each possible breeding place for flies and for mosquitoes. Each group should study the nature of each situation, determine what might be done to prevent it from continuing as a possible breeding place for these insects, and prepare a report containing suggestions for the improvement of the conditions found.

II. Conference. Each group may choose one of its number to report the results of its survey. Another member may report the suggestions of the committee for the improvement of conditions. The maps made by the various committees should be posted where they can be examined by each member of the class.

III. Each pupil may write a short paper summarizing the conditions found in the survey and suggesting remedial measures. The best of these papers might be published in the school or local newspaper.

EXERCISE 74

INTERRELATIONS OF LIVING THINGS

This project may vary according to conditions and the observations may be entirely individual if it is deemed advisable. It should be begun in early spring and should be continued for a number of weeks or throughout the spring.

I. 1. You have heard the remark, "We have too many English sparrows about our homes." Let us attempt to find out if this statement is true. Look up the history of the English sparrow's introduction into this country. What are the objections to English sparrows? Observe those which you find about your homes. Read all that you can find regarding their habits. You may choose a specific problem, such as:

a. Daily observations and records of the nest-building of English sparrows.

b. Observations and records of interference with other birds.

c. Observations and records of food habits.

d. Counts of the English sparrows as found on a single lot or in various typical locations.

Reports upon the reading and observations may be made in occasional class conferences.

2. To what native birds is the English sparrow related? Identify as many of these in the field as possible. What are the general characteristics of the sparrows with respect to food and habitat? We do not often hear of objections to native sparrows. Why not?

3. What factors have enabled the English sparrow to multiply so rapidly in this country?

II. Sparrows are seed-eating birds. Many are useful because they devour large numbers of weed seeds. (See Waggoner, Page 462.) What troublesome weeds need to be held in check in this community? Bring specimens of the most common weeds which grow in your garden. Identify each. Do the same for the weeds of your lawn and of other typical regions. From your reading, determine which plants are native and which have been introduced from other localities. By what means have weeds been introduced into this counry? Which, in general, are the more troublesome, the native or the introduced weeds?

III. The Domestic Cat. The domestic cat is an introduced animal. Find what you can of its history. What charges may be made against the cat? Why are such charges justified, at least to a certain extent? (See Waggoner, Page 464.)

IV. Do we have any definite means of knowing what will be the result when a new plant or animal is added to or removed from any region? What examples of such disturbances of the " balance in nature " are cited in the text? (See Waggoner, Page 422.) What has been the result of introducing into North America the English sparrow, certain weeds, and the domestic cat? Give additional examples, if possible.

EXERCISE 75

ANIMAL REACTIONS

I. Reaction to Light. Collect land sow bugs (*Porcellio*). (Look for these in moist, dark situations, such as the under side of boards which lie on the ground.) Place a number in a dish which has been half covered with black paper. Place the dish in the light. Leave undisturbed until the animals are resting. Then note the distribution of the animals. Record. Repeat the experiment several times. Average the results. To what stimulus have these animals responded? In what way? An animal's reaction to light is known as *phototaxis.*

II. *Reaction to Moisture.* Use land sow bugs. Cover the bottom of a pan, one half with rather moist soil and the other half with dry soil. (Use the same kind of soil for each half. Why?) Place the sow bugs near the center. Cover to exclude the light and allow the pan to remain undisturbed for some time. Then uncover and note the distribution of the enclosed animals. Record. Repeat a number of times. Average the results. To what stimulus have the animals responded? In what way? An animal's reaction to moisture is known as *hydrotaxis.*

EXERCISE 76

PLANT REACTIONS

I. Reaction to Light.

1. Place a box or pot in which young oat seedlings are beginning to appear above the soil, a short distance inside a sunny window. Leave undisturbed for a few days. Then note the position of the plants with relation to the light. Reverse the position of the box. Note any changes in the position of the plants.

2. Keep oat seedlings in darkness until about an inch high. Then expose for two minutes to sunlight which enters from one side only. Leave in darkness for a number of hours. Examine at the end of the period for any change in the position of the plants.

To what stimulus are the plants responding? This reaction is called *phototropism.*

II. Reaction to Gravity. Obtain the stems of large growing grasses. From these cut sections in such a way as to include two nodes and an internode in each. Place these sections in moist earth in a flower pot. See that they stand in a vertical position when the pot is upright. When prepared, turn the pot on its side. Leave undisturbed for twenty-four hours or longer. Observe at the end of this period. Where in a grass stem does growth occur? (See Waggoner, Page 15.) To what stimulus has the stem responded? This reaction is called *geotropism.*

EXERCISE 77

THE SUNFISH

Obtain a number of living sunfishes and keep them in an aquarium in the laboratory. Observe them very frequently.

I. Where were the fish obtained? In what kind of water, shallow or deep, still or running, clear or cloudy, were they found?

II. What is the position of the fish in the water? Note the shape of the body. Compare the body in length, width, and depth. Note the covering of the body. To what may the arrangement of the scales be compared? What makes holding the fish in the hand a difficult matter? How do the shape of the body and the slimy coating adapt a fish for its movement through the water? Note the *fins.* How many paired fins do you find? The anterior ones are the *pectoral* fins and the posterior, the *pelvic* fins. These fins correspond to the paired limbs of the higher vertebrates. Of the unpaired fins, the one in the median dorsal line is the *dorsal* fin; the one in the median ventral line, the *anal* fin; and the one at the posterior end, the tail or *caudal* fin. Which are used chiefly for propelling the fish through the water? Which are used chiefly for maintaining its balance? Note the structure of the fins. They are supported by *fin rays* and hard sharp *spines.* Compare the size

of the head with that of the remainder of the body. Note the position of the eyes. Does the fish close its eyes? Explain. Note the position, shape, and size of the mouth. Watch the movements of the mouth. Find the gill openings on either side of the body. The covering of each is an *operculum*. Note the form and the movement of the operculum. Does the operculum move in unison with the mouth?

III. Respiration in the Fish.

1. In a preserved (or freshly killed) fish, examine the gills. Note the four pairs of bony *arches* which act as supports for the delicate gill *filaments*. Water enters the mouth and passes out through the gills. As it passes through the gills, some of the oxygen which is in solution is removed by the blood circulating through the gill filaments. Review the method by which the human body obtains its supply of oxygen. Compare this with what takes place in the gills of a fish.

2. Slowly heat a beaker of cold water. Note the bubbles which form during the heating. These are air bubbles. What becomes of them? From this experiment determine which holds the more dissolved air, cold or warm water. Why do fish come near the surface in warm water? Why is ice packed about or placed in the minnow buckets used by fishermen?

3. In the process of photosynthesis, what gas is used by the plant? What is released? Why, then, can green water plants and fish live together in an aquarium to the great advantage of each other?

IV. Make a drawing of a side view of a sunfish.

EXERCISE 78

THE FROG

Capture one or more live frogs and bring them into the laboratory.

I. The Living Frog. Observe in the water and out of it. When quiet in the water, what is the frog's position? What is its rela-

tion to the surface of the water? Why cannot a frog remain under the water for an indefinite period? Watch the frog swim. How does it propel itself? Watch a frog move about outside of the water. What enables it to jump so far?

II. The External Structure.

1. What is the size of the mature frog? Of what parts does the body consist? What is the nature of the body covering? Compare with that of the sunfish. What is the color and what markings are present on the upper surface? Compare the under with the upper surface. Why is the difference in color of advantage to an animal which lives in water? Note the looseness of the body covering. Of what advantage is this looseness?

2. *The Head.* Compare the size of the head with that of the whole body. What is its shape? What is the size of the *mouth?* Determine in what direction the *lower jaws* move. Examine the *eyes.* What are their location, size, and shape? How many *eyelids* are present in each eye? Gently touch the eye of the living frog. Note how the eyes can be withdrawn into the *orbits.* (The orbits are depressions in the skull which partially enclose the eyeballs.) Back of the eyes look for the *eardrums,* circular areas of tightly drawn skin. Locate the *nostrils.* What is their use?

3. *The Limbs.* Compare the *fore* and *hind limbs* in respect to size. Note the parts of the fore limb. These are the *upper arm, fore arm,* and *hand.* Find the corresponding parts in the hind limb. They are the *thigh, shank,* and *foot.* How many *fingers* has the hand? How many *toes* has the foot? Compare with your hands and feet. Note that the hand and foot are " webbed." Of what use is this characteristic to the animal?

4. Make a drawing of the dorsal view of the frog.

III. The Internal Structure. Examine a preserved specimen.

1. Open the mouth. Find the *teeth* near the edge of the upper jaw and in the roof of the mouth. In the lower jaw note the attachment and the size of the *tongue.* How is the tongue adapted for capturing insects? In the lower jaw note the circular eleva-

tion. On it find a median, slit-like opening. This opening leads into the air passages which in turn open into the *lungs*. The back of the mouth leads into the *esophagus*.

2. Examine a prepared dissection. Note the skin which has been cut and turned back. What do you observe with respect to its thickness and character? Beneath the skin is a *muscular* layer. When the body wall is opened and turned back, the contents of the cavity of the trunk are exposed. Note the thin membranes in whose folds some of the organs are suspended. These are the *mesenteries*.

3. Find the *heart* at the anterior end of the body cavity. The pointed posterior part of it is the *ventricle;* the two dark-colored *auricles* are anterior and dorsal to this. From the right side of the base of the ventricle, a tube which forks into two branches carries the blood away from the heart. Each branch divides into three trunks, one pair of trunks uniting to form the *dorsal aorta*, the artery which supplies most of the body. The blood from the body returns by means of veins to the right auricle. On either side, near the heart, are the *lungs*. These connect with the opening in the mouth previously observed. The long digestive tube extends from the mouth to the *anus*. Beyond the *esophagus* lies the enlarged *stomach*. This connects with the coiled *small intestine*, which in turn leads into the *large intestine*. The three large, reddish-brown lobes of the *liver* lie at the side of and back of the heart. Situated in the loop formed by the intestine and stomach is the *pancreas*. On either side of the posterior part of the intestine in the dorsal region of the body cavity is a flattened reddish body, a *kidney*. Near the ventral surface of each kidney, in the male frog, is a white, elongated reproductive gland or *testis*. In the female, an *ovary* occupies a corresponding position. Each ovary is a large lobed mass, mainly composed of eggs. The eggs are black and white. The ducts of the ovaries are long and much coiled. They lie at either side of the ovaries. In both sexes a tuft of finger-like masses of yellow fat may be found connected with the reproductive glands. Find a thin sac, the *urinary bladder*, in the extreme posterior end of the body cavity. This is an outgrowth

of the intestine. (For a study of the nervous system a specially prepared dissection may be provided by the instructor.) The *brain* lies in a cavity in the top of the skull. What is its color? Note the parts of which it consists. Extending posteriorly from the brain is the *spinal cord.* How is it protected? Find some of the *spinal nerves* which emerge from the sides of the spinal column. Note that these are paired. The main part of the nervous system is in the dorsal region. Compare the nervous system with that of an invertebrate.

EXERCISE 79

THE METAMORPHOSIS OF A FROG

Collect a number of frog eggs in March or early April. Place in jars or aquariums in which some green water plants are present. Observe from day to day. A series of drawings and of brief notes, dated as the observations are made, will make a satisfactory record of what takes place in the development of the egg and young frog. Note any changes in form, size, and activity. How long is it before the tadpole in the jelly-like envelope begins to move? When does it escape from this covering? Note the head. Note the position and size of the mouth. When do the external gills disappear? When do the internal gills first appear? After the disappearance of the external gills, note the operculum. Through how many opercular openings does water escape after its circulation through the gills? On which side of the body is this opening? Compare the body of the tadpole with that of a fish with respect to its shape, gills, tail, and fins. What is the use of the tail? From the ventral side, try to see the coiled digestive tube. (This is adapted for the digestion of vegetable food.) Compare with that of the adult. How does the food of the adult differ from that of the tadpole? Which legs appear first? How is the disappearance of the tail related to the development of the legs? (The materials in the tissues of the tail are eventually absorbed and utilized during the development of the legs and of the remainder of the body.)

The fore legs are developed under the operculum. How soon after the hind legs do they appear?

How long a time is required for the frog to pass through the tadpole stage? What is its size at the end of this period? What changes must occur with relation to digestion, respiration, and locomotion before a frog leaves the tadpole stage?

EXERCISE 80 (Supplementary)

REPTILES

If possible, procure a living turtle (or tortoise) and a garter snake for observation in the laboratory. (Much needless fear of snakes may be overcome if interest in their habits is aroused.)

I. The Turtle (or tortoise — land forms are tortoises). What is the general shape of the body? What is the character of the covering? The upper part of the shell is the *carapace;* the under, the *plastron.* How many rows of plates do you find on the carapace? Note their markings. If an empty shell of a turtle (or tortoise) is available, note its structure. Observe that the outer plates are of a horny nature and that beneath them is a bony layer. Look at the inside of the shell. What does its structure suggest with regard to its relation to the skeleton? What is the use of the turtle's shell? Note the shape, the position, and the covering of the head. Explain the position of the nostrils; of the eyes. Note the character of the jaws. What are the nature, position, and covering of the legs? Note the character of the toes. Watch the turtle walk and swim. How does it carry on these activities? Observe the manner in which the animal protects or defends itself. Find out what you can of its food habits. What adaptations has it for securing food?

II. The Garter Snake. Observe the general form and color of this animal. What peculiar markings has it? What is the nature of the body covering? Note the arrangement and shape of the scales. How does the shape of the scales vary on different parts of the body? Compare the snake with the turtle. What

likenesses do you observe? What differences? Watch it " crawl " on a smooth surface, such as glass, and then on a rough one. How does it " crawl "? Why did it have difficulty in the first case? Note the large mouth. Induce the snake to " strike." How does it do this? Note its forked tongue. Find out what you can of the food habits of this snake. What adaptations has it which fit it for its manner of food-getting?

EXERCISE 81 (Supplementary)

A BIRD

Procure a live pigeon or English sparrow and place it in a cage. Supplement this with a mounted specimen of the same bird if possible.

What is the general form of the bird? How does its shape adapt it for flight? Note the body covering. What characteristics has such a covering which further fit the bird for flight? How are the wings adapted for flight? What is the shape of the head? How is it attached to the body? What is the advantage of a neck which moves as freely as that of the bird? Where are the eyes located? What are their size and shape? Note the eyelids. What is their nature? The ears are below and back of the eyes. Examine the *beak*. Determine which part of it is movable. Note the nostrils. What is their position? Draw the head. Where are the legs located with reference to the body as a whole? How are they adapted to the bird's mode of life? Note the feet. How many toes are there? What is their position? Draw a foot.

EXERCISE 82 (Supplementary)

A MAMMAL

For this study procure a live " rabbit " (hare) or a squirrel. Mounted specimens may be used if desired. (The rabbit and squirrel are *rodents*, or gnawing animals.)

What are the size and color of the animal? What is the general

nature of the body covering? What variation do you find in the *fur* on different parts of the body? Compare the fore and hind legs as to their size and use. Examine the feet. What are the number and nature of the toes? Of what use are the claws? Note the character of the under side of the feet. Note the size and location of the ears. Watch their movements. Observe the eyes. How many eyelids do you find? What is the nature of the front teeth? These teeth continue to grow throughout life. Since the outside is much harder then the inside, the inner portions wear away more rapidly than the outer, and the teeth remain sharp. What is this animal's food? How are the teeth adapted for the use of such food?

EXERCISE 83

INTERRELATIONS OF THE LIFE ABOUT A POND

I. Field Study. Make a survey of all the living forms in the pond or within three feet of the edge of the water. Collect specimens of each form. Let certain members of the class act as recorders. These recorders may make a note of the places where the specimens are found and of any activities observed before they are collected.

II. Laboratory Study and Conference. Identify the specimens which have been collected and determine the groups to which they belong. Look up their food habits. (See Needham and Lloyd, *Life of Inland Waters.*) Arrange the report in a table as suggested below:

POND LIFE

NAME	ANIMAL OR PLANT	GROUP	WHERE FOUND	FOOD
(*Example*) Whirligig beetle	Animal	Insect	Surface of water	Small insects which fall into the water

EXERCISE 84

INTERRELATIONS OF THE LIFE IN AND ABOUT A DECAYING STUMP

I. Field Study. Find a stump which is in an advanced stage of decay. First determine what animal life and plant life exist near the stump. Collect specimens for further study and identification. Next remove any bark which may be on the stump. Examine the under side of the bark and the exposed surface of the wood for the presence of living organisms. Break or saw open the upper part of the stump. Examine the wood for the evidence of or presence of borers. Do you find any indications of fungous growths either on the surface or in the wood? Now continue breaking away the stump until you have reached the ground. Dig both around and into the base of the stump, looking for living organisms as you do so. In all cases note the activities of the organisms found, determine what is the food of each, and make a note of these facts on the labels of the containers which are used to hold the specimens.

II. Laboratory Study. Identify and label all specimens taken into the laboratory. Read about and discuss their characteristics, their food habits, and their methods of reproduction. List in a tabulated form as follows:

Name	Plant or Animal	Where Found	Activities (*If any are observed*)	Food
(*Example*) White ant (termite)	Animal	In decaying wood		Dead wood

EXERCISE 85

SUPPLEMENTARY PROBLEMS

These exercises may be assigned to individuals or to groups, or they may be used by the class as a whole. The instructor may allow each member of the class to choose one or more problems for individual work upon which he may report to the class toward the end of the year, or he may grant this privilege only to those pupils whose general class work is above average. It is expected that through these exercises a greater appreciation of and interest in nature will be developed.

I

DEVELOPMENT OF THE LILAC BUD

Use a lilac shrub on the school grounds or your home grounds for the purpose of making these observations. Begin the observations before the buds have begun to open in the spring. (Buds of various other plants might be studied in the same manner.)

I. Note the size, the shape, and the color of the lilac buds as they appear in early spring. What is their arrangement on the stem? Remove the outer scales of a well developed bud. Note their number, size, shape, and color. To what are these scales attached? Next examine the tiny leaves within. To what are they attached? How do they differ from the outer scales? Make drawings to illustrate what you have seen.

II. Select several buds of the shrub which you observe. Mark the twig on which these are found. (This may be done by tying a string around it.) Note the changes which occur from day to day. What becomes of the outer scales? What has been their function? Note the scars which remain when these fall. Observe carefully the way in which the inner portions grow and into what each structure develops. What becomes of the central axis of the bud? Make very frequent sketches of the plant which will show the manner of development. Date each.

III. When was the lilac bud formed? Did all the buds develop in the same way? How do those branches which bear flower clusters differ from those which do not?

IV. Near the end of the term, write an account of the lilac bud's development based upon the notes of these observations. Use your sketches as illustrations.

II

THE DEVELOPMENT OF THE FLOWERS AND FRUITS OF THE DANDELION

I. What is the appearance of the dandelion plant when viewed from above? Of what value to the plant is this "rosette" arrangement? Note the character of the stem. What is the advantage of this to the plant? What is the character of the roots? What is the "fleshy" material present in them? Explain its use. Why is this plant hard to kill out?

II. Select a plant and study as follows for ten days or more: Observe the plant several times each day. Where do the buds arise? What are the color, size, and shape of the young buds? Note the length of the flower stem at first; also the green *bracts* that surround and cover the bud. What is the position of these bracts in the young bud?

III. Mark a bud and observe it from day to day. Note what takes place with reference to:

1. The successive position of the bracts.
2. The lengthening of the flower stem.
3. The effect of sunshiny and dark days upon the opening of the flower heads. Does a single head open more than once?

IV. Examine mature seed clusters. How are the seeds scattered? What is their position while suspended in the air? Explain this. Where did the "parachute" develop? Open a head which is in full flower and find the downy portions of the "parachutes." Next, open a head that has recently blossomed. How is the

" parachute " developing? Explain the use to the plant of the changes you have observed in the flower head and in the flower stem.

V. After you have observed definitely what occurs, write an account of the development of the dandelion flower and fruit.

III

THE DEVELOPMENT OF THE FLOWER AND FRUIT OF THE MAPLE OR ELM

I. Observe the date of flowering. (These trees blossom very early in spring.) How are the flowers borne? Are they showy or otherwise? Are the stamens and pistil in the same blossom? On the same tree? How are they pollinated? What evidence do you have of this? What becomes of the scales of the flower buds?

II. Flowers. If there are staminate flowers — flowers in which no pistils are present — what becomes of them? When does this occur? What is the function of these? Observe the pistillate flowers — flowers in which no stamens are present — of the same kind of tree. Are they borne on the same individual as the staminate flowers, or on a separate one? If the tree has perfect flowers — flowers in which both stamens and pistils are present — do these have parts other than the stamens and pistils? Observe either the pistillate or perfect flowers throughout their development. Note daily the changes which occur and the development of new structures. Do all of the flowers complete their development? In the case of the trees which bear separate pistillate and staminate flowers, do both of these develop with equal rapidity? Explain. Draw the flowers observed.

III. Fruits. How long does it take the fruit to develop? How are the fruits scattered? Where is the seed held? How far are the fruits carried from the parent plant by the wind? Estimate the number of seeds on a large tree. Why is it necessary for seeds to be scattered? Observe, if possible, when these seeds germinate. Draw the fruit.

IV

THE BEHAVIOR OF THE ROBIN AND THE RED-WINGED BLACKBIRD

Observe the robin or red-winged blackbird daily throughout the spring months and keep a report of your observations in the form of a diary. A week before school closes write an account of the observations which you have recorded in your diary.

I. What is the date of the first arrival? Note the increase in number from day to day. How long after the first arrival is the maximum number seen? Do the robins come singly or in flocks? Do they arrive by night or by day? Why do you think so?

II. What characterizes the behavior of the early arrivals? Note any changes in the actions of the birds as the spring advances. What is the date of the first nest-building? Where is the nest located? Note the effect of the weather upon nest-building. What materials are used for the nest? What are the manner and arrangement of the materials?

III. Note the date of the first appearance of eggs in the nest. What are the color, the size, and the number of the eggs? At what intervals are the eggs laid? Record the dates and the length of the period of incubation. What are the characteristics of the young birds? How long does it take the young to mature? (If your school closes before you have an opportunity to answer this question from observation, look up this fact in some book on birds.) What is the date when the young leave the nest? What is the color of the plumage at this time? The markings? Observe the behavior of the young; of the parents when the young are in the nest and when the young leave the nest.

IV. What do you observe to be the food of the adult? Of the young? How is it obtained? Study the birds as they appear upon the lawn when feeding. How do they obtain worms from the soil?

V. Note the call-notes of the early arrivals. What changes in these calls occur later in the season? At what time of day does this bird sing the most? How many call-notes does it have? Do its call-notes seem to indicate anything regarding its "mental state"? Explain your answer.

V

COMMON TREES OF THE VICINITY

Observe closely during the fall or spring months as many of the following trees as you find in your community, and others which you wish to add to the list. Note especially the type of branching; the characteristics of the bark, such as its color and its smoothness or roughness of surface; the nature and size of the buds; the arrangement, the form, and the character of the leaves; the time of the appearance or of the falling of the leaves; the nature of the flowers and of the fruits. Discover through observation and reading the uses and relative values of these trees. Learn which were introduced and which are native. (Gray's *New Manual of Botany* will be helpful in this work.) Make a chart on which to record your observations in a tabulated form.

Suggested list of trees:

Red, silver (soft), sugar (hard), and Norway maples
White and black oaks
Red and canoe birches
White (American) and red (slippery) elms
Sycamore
Catalpa
Tulip tree
"Carolina" poplar
Linden
Horse-chestnut
White ash
Redbud
Hickory
Walnut

VI

COMMON SHRUBS OF THE VICINITY

Learn what you can about twelve or more common shrubs. Choose those which you find on your school grounds, about your home, and in parks near by. Read descriptions of these and study pictures of them. Learn whether each is native or introduced. From your observations during the spring, determine if possible when the flowering of the shrub occurs, when the first leaves appear, and whether the shrub is hardy or not. What are the height, the nature of the branching, the appearance of the bark, the form and arrangement of the leaves, and the color and characteristics of the flowers? For what purposes may each shrub be used?

Among the shrubs which may be found in most communities are the following:

Lilac
Van Hout's Spirea (bridal wreath)
Japanese barberry
Common elder
Staghorn (hairy) and smooth sumach
Japanese quince
Forsythia (golden bell)
Mock orange (syringa)
Japanese rose
Snowball
Highbush cranberry
Privet
Flowering currant (golden)
Tartarian honeysuckle
Hydrangea
Deutzia

VII

WILD FLOWERS OF THE VICINITY

Observe the wild flowers as they appear in early spring. Keep a record, as suggested below, which will include the name, the date of flowering, the habitat (the type of place in which the plant is found), and the marked characteristics of the plant. Among the characteristics noted should be the arrangement and form of the leaves, of the flowers, and of the fruits. When possible determine the nature of the underground parts. Find out what you can of the purposes and principles of the Wild Flower Preservation Society of America.

Name	Date of flowering	Characteristics	Habitat

VIII

WEEDS OF LAWNS AND GARDENS OF THE VICINITY

This exercise may be used in the late spring or in the early fall. (It may have been used as a part of Exercise No. 74.)

Make a collection of specimens of all the weeds which you find on your lawn and another of those which you find in your garden. Identify each. Learn whether it is a native or an introduced plant. (See Gray, *New Manual of Botany*.) Why is it troublesome, how is it disseminated, and in what way can it be eradicated or kept in check?

IX

REPTILES OF THE VICINITY

Make careful observations of all the reptiles which you see during the spring months. Identify them and read any literature concerning them which is available. Record in a tabulated form.

Name	Place Found	Size	Color	Markings	Actions	Economic Importance

X

COMMON BIRDS OF THE VICINITY

Keep a record of the birds which you frequently observe in the spring near your home, near your school, along the roads, and along the wooded banks of streams. Note the time of year when they first arrive, when they leave, and when they nest; their size, color, and markings; and their food habits. From your reading determine the economic importance of each bird studied. (See Chapman, *Birds of Eastern North America.*) Plan a chart upon which you may record your observations. Find out what you can of the purposes and the work of the Audubon Society. (Address all inquiries to the National Association of Audubon Societies, 1974 Broadway, New York City.)

XI

SMALLER WILD MAMMALS OF THE VICINITY

Make careful observations of each of the smaller wild mammals which you see during the spring months. Observe their activities, especially when they are unaware of your presence. From your

reading learn as much as you can of their economic importance. Note the characteristics of each, such as the size, the general color, the peculiar markings, the food used, and the nature of the home. Note any adaptations which especially fit the animal for its mode of life. Plan a chart upon which to record your observations.

APPENDIX

I

A TEST FOR CARBON DIOXIDE

Add a little limewater to a test tube of the gas which is to be tested for the presence of CO_2. If CO_2 is present, the limewater becomes milky in appearance. (A drop of limewater adhering to the end of a glass rod can be inserted in the tube. This is the most convenient method of applying the test.) The limewater may be made by adding a piece of quicklime, about the size of an egg, to a quart of water. The liquid should be filtered before it is used. (See Waggoner, Fig. 123.)

II

A TEST FOR OXYGEN

Lower a glowing splinter into the gas which is to be tested for the presence of O. If it bursts quickly into a flame much free O is present. If it is extinguished, little or no free O is present.

III

FEHLING'S SOLUTION

To prepare, make up the following solutions and keep in separate bottles:

1. 35 gm. of copper sulphate dissolved in 500 cc. of H_2O.
2. 160 gm. of sodium hydroxide and 173 gm. of Rochelle salt dissolved in 500 cc. of H_2O.

When ready to use the solution, mix equal parts of the two.

IV

STARCH PASTE

To prepare starch paste mix 1 gm. of powdered starch with a little cold H_2O. Add this mixture, drop by drop, to 100 cc. of boiling H_2O, stirring all the time. Continue to boil for several minutes. This makes a thin starch paste suitable for use in the experiments concerned with tests for nutrients and for the action of enzymes.

V

FORMALIN AS A PRESERVATIVE

To preserve material for laboratory use, a solution of one part commercial formalin to nine or ten parts H_2O may be used.

BIBLIOGRAPHY

Chapman, Frank M., *Handbook of Birds of Eastern North America.* D. Appleton and Co., N. Y., 1923.

Comstock, John Henry, *Insect Life.* D. Appleton and Co., N. Y., 1923.

Conn, H. W., *Bacteria, Yeasts, and Molds in the Home.* Ginn and Co., Boston, 1917.

Ditmar, Raymond L., *The Reptile Book.* Doubleday, Page and Co., Garden City, N. Y. 1922.

Georgia, Ada E., *A Manual of Weeds,* Macmillan, N. Y., 1920.

Gray's New Manual of Botany. Rev'd by Robinson and Fernald. American Book Co., N. Y., 1908.

Keeler, Harriet L., *Our Native Trees,* Chas. Scribner's Sons, N. Y., 1920.

Keeler, Harriet L. *Our Northern Shrubs,* Chas. Scribner's Sons, N. Y., 1920.

Needham, James G. and Lloyd, J. T., *The Life of Inland Waters.* Comstock Publishing Co., Ithaca, N. Y.

Nelson, Edward W., Smaller Mammals of North America, *The National Geographic Magazine.* Vol. XXXIII, No. 5, May, 1918.

Nostrums and Quackery, Vol. I (1912), Vol. II (1921). American Medical Association, 535 N. Dearborn St., Chicago.

(NOTE. — See Waggoner's *Modern Biology* for additional reference.)

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