A Manual of Laboratory Studies in Biology

Linville & Olmstead

A MANUAL
OF
LABORATORY STUDIES IN BIOLOGY

TO ACCOMPANY LINVILLE'S
The Biology of Man and Other Organisms

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PREFACE

This series of laboratory studies is published to accompany Linville's *The Biology of Man and Other Organisms*. The book will meet the usual demand for a laboratory guide, but it is hoped that it will serve an even greater purpose than that of assisting overworked teachers to lighten the burdens created by large classes. Like the accompanying textbook, the Manual is the outcome of much thinking about how to present the subject of biology in the most interesting and effective way.

The authors have tried to introduce each laboratory study on the basis of the natural, or possibly the acquired, interest of the student. The development of the study is carried along with interspersed pieces of information, or suggestions and questions. In some of the studies the questions are numerous; in others few. The variety in the form of the presentation is in part due to the varying availability of the subject matter, and in part to a frank effort to experiment in a field which has been much trampled over by the leaden feet of uniformity. If the authors have disregarded the form of question and the itemized list of points that give the elusive mind of an unwilling student no chance of escape from the obligation to answer, it is because the authors believe that a new attitude in making laboratory studies will help the teacher get better results under more cheerful circumstances than may have been possible formerly.

This change of attitude carries with it an intention to impart here and there some idea to serve in every study as the basis for further suggestion on the part of the student.

The information given in these scattered paragraphs within the Studies is so placed as to provide for the continued development of new phases of the study. The authors trust, however, that the information thus given is always in itself to the point and worth while.

While providing for a continued development of interest in the laboratory studies, the authors have also paved the way for the practical development of a new educational plan in laboratory procedure. As a rule, teachers and writers of laboratory manuals select a small project, and organize a definite and speedy way of working it out. That accomplished, the next step is to take a related project, and organize the effort of the class to work that out also. The relation between the two projects may or may not be noticed by the student. However, the "experiments" are done, and progress is recorded.

But the present authors incline to the belief that the relation existing between processes in nature is liable to be slighted in the understanding, or missed altogether, by those who pursue the method of study just noted. In order to comprehend the important relation to be found between one set of facts and another, studies must be so organized as to make it possible for the student to see the relations as they work out. To do this takes time. We may not know whether it takes more time, or less, to study the biological principles in their relations than to study scraps of interesting information with the hope that they may be applied later on. The best that teachers of biology can do in the time allotted to their work is to formulate a method, and to try to apply it toward the accomplishment of their aims.

As an indication of the method the authors have followed, Laboratory Study 4, Oxygen and Oxidation, may be examined. In this study the student learns how to obtain oxygen. He also finds out something about the properties of a gas. He studies oxidation as a process, and learns something of the relation of oxygen to other elements in the manifestation of the process. He goes on in the same study to comprehend the connection of the release of energy and the formation of new compounds with the process of oxidation. He builds up a conception of the process; he is able to formulate his own definition of it, and to understand its industrial application and importance.

The authors would like also to call attention to the study on Osmosis. Here again topics that are sometimes spread over several only slightly connected projects are treated as functionally related facts. The authors believe students will really understand osmosis after following this study. The phases of osmosis as they are presented in unrelated fashion are not easily understandable by the adolescent mind.

The advantage of the plan of the Studies is nowhere shown better than in the animal and plant forms considered. The study of the Earthworm is an examination of the whole earthworm, except the internal anatomy. The student realizes that he is dealing with something more than a specimen. The creature is living. It moves, it breathes, it responds to stimuli, it reproduces, and it bears an economic relation to man himself.

The authors have endeavored to introduce throughout certain features that may be regarded as integrating in their effect, as well as being of fundamental importance in themselves. Among these are the following:

1. How organisms maintain their own life as well as the life of the species.
2. The relation of an organism to other organisms on which it subsists, and among which it lives.
3. The special relation of each species to the welfare of man, and the extent to which it may be modified in character or abundance to suit the needs of man.
4. The adaptation of structure to function.
5. The occurrence of beauty of form and color in life.

6. The fundamental biologic functions of sensation, motion, respiration, food-taking, digestion, absorption, circulation, assimilation, excretion and reproduction.

A fundamental biologic principle which the authors have illustrated and applied in LABORATORY STUDY 40 and elsewhere in the series is important enough to have still greater emphasis. It is perhaps not too strong a statement to say that one's understanding of biology is meager indeed if the conception of the great cycle of change from organic to inorganic, and from inorganic to organic, existence has been left out of account. It is this great and inclusive conception that constitutes one of the most vital stimuli to the imagination that science affords.

The Laboratory Studies are arranged in the order that has now become general. In their sequence and treatment some of the later studies clearly require the understanding of facts and principles that have been discussed in earlier studies. However, considerable flexibility in the sequence of studies as followed by a class is possible.

There is sometimes a demand for an extended series of suggestions to teachers. The authors have decided to depend on the Studies themselves to provide all the suggestions necessary for every teacher, save possibly the least prepared ones. And for these even a book of suggestions would hardly suffice.

AUGUST 1, 1924 THE AUTHORS

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MANUAL OF LABORATORY STUDIES IN BIOLOGY

LABORATORY STUDY 1

PHYSICAL CHANGE

The substance of the things we see about us does not always remain the same. Sometimes the size changes; sometimes the appearance changes, as the color or texture; and sometimes the state changes, as from liquid to solid or solid to liquid. So long as the change does not involve an alteration of chemical composition, we call it a *physical change.*

1. **What physical changes may take place in a piece of wood?**
2. **When have you seen iron change physically, always remaining iron?**
3. **What are the physical changes that may appear in water?**
4. **What are some physical changes that may take place in air?**

LABORATORY STUDY 2

CHEMICAL CHANGE

Considerable changes in matter are taking place constantly in nature and in the arts. When a change occurs in the properties or qualities of a substance, as well as in its appearance, we call it a *chemical change.*

1. **What happens in the burning of wood that leads you to think that a chemical change takes place?**

2. **What are the changed properties apparent in a piece of iron rust that indicates a chemical change?**
3. **Pour some sodium carbonate (washing soda) into a test tube containing some dilute hydrochloric acid. What is the evidence that a chemical change takes place?**

LABORATORY STUDY 3

ACIDS AND BASES

There are two classes of substances that are distinguished by their effect on certain chemical *indicators*, such as litmus paper, the chief property of which is provided by a saturation of logwood dye.

The color of a piece of litmus paper is red when dipped into acetic acid produced in vinegar, or blue when dipped into sodium carbonate solution (washing soda), or into a solution of sodium hydroxide (common lye). Substances that are neither *acid* nor *alkaline* are said to be *neutral.* Such substances have no effect on the litmus paper.

Bring from home a list of ten or more articles of food solutions which you have tested with the litmus paper. Which are acid? which are alkaline? and which are neutral?

LABORATORY STUDY 4

OXYGEN AND OXIDATION

Oxygen is an important element in the air. It is mixed with the gas nitrogen, small quantities of carbon dioxide, argon, and water vapor. In volume, oxygen is about one fifth of the air. It is present everywhere in chemical combination in the world of material things. We shall see how life itself depends on oxygen.

I. OBTAINING OXYGEN

The materials useful for obtaining oxygen are easy to secure. The laboratory pneumatic trough or a fairly deep vessel may be partly filled with water. Fill a jar or wide-mouthed bottle with water. Close the jar and invert it, lowering it into the water of the deep vessel until the mouth of the jar rests on the shelf on the pneumatic trough, or on two flat metal or glass articles in the bottom of a vessel.

What is the reason the water does not run out of the inverted jar?

Next take a large test tube to which a rubber one-hole stopper has been fitted. Thrust through the hole of the stopper a glass tube from twelve to eighteen inches long, bent to turn down into the test tube a short distance, and near the end bent to turn up into the mouth of the jar.

Mix one to two teaspoonfuls of *potassium chlorate* and *manganese dioxide* in a dish and pour one or two teaspoonsfuls of the mixture into the test tube. The two chemicals each contain a large amount of oxygen which they give off in the presence of heat. Close the mouth of the test tube, and adjust the outer end of the bent tube under the mouth of the jar. Support the test tube in the clamp of an iron stand, or hold it near the top by a loop of paper while you move the flame of an alcohol lamp or a gas flame back and forth across the lower end of the test tube. Soon you will see the bubbles of gas and air passing up through the water.

What are you learning about the properties of gas at this stage of the experiment?

When all the water has left the jar, close the mouth under water, reinvert it, shake the jar to "wash" the oxygen free from the smoke of heated chemicals as much as possible. Why should you expect oxygen itself to be transparent?

II. OXIDATION

Next light a long pine splinter, extinguish the flame, and immediately remove the stopper from the jar of oxygen, thrust the glowing ember into the jar, and note the result. What happens to a glowering ember if left in the air? Thrust a lighted splinter into the oxygen, and compare the flame with a flame in the air.

What have you learned thus far about the importance of oxygen?

Try lighting several splinters, lowering them into the oxygen jar and quickly closing the jar with the cover. What happens to the flame? Afterward uncover the jar and thrust a lighted splinter into the jar. What happens? You may be puzzled by what you see.

But let us study the burning of a splinter in the air. What happens to the splinter as the flame progresses? You see a black substance being disclosed. This is carbon. As the burning continues what happens to the carbon? When the burning is over what is left? Will this substance burn?

If you can burn up a whole stick by holding it in an iron spoon, weigh a stick and afterward weigh the ashes left. What per cent of the weight of the stick disappears into the air?

Now if the oxygen you had in the jar disappears, and if the carbon in the burning stick disappears, you are on the track of a very important chemical process. What do you think has happened?

This chemical process which is called *oxidation* is important because, in the combination of oxygen with some other element, energy is set free and *work* is done. The commonest forms of energy in the cases of oxidation are heat and light. But it is also important to note that, while the two elements, carbon and oxygen, disappear in this experiment they are not destroyed, for they exist as a gas in the air. How they act toward a flame, we see in the test of putting a lighted splinter into a jar where the gas—carbon dioxide—has been collected.

1. If we multiply the burnable substance in a stick by many tons of carbon, as in the coal used by a furnace in a house or in a factory, what happens chemically, and of what importance may the process of oxidation be in these cases?
2. What happens to the carbon dioxide formed?

III. COMPARISONS

It is important to know whether oxygen will combine chemically with any other element. Let us take a piece of magnesium such as is used in taking flashlight pictures, or in making fireworks. Try burning a piece by touching a match to it.

What forms of energy are set free?

Weigh a piece of magnesium. Then burn it and weigh the white powder resulting.

How do you explain the result you obtain?

Collect a new jar of oxygen. Take a piece of picture wire a foot in length. Fray out one end; heat it and dip into a spoonful of sulphur or paraffin. Dip the wire, while burning, into the jar of oxygen.

On comparing with the other two cases of oxidation, what do you think is probably formed in this case?

It is interesting also to note that iron will combine with oxygen, or will oxidize, in a low temperature in the presence of moisture. The result of this oxidation is the substance, iron rust.

Taking into account the facts you have learned, try to formulate your own definition of Oxidation.

In Laboratory Study 72 you will learn something on oxidation in the animal body and in plants. Oxidation will then appear to be the most fundamental process in life.

Textbook, pages 83, 251, 336, 347, 399.

LABORATORY STUDY 5

NITROGEN

Since Nitrogen comprises so large a portion of air, it is well to learn something of it by separating a little from a volume of air. Fill the pneumatic trough with water well above the suspended shelf. A deep vessel with sunken supports for an inverted bottle will also serve. Drop into a small crucible a piece of phosphorus. Float the crucible on the water. Touch a lighted match to the phosphorus. While it is burning invert over it and hold in place a jar containing air, lowering the bottle so that the mouth is beneath the surface of the water. Shortly after you have covered the phosphorus with the inverted jar, note the escape of large bubbles from the mouth of the jar.

1. **Explain what you have just seen.**
2. **What is being formed during the burning of the phosphorus?**
3. **Why does water come into the jar?**
4. **What have you learned about the approximate amount of oxygen in air?**

When the burning has ceased, let the fumes settle. Remove the bottle, close the mouth and set aside.

Have you reason to believe that all the oxygen in the jar has been consumed?

Explain.

Test the gas remaining in the jar with a glowing ember and also with a lighted splinter.

What do you learn?

You have obtained a quantity of nitrogen in nearly pure form.

What is the practical effect on burning or combustion of the large amount of nitrogen present in the air?

LABORATORY STUDY 6

ANALYZING WATER

Although water occurs widely in chemically unchanging condition, it can be "unmade" and made again. "Unmaking" or decomposing water is a striking experiment, and incidentally teaches much that is fundamental in science.

I. THE APPARATUS

A prepared piece of apparatus, called a *eudiometer*, can be obtained. This consists of a U-tube into each arm of which an electrode or terminal of exposed electric wire is extended. The electric current may be furnished by a direct current of a general circuit, or by dry batteries.

The arms of the U-tube should be filled with water in which is placed a small quantity of sulphuric acid to cause the electric current to be set up through the water. When the bubbles begin to pass to the collecting tubes take note of the disappearance of water as such.

What is the relative amount of the two gases coming off?

II. STUDYING THE RESULTS

When the collecting tubes are supplied with gas, invert and test each gas in turn with a glowing ember on a splinter.

1. **But first note whether either gas has an odor.**
2. **Does the gas in the larger amount or in the smaller amount encourage burning?**
3. **Next test both gases in turn with a lighted splinter, and tell which one of the gases actually burns?**

The more abundant gas is *hydrogen*, the less abundant is *oxygen*. In their relative amounts they give the basis for the chemical formula for water, which is H_2O, meaning two parts of hydrogen and one part of oxygen. We have taken the compound water, and have divided it into hydrogen and oxygen. Since we see that oxygen encourages burning, the burning of the hydrogen must have been "encouraged" to take place by oxygen.

1. **Where did the oxygen just referred to come from?**
2. **When hydrogen burns, what is being formed?**
3. **Where does this result bring us?**

LABORATORY STUDY 7

OSMOSIS

Most of the fundamental biologic processes that are carried on in the bodies of plants and animals are chemical in character. But here is one, Osmosis, that is purely physical. When you do this study, you will be able to tell why it is physical.

We often wonder how it is possible for water to pass from the ground upward through the roots and the stems to the tops of very tall trees. Similarly, you might wonder how a portion of your breakfasts, or the oxygen you breathe in, may make its way into blood vessels, and leave them later on in reaching the smallest muscle fibers of your little finger. A study of the process carried on with artificial cell contents and cell walls will aid us in understanding the matter.

I. PREPARATION OF APPARATUS

Prepare four sacs by pouring liquid celloidin into test tubes, turning the tubes about until the inner surfaces have been covered. Then dry out the solvents ether and alcohol, by waving the tubes about. Gently loosen at the margin the films thus formed, and pour water inside and back of the films. Draw out the film sacs and lay them in water until you are ready to use them. Thrust a glass tube through a cork or rubber stopper. Tie the open end of the film sac about the stopper as shown in the illustration on page 248 in the textbook.

Or, you may take four "thistle" tubes of small bore. Take squares of fresh sausage skins or parchment paper large enough to tie over the flange of the "thistle." Smear vaseline under the flanges to stop crevices when the squares are tied in place. Now tie the skins or pieces of parchment paper in place with many turns of common linen or shoemaker's thread.

What part of a real cell does the film, the skin or the paper, represent?

Prepare one small beaker of a solution of grape sugar (glucose) or molasses, and one of boiled starch (very thin), and one of uncooked white of egg. Carefully pour into each sac nearly to the top the solutions of glucose, starch and white of egg. Into the fourth pour clear water. Why fill this fourth with water? If the water soon ceases dripping from your apparatus while it is held in the air, it is watertight.

In the "set-up" what in the living cell are we representing with sugar, starch and white of egg? What represents the substances taken from the soil by a plant?

II. SETTING UP THE EXPERIMENT

Fill four battery jars with water. Lower the prepared cells into the battery jars until the water in the jars is level with the solution in the thistle tubes or sacs. Adjust them there with clamps extending over the edge of the battery jars. All solutions now have an even start. Note the hour.

1. **In twenty-four hours what has happened?**
2. **Has any sugar or starch or white of egg passed through the membrane into the surrounding water?**
3. **How did you find out?**

III. STUDYING THE RESULTS

Place a spoonful of sugar on a piece of paper, and near it pour a few drops of water. Gently connect the sugar with the water.

Describe what happens.

Do the same thing with a mass of boiled starch, and also with uncooked white of egg. Note what happens.

Next drop a spoonful of sugar into a tumbler of water and into another some boiled starch, and into a third some uncooked white of egg. In a few minutes test the water in each tumbler for the presence of the substance poured into it.

What has happened in each case?

You have noted an important fact about substances that in some cases are *soluble* in water, and in other cases slightly or not at all soluble. The process by which soluble substances like any kind of sugar mix readily with water and scatter throughout the *solvent* is called *diffusion*. This process is apparently hastened in solutions in which the solid has a great attraction for water. You saw the attraction being manifested when the spoonful of sugar lay adjacent to the water.

1. How does the physical attraction between water and a soluble substance manifest itself when a membrane is interposed between the two?
2. What is the result when the membrane is interposed between water and an insoluble substance?
3. Supposing the glucose in the cell contents of the root-hairs attracts the soil water carrying the minerals in solution, what do you think may happen to the glucose in the succeeding cells, on the way upward to the leaves, that would make it possible for the stream of water and minerals to continue?
4. What do you think may happen to the incoming minerals that prevents a clogging of the pathway to the leaves?
5. What happens to the water that makes it possible for the stream to continue flowing?

We come now to the matter of considering now it is possible that starch which cannot pass through the membrane nevertheless is found in plant cells. If starch is made in leaves, we must explain how it comes to be found in the roots also. If we eat the starch in bread and potatoes, is starch also found in the tissues of the body? We know that starch is not found in animal tissue. Some of these points we may be able to answer now, but others will be taken up in connection with the food-making process in plants.

1. What must happen to the starch that we eat?
2. What may happen to the starch that is made in the leaves?
3. Similarly, what may happen to the protein that we

eat in the form of egg, meat or cereal, before osmosis can occur?

4. **Why is it correct to say that osmosis is a fundamental biologic process?**
5. **And why do we call it a physical process?**

Textbook, pages 248, 249.

LABORATORY STUDY 8

THE TESTS FOR THE ORGANIC NUTRIENTS

Chemists have studied the composition of foods, and have discovered four distinct kinds of organic nutrients (from plant or animal sources, see textbook, page 331) occurring in varying proportions in the foods we consume. Sometimes all four nutrients occur in a single food, as in bread, but more frequently one of the nutrients predominates in the composition, one or two other organic nutrients being present in smaller percentages. The four organic nutrients are *starch*, *sugar*, *protein*, and *oil* or *fat*. Frequently starch and sugar are called *carbohydrates* (see textbook, page 332).

The chemists have not only discovered these nutrients, but also they have worked out certain tests by which the presence or absence of a nutrient may be ascertained. This study will show what these tests are, and how they may be applied.

I. THE TEST FOR STARCH

A lump of laundry starch contains nothing but starch. Drop a piece of it into a test tube containing water. Heat to boiling point and set aside to cool. Prepare a dilute solution of *iodine*, mixed with a small quantity of *potassium iodide*. Pour a little of this into the test tube containing starch.

1. What is the result?
2. Into a second test tube place a piece of bread; carry through the same process; tell the result and state your conclusion.
3. Experiment with a piece of cooked meat in the same way, and state the result and the conclusion.

II. THE TEST FOR GLUCOSE

Pour into a clean test tube of water a small amount of corn syrup. Heat to the boiling point, and before cooling pour in a small quantity of Fehling's solution, which is a mixture of copper sulphate, potassium hydroxide and Rochelle salt.

1. Describe what you see.
   The resulting color and precipitate (sediment) is the test for glucose, but fruit sugar and milk sugar, though not cane sugar, will show similar precipitates.
2. In a second test tube drop a piece of bread, and boil. Pour in some Fehling's solution; describe the result and state your conclusion. (Heat is known to have effect in transforming starch into sugar.)
3. Experiment with a piece of cooked meat in the same way, stating the result and your conclusion.

III. THE TEST FOR PROTEIN

White of egg is practically pure protein. Drop a piece of cooked white of egg into a clean test tube with water. After observing the result add a little concentrated nitric acid and boil. Cool, and add a little strong ammonia (ammonium hydroxide).

1. What is the color of the white of egg after the treatment with nitric acid, and also after the ammonia treatment?
2. Apply the test to a piece of meat, state results and conclusions.

3. **Try also on a piece of bread, stating results and conclusions.**
4. **Probably you have some marks on the skin of your fingers from this experiment. What does this mean?**

IV. THE TESTS FOR OIL

There are two simple tests for oil or fat. They are both physical in character. For the first test, prepare plain white sheets of paper four or five inches square or larger. Drop on one some olive oil or lard. Drop on another some water. Let both dry.

What difference do you notice?

Grind small lots of different seeds with mortar and pestle, or pound them in small pieces of cloth, transferring the pieces to the squares of paper. Or take common articles of food, and place them on the squares of paper in an oven for an hour or more, but not where it is hot enough to scorch the paper.

What is your conclusion about the presence of oil or fat in seeds?

For the other test, prepare a series of cylindrical stand tubes or other convenient vessel that can be closed tightly with a stopper. Place in the series samples of the same materials used in the other test. Pour into each enough ether to cover the contents. Close tightly and set aside for twenty-four hours.

At the end of that time, pour small quantities on squares of white paper, comparing the results with the result of pouring on ether itself and water. What is your conclusion in each case?

Textbook, pages 331, 334.

LABORATORY STUDY 9

PARAMŒCIUM

If you should take a bit of pond weed or even a wisp of hay and place it in a jar of water, a brown scum will appear on the top of the water in a few days. If a drop of this scum is examined under the microscope it will be found to be teeming with life, hundreds of minute animals swimming rapidly back and forth. The largest of these forms that whirls its way across your field of vision has a shape similar to the sole of a slipper. This is a paramœcium, one of the simplest of animals and a good representative of that large group of one-cell animals, the Protozoa. It is interesting because all its life activities are carried on in the simple cell.

I. LOCOMOTION

Place a drop of the scum from a hay infusion (hay standing in water for several days) on a clean slide, cover with a glass, and examine with the high power lens of the compound microscope. Observe the shape of the animal. Is the heel or toe of the "slipper" forward as the animal swims? Is this always true? By means of a few cotton fibers placed in the drop of water under the cover glass you will be able to study more closely those individuals that are imprisoned between the fibers. Notice the minute hair-like organs (cilia) that cover the body. Of what importance are they?

How does paramœcium propel itself through the water?

II. FOOD TAKING AND EXCRETION

Find a depression, the gullet, that extends crosswise from the forward end to a little distance beyond the middle of the animal. If you observe closely you will be able to see small particles of food being swept into this gullet. How is this taking-in of food carried on?

What are the functions of the cilia?

Notice the movement of the particles of food throughout the transparent interior of paramœcium. Now locate the clear areas, the *contractile vacuoles*, that are to be found half way between the center and each end. Watch one closely and see what happens.

What is the function of the contractile vacuoles?

III. RESPIRATION

Air is mixed with the water in which paramœcia are living.

How can paramœcium obtain its supply of air?

IV. THE NUCLEUS

Place a drop of iodine on the slide near the cover glass and draw it under the cover glass by means of a bit of blotting paper. This will make the nucleus visible. This is a very important part of the animal.

Find out all you can about the nucleus from your textbook.

Make a drawing of paramœcium at least two inches long showing these parts: cell wall, gullet, cilia, food particles, vacuoles, and nucleus. A drawing made up of your own observations is better than one copied from the book.

V. REPRODUCTION

When the paramœcia are increasing rapidly you are likely to see a few specimens looking as if they were about to be cut through the middle.

What do you think this means?

When the hay infusion has been standing a long time, you are likely to find two paramœcia joined side by side. This is called *conjugation.* Internal changes are taking place, and each is receiving a minute bit of nuclear substance from the other. Following this process the animals are able to increase more rapidly.

Can you make out where the animals are joined, and whether the united ones are smaller or larger than the single ones?

Textbook, pages 6–7.

LABORATORY STUDY 10

AMŒBA

If you are fortunate and have considerable patience you will be able to find in the sediment on both sides or the bottom of the jar from which you obtained paramœcium something that appears at first under the high power of the microscope to be a colorless, irregular little speck. This is another protozoan called the amoeba. Often amœba lives in slimy pools even in vacant lots.

I. LOCOMOTION AND FOOD-TAKING

Obtain an amœba. With the help of the teacher, watch it closely for several minutes and note its outline. Does the shape change while you watch it? The little projecting knobs that you see are called *pseudopodia* (false feet). Is there any evidence of a gullet as found in paramœcium?

What are the functions of the pseudopodia?

II. CELL STRUCTURE

Notice the differentiation of the protoplasm into a colorless outer layer (the ectoplasm) and a granular inner layer (the endoplasm). Careful observation will show a contractile vacuole, and staining with iodine will bring out the nucleus

Make a drawing of the amœba, including in it and labeling only such parts of the cell as you have actually seen.

Textbook, pages 7–8–9.

LABORATORY STUDY 11

THE MALARIAL PARASITE

There are several species of Protozoa that cause disease, the most important of which belong to the genus Plasmodium which is responsible for malaria in man. This organism spends the asexual part of its life cycle in the blood. It gets into the red blood corpuscles where spores are produced. The spores break out from the red blood corpuscles, and this causes a fever. The spores attach themselves to other cells and the process begins again. Now if an Anopheles mosquito bites the patient, some of the spores are taken with the blood into the body of the mosquito. Here the spores produce male and female cells which unite to form a fertilized egg (the sexual stage). From this ultimately come little filament-like spores which get unto the salivary glands of the mosquito. This process in the mosquito takes about eight or ten days, and then if the insect bites someone else the spores get into the blood and cause the disease.

What is the biological principle involved in each of the following preventive measures that are employed against malaria?

1. **The screening of windows and doors of hospitals and houses in malarial zones.**
2. **The drainage of marshy and swampy lands.**
3. **The removal of rain barrels and any similar places**

where small amounts of water might collect from time to time.

4. The spraying of kerosene in a thin film over certain bodies of water that can not be drained easily.
5. The introduction of fishes into bodies of water in malarial regions.
6. The erection of roosts to harbor bats in malarial regions.

Textbook, pages 10–12.

LABORATORY STUDY 12

HYDRA

Hydra belongs to a group of marine and fresh water animals. You will be interested in the unusual way in which members of this group obtain and digest their food. The fresh water hydra, either green or brown, lives in ponds or streams attached to some water plant.

I. FOOD-TAKING AND REACTION TO TOUCH

Examine the sides of the aquarium and the stems of the water plants for hydras. Remove one of them carefully, by means of a camel's hair brush, to a watch glass or a slide with a hollow cell, and place it under the low power of the microscope. What shape is the animal? Does this change, as you gently touch the hydra? How many arms or tentacles do you see, and how are they arranged? The mouth is located at the center of one end surrounded by the arms.

What seems to be the function of the tentacles?

II. REPRODUCTION

Do you see any small individuals budding from your hydra? Also you may see little lumps projecting from the sides of the hydra. The one nearest the base is the ovary in which egg cells are produced, and that nearest the other end is the spermary in which sperm cells are produced.

Describe the methods of reproduction in hydra.

Make a drawing of an extended hydra showing the mouth, tentacles, body, buds, and the sex organs, if they are present.

Make another drawing of the animal as it appears when contracted.

Textbook, pages 18–19.

LABORATORY STUDY 13

THE STARFISH

This curious five-pointed star-shaped animal lives in the sea, as does the whole group of "spiny skinned" animals, the Echinoderma, of which it is a member. We may classify them as "pests" because they feed on oysters and clams. They are remarkable because if they are cut in two, each half will regenerate an entire new animal.

Examine a dried or preserved specimen of a starfish. Do you find an anterior and a posterior end? Do you consider the word "starfish" a good name for the animal? Such an arrangement of parts is called *radial symmetry*. With the aid of a hand lens observe the rough dorsal (upper) surface of the arms or *rays*. The short blunt projections are called *spines* and are a part of the skeleton which is made up of limy plates bound together. Of what use are the spines?

Observe the ventral surface and notice the *grooves* in each ray which come together in the center. In each groove you will find rows of short, cylindrical *tube feet* which are a part of a complicated apparatus for locomotion. In the center of the ventral side is the *mouth*. At the end of each ray is a tiny red spot called the *eye-spot* (noticeable only in living animal), so called because it is sensitive to light.

Make a drawing of the ventral side of a starfish and label all the parts you have seen.

The starfish has an interesting method of obtaining and eating its food. Find out about this from your textbook.

Textbook, pages 23–27.

LABORATORY STUDY 14

THE EARTHWORM

In case you do not know where earthworms may be found in abundance, ask one of your friends who is a fisherman. If you give him half a chance he will undoubtedly tell you how these insignificant animals have helped him to secure many a delectable meal. The great English naturalist, Charles Darwin, found out that earthworms perform a service to mankind of far greater importance than that of serving as an effective bait on a fishing trip. His researches proved them to be the original plowmen. For further information concerning the activities of these dwellers in the soil consult chapter VI in the textbook.

I. LOCOMOTION

Let a living earthworm crawl over your hand, or if you object to this, place one on some moist blotting paper in a shallow tray. Notice that the body is made up of a series of rings called somites or segments. How many do you find in your worm? What is the difference between the front (anterior) and the hinder (posterior) ends? Touch both ends with a pencil and see if they are equally sensitive.

What is the approximate length of the worm when it is stretched out? When it is contracted? Does the under (ventral) surface feel different from the upper (dorsal) surface? What is the reason for this? By means of a hand lens find out the number of bristles or setæ on each segment. Have you ever seen an earthworm stretched out while a robin is trying to capture it? What is happening?

Describe carefully the way in which the earthworm moves.

II. RESPIRATION

The earthworm has neither lungs nor gills. Can you think how it is able to secure its air? Have you ever seen earthworms lying partly outside their holes on the lawn? What conditions seem to disturb them and make them withdraw from their holes? Why do we see so many earthworms on top of the soil after a heavy rain?

How and under what conditions does the earthworm receive its air?

III. SENSATION

Cover one half of the pan with a piece of cardboard. Does the earthworm prefer the darkness to the light?

What senses would you say the earthworm possesses?

IV. REPRODUCTION

The swollen band that you see about the worm is called the *clitellum*, and it secretes a sac for the eggs when they are laid.

Search for one of these sacs, about the size of a grain of wheat, in the soil of a box of earthworms, in the laboratory.

V. EFFECT ON THE SOIL

Examine your lawns or the terrarium carefully for little pellets of earth that have passed through the body of the animal. It is in this way that the worm does the plowing. What importance was attached to this phenomenon as a result of Darwin's work?

Make a drawing of the earthworm showing the mouth, segments, clitellum and the setæ.

Textbook, pages 27–30.

LABORATORY STUDY 15

THE HOOKWORM

The hookworm is a small round worm about one half inch long that lives as a parasite in the human intestine. It has interfered with the physical and mental development of a large number of children and adults in our Southern states for many years. Early treatment tends to alleviate the ill effects in infected children, but it is of vastly greater importance that each child shall be educated in certain principles that will tend to prevent infection.

The female worm that lives in the intestine sucking the blood and sending a poison into the system lays about 3,000 eggs a day which pass out of the body with the excrement. In places where there are no sewerage systems and where sanitary conditions are bad, the eggs get on the ground and are spread around by rains. The eggs hatch into tiny worms which get on the bare feet of children and adults, particularly in wet weather. They bore through the skin and cause what is known as "ground itch." Then they travel in the blood and finally get into the intestine. After an attack of ground itch it takes about seven months for the worms to arrive in the intestine and begin sucking blood.

The following recommendations were made to school children in infected districts of our Southern states (Alabama State Board of Health, Teachers Bulletin on "Hookworm Campaign in Alabama," 1912):

1. Never go with bare feet unless the ground is perfectly dry.
2. Never go with bare feet through muddy places.
3. Always wear shoes when it is raining.
4. Always wear shoes when the ground is wet.
5. Always wear shoes when the dew is on the ground.
6. If you have ground itch get it treated at once.
7. Always take treatment for hookworm disease within three months after an attack of ground itch.
8. Build and use at schools and homes privies that will prevent soil pollution and keep flies and other animals from gaining access to the contents.

Explain the biological principle underlying each one of these recommendations.

Textbook, pages 33–35.

LABORATORY STUDY 16

THE HOUSE-FLY

As a destroyer, man has succeeded far better against lesser enemies, and even against certain beneficial species, notably the passenger pigeon and the American Bison, than he has against the house-fly. In spite of many indifferent "swat-the-fly" campaigns, this pest persists in inconceivable numbers. Wherever you find man there the house-fly abounds and always to man's detriment. How well the fly is fitted to survive, and why he is always a source of danger, will be evident from the following study.

I. LIFE HISTORY

Examine with a hand lens some of the maggots or larvæ of flies that breed in decaying fish or meat.[1] Do they have legs? In about a week these larvæ become pupæ. Examine a pupa. What color is it? Is it able to move or to eat? After five or six days the skin of the pupa splits open and the adult fly emerges.

1. **Is it true that a little fly can grow into a big one?**
2. **Are all house-flies the same size?**
3. **Write a short account of the life history of the house-fly.**

II. THE ADULT

Examine either living specimens of house-flies placed in small vials or preserved specimens. You should use a hand lens for this work, and in addition, if it is possible, you should observe a fly under the low power lens of the compound microscope. Notice the divisions of the body. How many divisions or segments are there in the middle region or thorax? How many in the abdomen? How does the size of the eyes aid the fly? Watch a fly as it eats and observe the shape of the "tongue." Can you see this when the fly is not eating? Does the fly possess biting, sucking, or piercing mouth parts?

Where are the fly's wings attached? How many pairs are there? Back of each wing you will see a little white "balancer." How many legs are there, and to what portion of the body are they attached? Notice especially the coverings of the body and legs.

[1] You must keep in mind that house-flies breed preferably in horse manure. The larval and pupal stages that you are studying may be the progeny of the blue bottle fly or blow fly, both of which lay eggs in meat, but they are similar to the corresponding stages of the house-fly. Ask your teacher about the specimens you are working with, to make sure.

1. **Explain how flies are able to distribute germs and hence why they are a source of danger.**
2. **What means would be effective in combating this pest.**
3. **Make a drawing of a house-fly (x 5) and label all parts that you have seen.**

Textbook, pages 36–38.

LABORATORY STUDY 17

THE MOSQUITO

If you have ever noticed the countless tiny objects jerkily wending their way through the water near the surface of some stagnant pool or rain barrel, then you have come in intimate contact with the early stages in the life of a mosquito. These young mosquitoes are interesting creatures to study at close range, and in order to do this you should take some of them into the laboratory and place them in small jars. If you place a few by means of a pipette in small vial you may study them easily with a hand lens.

I. EGGS

The eggs are grouped in tiny raft-like masses that float on the surface of the water. Approximately how many larvæ may hatch from one of the egg masses?

Make a sketch of an egg mass.

II. LARVÆ

You may see some larvæ hanging just below the surface of the water. Which is nearer the surface of the water, the the head (the larger end), or the abdomen? What is the function of the tube at the end of the body? On the head are tiny hair-like tufts that brush food particles into the mouth.

Make a drawing (at least one and one half inches long) of a larva, labeling the parts that you have been able to distinguish.

III. PUPÆ

The head and the thorax of the pupa are quite large in comparison to the rest of the body. Does the pupa hang in the same position from the surface of the water as does the larva? How is breathing carried on? Does it swim about as much as the larva? Are you able to distinguish the eyes? the wings?

Make a drawing (at least one inch long) of the pupa, labeling the parts you have seen.

IV. THE ADULT

If you are fortunate you may see an adult emerge through a break in the top of the pupa skin and then rest there for a few minutes before it is able to fly. Observe a preserved specimen and determine its sex (the males have feathery antennæ). How many parts to the body? How many legs? How many wings?

Make a drawing (at least one and one half inches long) of the adult.

V. RELATIONS TO MAN

Do all mosquitoes bite? Is your specimen one of the common type (Culex), or is it a malarial mosquito? How can you distinguish the two? How can mosquitoes distribute malaria and yellow fever? Explain how the mosquito prevented the French from building the Panama Canal? What is the common means of extermination employed against the mosquito? How may everyone help?

What animals aid in exterminating mosquitoes? (It is said that a certain locality at Mitchell's Lake near San Antonio, Texas, was once notoriously malarial. Many roosts were built for the purpose of harboring bats, and now the locality is freed from malaria.) What is the significance of this?

Write a short story on the relation of mosquitoes to man, using the above questions to guide you.

Textbook, pages 10–12, 38–41.

LABORATORY STUDY 18

THE HONEY-BEE

The honey-bee is an excellent example of a social animal that shows high development of communal life. In the hive we have many individuals living together and working for the good of the group, and though certain individuals perform highly specialized tasks they all are benefited by this division of labor. Bees are interesting also because of their economic importance. Although several millions of dollars' worth of honey is produced annually in the United States, this fact is insignificant when compared with the activities carried on by bees in the pollination of flowers, which helps to make possible the continuance of many interesting or useful species of plants.

I. WORKER

Examine a preserved specimen of a worker and notice the size, the divisions of the body, and the body covering. Describe the antennæ. How many do you find. How many eyes are there? Are they all alike? Study the mouth parts with a strong hand lens (if possible from a prepared slide under the low power of the compound microscope). How are they fitted for obtaining nectar.

Where are the wings attached? How many are there? How many legs does the insect have and where are they attached? Notice that the third segment on each hind leg has rows of curved bristles bordering a concave area where the pollen is carried. This forms the pollen "basket." It should be examined under the microscope.

How many rings or segments are there in the abdomen? At the end of the abdomen the sting will be found. Of what use is the sting to the bee?

Make a drawing (side view) of a worker and label all parts that you have seen.

Compare specimens of queen bees and drones with the worker.

In what respect does the queen bee differ from the worker?

In what respect does the drone or male differ from the worker?

II. THE COLONY

Examine a colony of bees in an observation hive. How many different forms are there in the hive? How do they compare in size, shape, and number? What are the duties of each type of bee? Is the hive clean? What bees are responsible for this? Notice that any cracks are filled up with a brownish, waxy "bee glue."

III. THE COMB

Observe the comb. What is the shape of the cells? How are they arranged? Are all of the cells alike? Are they all used for the same purpose? How may one distinguish a queen cell? Where is the honey? Why are "supers" placed on a bee hive?

IV. LIFE HISTORY

Where are the eggs laid? The eggs hatch after about three days into larvæ. What is the appearance of the larvæ? How and with what kind of food are the larvæ fed? In a week or so the larva changes to a pupa. Do you see any pupæ? These emerge in about two weeks as adult workers. When a queen is desired the workers connect three cells in one large one and then give the larva a special diet of "royal jelly," while the larvæ that become workers are fed on digested honey and pollen. Workers develop from fertilized eggs and drones come from unfertilized eggs.

Write a story on the "Communal Life of the Hive."

Textbook, pages 41–44.

LABORATORY STUDY 19

A COLONY OF ANTS

Ants, like bees, are interesting on account of their complex social life. One may learn much about them by studying a colony in the laboratory. Perhaps the simplest way to do this is to transfer a colony that has been dug up to a Fielde Ant Nest. This nest was devised by Miss Adele Fielde, an American student of ants, and may be easily constructed by anyone.

In order to construct the nest two pieces of glass, 4 x 5 inches, are needed for the top and bottom. The walls are made of strips of glass one-half inch wide which are glued to the foundation plate (flat side down) along the edges. Two thicknesses are necessary for the walls so as to allow the ants to move around freely. At one corner an entrance one-half inch wide is left. The nest is divided into two chambers, a living room and a dining room, by a glass partition made of two strips, each one inch wide. An opening is left at one end of the partition to serve as a door connecting the two rooms. Ants are annoyed by the light, so in order to make the walls opaque they are covered with strips of calico or cambric one inch wide which are glued on with the edges overlapping the top and bottom. In order that the nest may be well ventilated when the top glass plates are laid on, strips of Turkish toweling one inch wide which have been folded over once, are cemented on the top of the glass walls and partition. After the glue has dried, and the nest is ready for use, a bit of moistened sponge is placed in the inner chamber. The top is then covered by two glass plates, each one-half the size of the foundation plate. A piece of cardboard the size of the foundation plate is laid over the top plates to keep out the light, and all the parts may be kept in place by rubber bands.

The nest is now ready for its inhabitants. An ant's nest is dug up with a strong trowel, and all of the colony including eggs, larvæ, pupæ, and adults along with some of the soil is carefully transferred to a fruit jar. In order to transfer the ants to the nest the Fielde nest is placed on a board or pan which is floated in some water in a still larger pan. The contents of the fruit jar are placed on the board near the Fielde nest and are spread out carefully in order to dry out as soon as possible. After a time the ants discover the dark moist chamber and transport their belongings into the nest. When most of the ants have moved in, the hole is plugged up with absorbent cotton, and the nest is removed from the board. The ants will live this way for some time, and their activities may be studied by removing the pieces of cardboard or lifting the nest up and observing it from below. Miss Fielde states that the food, which should consist of tiny bits of apple, banana, sponge cake moistened with honey, etc., may be introduced into the food chamber. No bits of food not eaten should be left in the nest, and the nest should be cleaned weekly to prevent the growth of mold, which is a great enemy of ants. The cleaning may be done by removing the cover from the food room whereupon the ants retire to the other darkened room. The entrance is now plugged up with cotton and the chamber cleaned with a bit of cheese cloth moistened with alcohol. The glass cover is left off until the alcohol has evaporated.

THE COLONY

Observe the activities of the ants in a Fielde nest, and study an individual with a hand lens. Do the antennæ appear to be important organs? Are the eyes as large relatively as those of other insects you have studied? What kind of mouth parts does the ant possess? How do you know? How does the ant carry an object? Where are the legs attached? Do they seem to be efficient organs of locomotion? Does your colony have a queen or queens (individuals larger than the rest)?

The eggs are laid, and then stuck together in tiny bundles. The larvæ are small white grubs, and when young feed upon regurgitated food that is supplied by the workers. Later they eat bits of food that is brought to them by the workers. You may see the ants dragging some of the larvae about. If so, find out the reason for this. The pupæ (these are the "ants eggs" that are sold by the goldfish dealers for turtle food) in their light-colored cocoons resemble wheat grains and are carried about by the workers, with the result that the embryos get the proper degree of temperature and moisture for their development. You may see some young ants that have just emerged from the pupæ cases. Are they the same color as the adults? Do they appear to be able to take care of themselves?

Write a story of your observations of an ant's nest.

Textbook, pages 44–47.

LABORATORY STUDY 20

WASPS

Wasps may be seen in the late spring, in summer and in the autumn. They are best studied alive. Held in a small, clear vial, stoppered loosely with cotton, it is possible to examine one with ease. You should know the kind of wasp you are studying, whether it is (1) a solitary wasp, the lustrous blue mud-dauber (Pelopœus), or (2) the brown, stout-bodied social wasp, the hornet (Vespa), that constructs the great globular nests of wood-pulp, or (3) the more slender "yellow jacket" (Polistes) that forms the pendant cluster of wood-pulp hexagonal "cells" under the eaves of the house, or under logs or stones.

I. THE ADULT

With a hand lens make an examination of the wasp in the vial. By this time you are familiar with the sections of the body and the organs that are typical of the body of an insect.

Make a comparison of the body of the wasp with that of another insect you have studied.

If possible, transfer the wasp to a larger bottle having clear glass. If your wasp is a "yellow jacket," put into the bottle with it a clover blossom or other flower and a small splinter. If the wasp is a mud-dauber, put in a pellet of mud.

1. **What does the wasp do with its mouth parts?**
2. **What evidence of breathing can you observe?**

II. THE LIFE HISTORY

Obtain a nest containing the living young of a wasp.

1. **If you have the paper-making wasp, what do you find in the open " cells " of the nest?**
2. **What do you find in the closed cells?**

If you can secure a mud-dauber's nest, cautiously break it open from the top down. The adult is not at home.

What do you find? Tell about it.

Textbook, pages 48, 49.

LABORATORY STUDY 21

THE BEETLE

"June Bugs," or more properly May Beetles, are the big brown beetles that annoy us by flying in our open windows on summer evenings. They annoy the farmer, however, more than anyone else because their larvæ (white grubs) feed upon the roots of strawberries, potatoes, grains, nursery stock, etc.

Examine a living preserved specimen of a May beetle and notice the size, covering, and divisions of the body. Considering the relative size of the eyes and antennæ, which do you judge to be of greater value to the insect? Observe the mouth parts by means of a hand lens, and determine how the beetle obtains its food. (If there are any living beetles in the laboratory watch them while they are feeding.)

Are there divisions between the head, thorax, and abdomen plainly marked? Where are the legs attached? How many are there? Do you think they are well fitted for the work they have to do? Why? How many wings do you find and where are they attached? What is the function of the fore wings? How are they used in flight? Is the beetle as good a flyer as the house fly? Explain.

Examine if possible some of the larvæ of the May beetle. What color are they? Are the legs well developed? Notice the spiracles (breathing pores).

Make a drawing, dorsal view, of the May beetle.

About three years are required to complete the life history of a May beetle. The eggs are laid in the soil, and the grubs remain there for two summers. The pupa stage requires about two months, but the newly formed adult stays in the ground until the following spring.

Textbook, pages 51–55.

LABORATORY STUDY 22

THE METAMORPHOSIS OF A MOTH OR A BUTTERFLY

It is a common thing for people to fail to distinguish between a butterfly and a moth. In general we may say that a butterfly, when it alights, folds its wings vertically over its back, while the moth's wings are extended horizontally. The butterfly has knobbed antennæ, while the moth's are feathery or pointed. Butterflies are active in the daytime and moths at twilight or at night. The butterfly's body is usually less heavy or bulky than that of the moth.

The monarch butterfly which feeds on milkweed, or the cabbage butterfly, may be used for this study. The latter will probably be easier to secure.

I. THE EGGS

Examine some eggs of the butterfly with a hand lens. Where were they found? What is their shape? How many do you find?

Make a drawing (X 10) of the eggs.

II. THE LARVA

Observe some larvæ in a cage from time to time. How do they eat? Are they all the same size? Explain. How many segments are there in the body? Do you find a head, a thorax, and an abdomen? How many legs does the larva have? Where are they attached? Are they all alike? Is the larva active? What finally becomes of it?

Make a drawing of a larva (X 2).

III. THE PUPA

What does the larva do in passing into this state? Is the pupa active? Is there any protection for it. Where was the pupa found? After examining several pupæ are you able to learn what is happening?

Make a drawing of a pupa (X 2).

IV. THE ADULT

Examine some mounted specimens and also observe some of the living butterflies in a cage, if possible. How many parts are there in the body? How many wings are there and where are they attached? How many legs are there and where are they attached? What is the shape and what is the length of the antennæ? How many eyes are there? Does the butterfly eat in a manner similar to the larva? Of what does its food consist? How are the mouth parts adapted to securing the food? Examine a bit of a butterfly's wing under the low power of the compound microscope. What does it look like? When you hold the insect by the wings a bit of powder may come off on your fingers. What is this powder? Is it of any use to the butterfly?

Make a drawing of a butterfly showing all the parts you have seen.

Write a short life history of the butterfly you have studied.

Textbook, pages 55–60.

LABORATORY STUDY 23

THE GRASSHOPPER

As one strolls through a grassy meadow in the heat of a late summer's day he is sure to be conscious of an insect life that is vibrant and active in spite of the oppressive warmth. Not the least noticeable of these creatures are the grasshoppers that spring up before him, their wings crackling as they cleave the hot currents of air that rise from the sun-baked soil. As the grasshopper alights from his short flight, his colors blend so well with those of his surroundings that it is only with difficulty that one is able to discern him. How well he is fitted to carry on the struggle for existence will be evident from the following studies.

I. LOCOMOTION

Observe closely the living grasshoppers in a cage or in the field. How do the insects move about? Are there any special adaptations for such methods of locomotion; what are they?

Describe the grasshopper's manner of walking and jumping.

When you are in the field pay careful attention to the insect's method of flight. Determine, if possible, the functions of the front and hind wings in flight and at rest.

Describe the manner of flight of the grasshopper.

II. FOOD-TAKING

Observe the grasshoppers feeding in the cage or in the field and notice the food that they prefer. How is feeding carried on?

Would you consider the grasshopper a pest or a friend? Why?

III. PROTECTION FROM ENEMIES

Take a living grasshopper in your hand. Does it seem to have any means of protecting itself? Do you experience any difficulty in distinguishing the grasshopper in its natural surroundings in the field?

How are grasshoppers protected against their enemies?

IV. EXTERNAL ANATOMY

Examine a preserved specimen. The body is divided into three regions: the head, the thorax, and the abdomen. Examine the head with a hand lens. What is peculiar about the eyes? There are three simple eyes that you should see, one in the center of the forehead and one above each of the antennæ. Pull off the upper lip, *the labrum*, and notice beneath it the jaws or *mandibles*. Remove one and examine it closely. What do you think it is used for? How many antennæ are there? What is their function?

Make a drawing of the head (front view) and label those parts that you have seen.

How many parts are there in the thorax? How many pairs of wings do you find and where are they attached? How many pairs of legs are there, and where does each pair join the body? How many rings, or *somites* or segments, do you find in the abdomen? Notice a tiny row of pores on each side of the abdomen, one on each side of a somite. These are the *spiracles*. What is their function? If you find a pair of spine-like organs on the end of the abdomen your specimen is a female. These organs are used for digging when the female lays her eggs.

Make a drawing of the insect (side view) labeling such parts as you have seen. Be careful to make a good drawing of the large jumping leg and distinguish

the three main parts — the thigh or femur, the tibia, the foot or tarsus.

V. REPRODUCTION

As has already been intimated, the female lays her eggs in the soil by means of the spine-like *ovipositors* on the end of the abdomen. Try to recall your experiences with grasshoppers during the past summer. At what time did they first become abundant? Were they large or small? Did they have wings? How do you account for the fact that in general the large grasshoppers are not seen until after the small ones? Do they have a "complete" or an "incomplete" metamorphosis?

Write a short account of the life history of a grasshopper.

Textbook, pages 62–64.

LABORATORY STUDY 24

THE CRAYFISH

Crayfishes are found in fresh water in regions where there is lime in the soil. The hard outer skeleton of the animal is supplied with lime compounds from the food it consumes. The plants on which the crayfishes feed take lime in solution from the soil. Where crayfishes are abundant, they sometimes frequent low or marshy places and dig "wells" to the water, carrying mud to the surface and forming crude "chimneys" about the openings. In brooks, rivers and lakes they crawl or swim about at the bottom, concealing themselves under jutting rocks when necessary to escape the notice of large fishes, or when lying in wait for small fishes, tadpoles or insect larvæ.

I. LOCOMOTION

Live crayfishes don't mind performing in public. Watch them crawling along the gravelly bottom of a temporary aquarium. Can you make out whether they have a system of moving their numerous legs? Do you notice any differences in the structure of the legs? Do they use the large legs (*chelipeds*, claw-feet) in walking? Do crayfishes make any use of their "feelers" (*antennæ* and *antennules*) as an aid in finding their way?

If you lower a stick in front of a crayfish, does the animal notice it? What sense seem to warn it of danger? How does it escape quickly? Watch to see when the *swimmerets* of the abdomen are working and what they are doing.

Write a story of what you have learned in this study thus far.

II. BREATHING

Living things have to breathe to live; it is the same with both plants and animals. This is why respiration or breathing is called a fundamental biological process. To discover the location of the breathing organs of the crayfish, place a live one in a tray of water. Fill a pipette full of carmine solution (it is harmless), and press out a quantity along the side of the crayfish until you have discovered where the carmine is drawn in and where it is sent out from the body.

What is the meaning of the facts you have noted?

Examine a specimen of a crayfish from which a portion of the shell has been removed. Find the "gill-bailers" which set up a circulation of air-laden water. Study the texture of the gills.

In what way do the gills appear to be adapted to the function of breathing?

III. FOOD-TAKING

Place a small piece of meat on a long needle or on a pointed glass rod, and try leaving the meat cautiously on the bottom near the crayfish. Do not tease the crayfish. Watch carefully to see if any organs are moving. What happens? For comparison place a small live fish or tadpole or snail in the water near the crayfish. Follow the work of the claw-feet and the mouth-parts. In the mouth-parts are the very small *maxillæ*, the *maxillipeds*, and the heavy jaws called the *mandibles*.

What are the organs of the body that take part in the capture and the consumption of food, and what does each organ do?

IV. THE EXTERNAL ANATOMY

The cells of the skin of the crayfish are filled with an accumulation of a lime compound. The shell thus formed serves the function of protecting the animal from being attacked by large fishes. It also acts as a surface for the attachment of muscles in the body, and gives the animal its definite form.

Can you see any advantage to the crayfish in its color? Are there mechanical advantages in the solid shell of the head and thorax (chest) regions, and in the movable segments or somites of the abdomen? Is there an advantage to the crayfish in having its eyes on stalks? These points illustrate well one of the important biological principles called *adaptation to use* or function.

1. **Give a description of other illustrations of this principle in the external organs of the crayfish.**
2. **Make a drawing of the side view of the crayfish (X 1), and label the parts.**
3. **Make a drawing of a leg and gill attached (X 2), and label.**
4. **Make a drawing of the ventral (under) surface of the abdomen (X 2), and label the parts.**

V. IMPORTANCE TO MAN

You may have heard more about the value of lobsters (a near relative of the crayfish) as food for human beings than you have heard of crayfishes. But in France there are farms on which crayfishes are raised for the market. Lobsters are expensive food now, owing to the fashion for eating them. Crayfishes are cheap.

In what parts of the United States do you think crayfish farms might be started, considering the points of suitability of soil and the character of the population to which crayfishes might be sold?

Textbook, page 65.
Linville and Kelly: *Textbook in General Zoölogy* (Crayfish), page 125.

LABORATORY STUDY 25

THE SPIDER

A walk through a field on a dewy morning will reveal masterpieces of spider architecture in all their glory. The silvery beauty of the orb webs and the funnel webs strikes the eye at once. When we realize, however, that each web is an ambuscade for some unwary insect, then we may appreciate its full significance. The orb web is the seat of activities of the garden spider which we may add to our list of friends.

If possible, large living specimens of the garden spider in wide mouth bottles should be used for this study; otherwise, preserved specimens will serve the purpose.

Notice the two divisions of the spider's body. The first division is made up of the head and thorax together; the second is the abdomen.

How does this arrangement differ from that of insects? To what part of the body are the legs attached, and how many pairs do you find? Compare the spider's eyes with those of an insect as to number and size.

There are no antennæ; those appendages which appear to resemble antennæ are really mouth-parts.

With the aid of a good hand lens locate near the posterior end of the abdomen the three pairs of tubercle-like *spinnerets*. These are the organs with which the spider spins the thread for its web.

What are some of the uses that the spider makes of this silk? How does the spider care for its young?

Make a drawing (dorsal view) of a spider and label all the parts that you have seen.

A field trip will reveal some interesting types of spider's webs.

Textbook, pages 67–68.

LABORATORY STUDY 26

THE SLUG

If you have had any experience in gardening you have come in contact either directly or indirectly with slugs. They often do considerable damage to garden crops by feeding on the succulent young leaves. They have a habit of feeding at night. During the day they remain in some cool dark place. They are often troublesome pests in greenhouses. The slugs may be trapped by placing boards or other flat objects wherever they are present; they will be found hiding beneath the boards during the day.

THE LIVING SLUG

Observe a living slug in a vivarium or in a large beaker containing some cabbage or lettuce leaves. Describe the shell. Is the slug like other snails in this respect? Look at some snails in the laboratory aquarium. How does the animal move? What do you observe as to its rate of locomotion? Does it leave any traces behind as it moves about? Of what use is the mucus to the slug? How many tentacles are there? Locate the eyes and see what happens to them when they are touched. Do you think the slug has an efficient sense of vision? What are the functions of the tentacles. Find the mouth and observe the animal eating. How is eating carried on? Examine the mouth with a hand lens and notice the rasp-like tongue or *radula*. Find the breathing pore on the right side of the body.

Make a drawing of the slug, showing all the parts that you have seen.

Compare the slug with the different snails that you find in the laboratory aquarium.

Textbook, pages 77–79.

LABORATORY STUDY 27

THE FISH

Since all fishes live in the water they must necessarily possess a bodily form together with organs of locomotion, breathing, and sensation which enable them to meet efficiently the requirements of such an environment. They are interesting because they possess bodily adaptations that are different from those of animals that live on land.

The goldfish lends itself easily as an object for study. By selective breeding man has been able to develop the brilliant hues of the goldfish, although its ancestors were dull-colored individuals that lived in certain streams in China. What do you think would happen if you set a goldfish free in one of our streams?

I. LOCOMOTION

Observe the fish as it swims about in the aquarium. How many fins has it? How many of them are in pairs? The front pair are the *pectoral fins;* the *pelvic fins* are the pair in the middle of the body on the ventral side. On the upper side of the body is the *dorsal fin.* The unpaired fin on the ventral side is the *anal fin*, and the tail fin is called the *caudal fin.* Which of the fins are used to propel the fish forward? What fins are used in moving upwards? in moving downwards? in turning? in balancing? When the fish is motionless in the water observe its shape from a position directly above it. How does the shape adapt the fish to life in the water? Make an outline drawing of what you have just observed. A cross-section of an airplane strut shows a shape similar to the sketch you have just made. What is the advantage of such a shape?

Describe the locomotion of the fish and state the use of each type of fin.

II. FOOD-TAKING AND RESPIRATION

Drop a little fish food in the aquarium and notice how the fish takes in its food. Does it chew the food?

Do you see any nostrils? Does the fish use them for breathing? What is their function?

Can the fish move its eyes? Do they have lids? What would you say concerning the vision of the fish?

Notice the movements of the mouth. Why is it continually opening and closing? Does there seem to be any relation between the movements of the mouth and those of the gill-covers (*opercula*)?

Describe the manner in which a fish (a) obtains its food, (b) breathes. Make a drawing (side view) of the fish, labeling all parts.

III. GILL STRUCTURE

Remove the operculum from a preserved specimen. How many gills do you find? How are they arranged? Remove a gill and observe that it is composed of a bony arch with spiny gill rakers and many feather-like filaments. What is the purpose of the operculum? Of the rakers? Of the filaments?

Make a drawing of a gill, labeling the parts.

IV. REPRODUCTION

In New York State, for example, the open season for brook trout is from April 15th to September 1st, and the State Game Laws make it illegal to take trout that are less than five inches long. It is known that trout that are six inches long may lay eggs, and that the spawning season is from September to the latter part of November. The female trout seeks a spot on the gravel bottom of the brook near the opening into a larger stream and there lays her eggs.

Write your comments upon the wisdom of this New York State Game Law.

Textbook, Chapter IX.

LABORATORY STUDY 28

THE FROG

The frog belongs to that class of Vertebrates, the Amphibia, all of whose members spend at least some part of their life history in the water. Because there are many points of similarity between the frog and man it is well to study it in some detail. As you study it be watchful for adaptations to special functions.

I. A LIVING FROG

Take a frog from an aquarium or a moist cage. How does it feel? Account for the difference in color of the ventral and dorsal sides, and for any benefits that may or may not be derived from this coloration.

Watch the movements of the nostrils, the throat, and the body wall and determine how breathing takes place. Would this account for the frog's ability to stay under water for so long a time?

Just how does breathing occur in the water and out of it?

When you touch the eyeball what happens? Is there anything peculiar about the movement of the eyelids?

Where are the ears found?

How does the frog move on land? Determine its stroke in swimming. How does the foreleg differ from the hind leg?

1. **What adaptations does the frog possess for locomotion on land and in the water?**
2. **Make a drawing of a frog (dorsal or back view), being careful to include all external organs that you have observed and to show the distinctions between the forelegs and the hind legs.**

Place the frog in a cage with a few flies and see how the frog obtains its food.

II. THE DISSECTION

Open the mouth of a freshly killed or preserved specimen of a frog, pull out the tongue and notice how it is attached. Do you find any teeth? Do they look as though they are used for chewing? Force a very small piece of fine wire or a bristle through a nostril and notice the connection with the mouth. Just back of the tongue find a slit, the *glottis*, which opens into the windpipe. Behind it you will find an opening to the gullet or the *œsophagus*.

Make a drawing of the mouth wide open and label all parts that you have observed.

Place a frog on its back in a dissecting pan and pin down the legs. Cut forward through the skin and abdominal muscles with the scissors from the hind legs to the floor of the mouth along the midventral line. Be careful not to cut too deeply. (Avoid this by holding the skin up with the forceps while you are cutting.) Cut away all of the skin so as to expose the powerful ventral muscles and the muscles of the legs. Carefully remove the ventral muscular wall and identify the following organs:

1. The Blood System.

Notice the three-chambered heart with two thin membranous auricles and a conical, muscular ventricle pointing downward. Trace the blood vessels leaving the heart as far as you are able.

2. The Respiratory System.

Find the two dark membranous lungs, one on each side of the heart. With what do they connect? Thrust a blowpipe or a glass tube that has been drawn to a jet into the glottis and blow gently, meanwhile observing the shape the lungs take.

3. The Digestive System.

The large, reddish, three-lobed, conspicuous mass is the liver. In the folds of the liver you will notice a small greenish body, the gall bladder. The bile duct is a tiny tube leading from this to the beginning of the small intestine. Trace its course.

Be sure to locate and recognize the following organs of the digestive system: the œsophagus opening into the thick-walled, light-colored *stomach;* a slender, coiled tube, *the small intestine*, leading from the stomach and terminating in the *cloaca; the pancreas*, a long yellowish mass near the stomach. (Notice its attachment.)

Make a careful drawing showing all of these organs in their proper places.

Remove the digestive system and find the following organs:

4. The Excretory Organs.

The *kidneys* are a pair of dark reddish, elongate organs lying against the back.

5. The Reproductive Organs.

If the specimen is a male frog there will be two light-colored oval *testes* to be found near the kidneys. If the specimen is a female the *ovaries* may contain (in early spring) a large number of eggs which nearly fill the entire body cavity, and which must necessarily be removed before you can study the other organs. The *oviducts* are light-colored ducts that lead to the cloaca.

6. The Spleen.

A small, round, red organ near the intestine.

Make a drawing of the reproductive organs.

III. THE LIFE HISTORY OF A FROG

In April when from the ponds the frogs are heralding the approach of spring, the mother frogs are busy laying their eggs in masses of jelly, and usually fastening them to sticks in the bottom of the pond. If a mass of these eggs is placed in an aquarium jar in the laboratory the development of the eggs may be watched from day to day. Some pond scum, such as spirogyra, should be added and a fresh supply put in from time to time as the young tadpoles develop. Be careful that the water does not get too warm.

As soon as the eggs hatch, look for tiny fringes on either side of the head of the tadpoles. These are the gills. What is their function? Watch the young tadpoles from day to day and notice what happens to the gills. When does this change take place?

Observe older specimens of tadpoles in other aquaria in the laboratory (or preserved specimens may be used), and locate the gill slits. By dropping a bit of finely powdered carmine in the aquarium the course of the water through the mouth and out the gill slits may be traced.

Observe some specimens on which the legs have started to develop. Which pair comes first? As the legs increase in size what becomes of the tail?

Write a complete life history of the frog.

Textbook, pages 92–95, 100–101.

LABORATORY STUDY 29

THE TOAD

It is true that the toad can scarcely be called an object of beauty, yet we must admit that its ugliness is only skin deep. Those who know it well make no excuses for its outward appearance. It is a humble fellow that inauspiciously goes about doing its bit unconsciously, incidentally making the world a better place for us to live in. This fact alone makes the toad deserving of respect at least.

I. THE DEVELOPMENT OF THE TOAD

Sometime about the first of May, in the Northern States, the female toad deposits her eggs among the water weeds near the bottom of some pond or in the still water of a sluggish stream. They are long, clear strings of jelly-like material, at first, but soon become discolored. If some of these eggs are brought into the laboratory and placed in an aquarium along with some water plants their development may be easily watched from day to day.

Make a calendar-like chart in your notebook and record your observations from day to day. Be sure to make observations (*a*) when the eggs hatch, (*b*) about three days after hatching, (*c*) about ten days after hatching, (*d*) thirty days after hatching, (*e*) forty days after hatching, (*f*) and, if possible, when the tadpoles become young toads.

> **Your record should show when the gills appear, when they disappear, when the tadpole begins to eat, its food, when the hind legs appear, when the front legs appear, and the changes that occur in the tail.**
>
> **Compare the development of the toad with that of the frog.**

In early July the young toads are found leaving the ponds in great numbers. Their migrations are inconspicuous, except on rainy days, when so many appear that the uninformed think they are being rained down. How can you explain the coincidence of large numbers of small toads with the rainy weather?

II. THE ADULT TOAD

The toad to be used for study may be kept fairly comfortable in a screen cage placed over some wet moss in a box or large pan. Be sure that the moss is always kept moist.

Study the living toad and determine how the color and the appearance serve to protect the toad against its enemies. What other means of protection does the toad possess? Notice the eyes. Does their prominent position serve the toad well? Compare the front and hind legs as to size, number of toes, and character of the feet. Account for any differences that you observe. If you place some house-flies, or some other living insect in the cage, you may see how the toad captures its food. What is the purpose of the movements of a toad's throat? What are some enemies of the toad?

Write a short account of how toads may be helpful to man.

Textbook, pages 95–98, 100–101.

LABORATORY STUDY 30

THE NEWT

A great many people incorrectly call this little animal a lizard. The latter belongs to an entirely different group of animals, the reptiles, which includes also the turtles and the snakes. You will see why the newt or salamander should not be called a lizard when you come to the study of reptiles, and *this* study should show you why it is classed with the frog and the toad as an amphibian. It has an interesting life history, that is carefully described in your textbook.

What color is the newt in your aquarium? Have you ever seen one that is another color? Where? Notice how it swims. What appendages are used? Does the tail help the newt when walking? What is the manner of walking? How many toes are there on the front feet? On the hind feet? Are any of them webbed? Notice the newt's eyes. Do you think it can see as well as the toad or frog? How do you account for its being found, like the earthworm and the young toad, usually only after a rainy spell? If you place some small earthworms in the aquarium you may see the newt eat. What kind of food would it eat on land and how would this be obtained?

Describe the newt's methods of locomotion and how it obtains its food.

Show how frogs, toads, and salamanders resemble one another.

Familiarize yourself with the newt's life history.

Textbook, pages 98–100.

LABORATORY STUDY 31

THE GARTER SNAKE

These are the denizens of the stony hillside or the meadow that glide silently away as you approach. You may come across one sometime which is greatly swollen behind the head and that moves with difficulty. This simply means that the reptile has been enjoying a repast that undoubtedly consisted of some unlucky toad or frog.

You may learn a great deal about snakes by bringing in a garter snake from the fields and keeping it in a screened box in the laboratory for a day or two.

Notice the color and markings of your specimen. (Not all garter snakes are marked alike.)

Is it full grown? What does the snake do when it is disturbed? What is the shape of the tongue? Is the tongue a weapon of offense? What do you think it is used for? Watch the ventral (under) plates carefully as the snake moves about the box. How is locomotion accomplished? How many sense organs do you find on the snake? What are the enemies of the garter snake?

Write a short account of the economic importance of snakes.

Textbook, pages 102–106.

LABORATORY STUDY 32

THE TURTLE

The word "reptile," which means crawling or creeping, is well applied in the case of the turtle. In time of danger this creature is not at all handicapped by its inability to make rapid flight in the face of an enemy. It merely assumes a passive resistance by retiring into its well-nigh impregnable fortress and waits for the danger to pass. Some turtles are terrestrial, spending all of their time on land; others are aquatic, and still others spend part of the time in the water and part on land. Be sure you know under which one of the types your specimen belongs.

THE LIVING TURTLE

Observe a living turtle. How does it differ from its relative, the garter snake? Describe the movements of the turtle in the water. Take the turtle out of the water and place it on the table. Describe the movements out of the water. Where does it seem to get along better, in or out of the water? Are there the same number of toes on the front and hind feet? Are any of these toes webbed? What sort of a covering is there on the legs and head? Touch any of the soft parts of the turtle with your pencil. Are they sensitive? What benefits, if any, does the animal derive from the shell? Compare the upper part, *the carapace*, with the lower part, *the plastron*.

Make accurate drawings of the carapace and of the plastron, showing the number and arrangement of the plates.

Observe the head. Can it extend out far from the shell? Is there any similarity between the turtle's head and that of the garter snake? Watch the eyes and determine how the animal winks. Find the nostrils. Watch the movements of the throat. Does the turtle appear to breathe like any other animal that you have studied? Most of the water turtles are carnivorous. Of what would their prey consist? Are there any teeth? How does the turtle bite off bits of its food?

Compare the turtle with (a) the garter snake, (b) the salamander.

Textbook, pages 106–107.

LABORATORY STUDY 33

BIRDS

Bird neighbors are always interesting creatures. Their joyous songs and their beauty bring cheer to human beings. They become more interesting when we learn about their peculiarities, their migrations, and especially about *what they do*. It is only when we learn what they actually do that we become fully cognizant of their importance to man, and awake to the necessity of giving them our protection.

I. A LIVING BIRD

For this study, living canaries or pigeons in cages in the laboratory should be used. If this is not practicable, the work may be carried on independently by each student. English sparrows in the street, or robins on the lawn, serve as excellent subjects.

Notice the shape of the bird's body. How is it adapted for flying? Are there any other animals that have feathers? How are the feathers arranged as an aid to the bird in flight?

Where are the largest and strongest feathers on the bird's body? The broad feathers that cover the body, giving it its outline, are called *contour* feathers; *down* is the name given to the small soft feathers of young birds, or to those that are next the skin on the mature birds. Examine a contour feather from some bird and notice the *quill*, the stiff part; the *vane*, which is the broad blade-like part of the feather. If a part of the vane is examined under the microscope it will be seen to be made up of delicate fibers, the *barbs*, which are further divided into *barbules*. It is because of the interlacing of the hooks on the barbules that the feather is resistant to the air, and also flexible during flight. Name as many uses of feathers as you can.

What organs of the body play an important part in flight? Notice carefully the shape of the wing. The front edge is thicker than the hinder edge, and the wing itself is convex upward. (The wings of an airplane are convex, and also the leading edge is thicker than the trailing edge. Aeronautical engineers have found that this type of wing section is the most efficient.) What is the point of this fact? How is the body propelled through the air? What part does the tail play in flight?

What is the method of locomotion employed when on the ground? Are the feet well adapted for this method of locomotion? How many toes on each foot? How are the feet adapted to perching? How may they be used other than for perching and for locomotion?

Notice the shape of the beak. How does the bird obtain its food? How is the food ground up, preparatory to digestion? How does the bird drink?

Do birds have an acute sense of hearing? Give evidence to prove your answer. Are the ears visible? Where are they located? Give reasons for believing that a bird may have a well-developed sense of sight, and can see plainly both far and near. What senses are most useful to the bird in helping it to obtain its food? What birds have you seen capturing insects, or eating weed seeds?

Make a drawing (side view) of a bird, labeling such parts as you have seen.

II. IDENTIFICATION AND THE HABITS OF BIRDS

Beginning in the winter and continuing through the spring and summer months until the close of school, make observations of the birds in your neighborhood and keep records of what you have observed. Your record should show (1) the name of the bird, (2) date, (3) where it was seen, (4) comparative size, (5) coloration, (6) what it was doing, (7) shape of beak, (8) distinctive features such as method of flight or conspicuous identification marks, etc., (9) food and how it is obtained. If possible you should make observations of its nesting habits. Finally, you should look up information concerning its migratory habits, and the relation of the bird to other animals and to man.

Your list should include such common birds as the English sparrow, robin, chickadee, downy woodpecker, bluebird, Baltimore oriole, crow, catbird, phoebe, song sparrow, chipping sparrow, yellow warbler, and others.

Write a story on the economic importance of birds.

Some reference books that will help you in learning about the relations of birds to one another and to other animals and man are:

Pearson and others — *Birds of America*, 3 vols. University Society of New York, Inc.
New York State Museum publications — *Memoir*, 12.
Chapman — *Birds of North America.*
Reed — *Bird Guide.*

Textbook, pages 112–122.

LABORATORY STUDY 34

CHICKENS

What cattle are among mammals, so chickens are among birds — fundamentally and biologically essential to man in the food they each produce. And after each species has produced its maximum, the reserve flesh of the animals themselves is drawn upon for human food. The food wealth of the two species is marvellously great.

I. AS BIRDS

The ancestors of chickens are still in existence, the Jungle Fowl of India. Considering the large number of varieties of chickens now common everywhere, it is obvious that variation in the species has been extensive, and also that the variations have been rapidly improved upon through selection by the chicken fanciers.

How many varieties do you know, and what are the characteristics of color and form of the birds, and the color of the eggs they yield?

Comparisons of the structural features and the habits of chickens with those of typical birds will bring out some interesting facts connected with the adaptations in chickens to life in a restricted habitat.

1. **Have you seen chickens trying to fly? What success do they make of it? Explain.**
2. **Are chickens good runners? What use do they make of their capacity to run?**
3. **To what extent do chickens follow the habits of other birds in bringing up their young?**

II. CHICKEN FARMING

There are chicken farms nearly everywhere in the vicinity of large cities, or in the regions where food is produced that may be shipped to large cities. Every farm has its own chickens for the egg and meat product yielded.

1. **What are some of the problems to be met in practical chicken farming?**
2. **Why do some fail and some succeed in this business?**
3. **Knowing the feeding habits of birds, do you think chickens may be of any indirect benefit to the farmer? If so, what?**

III. AS FOOD

Poultry that is being prepared for the market is often fed intensively for two weeks with clean grain mixed with buttermilk. Incidentally, this creates a market for buttermilk.

1. **What is the difference in cost between "milk-fed" chickens and other kinds on the retail market?**
2. **In what form and condition are chickens sent to the markets?**

The nutrient content of chicken is much the same as in other meats, except that the fat is not so abundant in the muscle itself. Connective tissue is largely absent from the "white meat," making that kind of meat easily digestible.

1. **Have you observed any other fact about chicken meat that may make it desirable?**
2. **Pound for pound as the fowl is sold, is chicken meat more, or less, expensive than other meat?**

IV. IN DEVELOPMENT

We have realized that the eggs of birds are the carriers of the germ or embryo of the young undeveloped bird. When eggs that have been fertilized by the spermatozoa of the male bird before laying are placed in a protected spot in a temperature equal to the body heat of the bird slightly over 100 degrees, they will develop to hatching within twenty-one days. A setting hen or an incubator will provide the necessary conditions. If the laboratory has an incubator, some interesting studies in development may be made.

Take from the incubator at certain stated periods of development one egg at a time. Provide a labeled dish for the egg when the shell has been removed.

1. **On the second day of incubation, and also on the fifth, the eighth, the twelfth, and the sixteenth days, remove from the incubator one egg, and pick off the shell and the shell membrane and drop carefully into the dishes for demonstration to the class.**
2. **Follow as much as you can the development of the systems of organs, and observe the gradual transformation of food reserve into chick, and the preparation of the young for independent life.**

Textbook, pages 199–201.

LABORATORY STUDY 35

HENS' EGGS

Animals, like plants, produce eggs as a means to continuing the species. In the case of birds, and of some other animals, the egg is deposited by the mother, and the young contained in it develop more or less under her protection. Man has found that hens' eggs are valuable as food, and as a result of his discovery over twenty billion hens' eggs are produced in this country each year.

I. PARTS OF AN EGG

The shell of an egg protects the contents while permitting the young to obtain air during development.

Lower an uncooked egg into a vessel of cold water and tell what you see, bearing on this point.

Cut a hole in a paper box large enough to permit an egg to fit in without dropping through. Set the box and egg over an electric light bulb and examine the egg contents. This is called "candling" in reference to the old-time custom of using a candle for the test.

Describe what you see.

Next remove the shell, beginning at the large end and noting what you saw while candling. Note the number of membranes you come in contact with. Cut the membrane carefully with scissors, letting the contents out through a large opening into a shallow dish without breaking the inner egg membrane.

1. **Note and describe the white of the egg and two ropey cords (*chalazae*) that help to suspend the yolk in the fluid white; also take note of the yolk itself and especially the little margined spot on top, the germ or embryo of the young chick.**
2. **Take a hard-boiled egg, and apply the tests for nutrients, and report what you find.**

II. THE PRODUCTION AND THE CARE OF EGGS

A map indicating the distribution of chickens in the United States shows that nearly all are to be found in the eastern half of the country. But they are most abundant in the North Central States. All through that country limestone is plentiful. Egg shells require lime. Where there is no limestone, chickens must be fed ground oyster shells, or other limey substance, to give hardness to egg shells. Food also must be abundant in order that eggs may be produced at all.

What kinds of food are consumed by chickens?

Eggs are laid in the largest quantity in the spring and early summer, in the months of March, April, May and June.

Eggs are cheapest at that time. A large number are put into cold storage in those months, and large broods of chickens are raised.

> **What steps must man have taken in dealing with the race of chickens to bring about so great an abundance?**

When eggs are plentiful and cheap they are shipped in large quantities to the vicinity of large cities and held there in cold storage. When fresh eggs become scarcer in late summer, and through the fall and winter, these cold storage eggs are sold.

1. **What is the difference in the price of cold storage eggs and the fresh eggs at the same time?**
2. **What is the object of cold storage?**
3. **Do you know of any actual differences between cold storage eggs and the fresh ones?**
4. **What is your opinion of the system of placing eggs in cold storage?**

Take some eggs of various ages and sources, and "candle" them over an electric light bulb.

> **Describe what you see, and give your opinion of the internal condition of the eggs. Break some of the " bad " eggs and tell what you find.**

Textbook, pages 315, 316.

LABORATORY STUDY 36

MAMMALS

Mammals constitute the highest group in the animal kingdom, at the top of which stands man himself. Man has long been dependent on mammals for food, clothing, and for help in doing his work. Hence from an economic standpoint they are the most important of all animals.

A LIVING MAMMAL

For this study, living rabbits, guinea pigs, dogs or cats, should be used.

Describe the external appearance of the animal. How many divisions are there in the body? What kind of a covering does the body have? (This is applicable to all mammals at some period in their life history.) What are the uses of this type of covering?

How is locomotion accomplished? Does the animal walk on its feet or on its toes? Are the fore and hind limbs similar to the arms and legs of man? Do you find any claws or nails? Of what use are they? What are some of the uses of the limbs other than for locomotion?

What kinds of food are preferred by the animal? What adaptations does the animal have for securing food? How are the teeth fitted for this kind of activity?

Notice the movements of the body as the animal breathes. Is the rate of breathing the same as your own?

Locate the nostrils. What can you say as to the animal's keenness of scent compared to other animals that you have studied and compared with man? Where are the eyes placed? How many eyelids are there? What sort of an external ear is present? Do you think it is an important aid in hearing? Do you think the animal has a keen sense of hearing? Give evidence to support your answer. Are there any special organs of touch present? What parts of the body are more sensitive than others?

What does the animal do when frightened? What means of defense has it? What are some of its enemies?

How are the young nourished and cared for after birth?

Of what economic importance is the animal?

Make a drawing (side view) of the mammal and label all the parts you have seen.

Make a list of the important characteristics that distinguish mammals from other animals.

Textbook, pages 123–137, 181–199.

LABORATORY STUDY 37

HORSES

Of the larger domesticated animals none is better known than the horse. So great is the adaptability of the horse to the wishes of man that it does not occur to us to recall his wild, ungoverned ancestors.

I. THE STRUCTURE OF THE HORSE

The horse belongs to the great Class Mammalia, the same Class of vertebrates to which human beings belong.

What main divisions of the body and appendages are common to us and the horse?

You will notice that because our way of standing differs from that of the horse, — we on our rear appendages and the horse on all fours, — when we estimate height of body we are measuring different dimensions. Furthermore, man's height is measured in feet and inches while a horse's height is measured in "hands." A "hand" means the width of an average man's hand, about four inches. The measurement is taken at the front leg by standing a pole against the horse and noting the height to the top of the shoulder.

Measure three or four horses and thus get an idea of the height of the average horse you see.

Examine the picture of the horse's skeleton on page 183 of the textbook, and compare with the parts as seen in a live horse.

1. **Describe the position in the front leg of the elbow, the wrist (wrongly called the knee), and the long hand bones with the nail of the third finger (the front hoof).**
2. **Describe also the position in the hind leg of the knee, the ankle (hock) and the long foot bones with the nail of the third toe (the hind hoof).**
3. **Study the "Evolution of the Horse" (page 151 in the textbook), and account for some of the facts you noted in answers 1 and 2 above.**
4. **Find and describe the "ergot" and the "chestnuts" on the leg as mentioned on page 185 of the textbook.**
5. **Try estimating the age of a horse in accordance with the description given on page 185.**

II. THE HABITS OF THE HORSE

Information can be obtained on the following points by observing almost any horse.

1. **What are a horse's feeding habits, the use of the lips and the teeth and the direction of movement in biting?**
2. **What are differences between the gaits of horses, walking, trotting, galloping?**
3. **How does the horse defend itself?**
4. **Have you seen indications of definite response by a horse to the treatment given it, either ill treatment or good treatment?**

III. THE USES OF THE HORSE

The number of horses in active service has decreased because of the enormous number of automobiles that are in use; but there are still a great many things that horses do.

What kinds of work may continue to be done by horses?

Textbook, pages 150, 151, 182–187.

LABORATORY STUDY 38

CATTLE AND CATTLE INDUSTRIES

Cattle or oxen are without question the most indispensable of all our domesticated animals. Owing to our dependence on them for food in the form of milk or meat there must always be space and food for them.

I. THE STRUCTURE OF THE BODY

The parts of the body of the ox are easily comparable with those of the horse, although oxen have entirely different foot structure. These parts have their technical names, which indicate their similarity to corresponding parts in other mammalian vertebrates, even in man. But owing to the custom followed in the meat industry, special common names have come to be applied.

There are fifteen of these names which ought to be familiar to everyone. An outline of a cow is easily made, and within such an outline the parts can be marked off by comparison with a chart showing them. Suitable drawings may be obtained from *Bulletin 28*, U.S. Department of Agriculture (Atwater and Bryant).

1. **Make a similar chart and try to apply your sketch by examining a side of beef hung up in a butcher shop. Become familiar with the following: Neck, chuck, ribs, shoulder clod, fore shank,**

brisket, cross ribs, plate, loin, flank, rump, round, second cut round, hind shank.

2. **Also take the opportunity at the butcher shop to note and report on the size and appearance of important internal organs, especially the heart, the liver and the kidneys.**

II. THE DAIRY INDUSTRY

In the study of milk (Laboratory Study 39) many important points about the dairy industry are brought out. Consider them here also. Alderney, Jersey, and Holstein cows produce the largest quantity and the best milk.

1. **Ascertain the origin of each of these breeds, and the time they were brought to this country.**
2. **From the publications of the Bureau of Animal Industry of the Department of Agriculture and from milk distributing agencies, including dairymen's leagues, ascertain the extent of the dairy industry.**
3. **Do any suggestions occur to you for making dairy products less expensive while maintaining the system of protection against unhealthful conditions?**

III. THE MEAT INDUSTRY

The meat industry is the largest manufacturing industry in the United States. The center of this industry is within the region where most of the cattle, as well as the hogs, are fed in the final stage of preparation for the market. The North Central States include this region. Thus Chicago, Kansas City and Omaha are the chief cities where the meat food of this country is prepared, and from which it is sent out in refrigerator cars everywhere. But all the great plains states rear the cattle.

As you have seen beef unloaded from trucks or from cars, in what form does it reach the wholesalers and the retailers?

Meat is sometimes kept in cold storage at the centers of the meat industry or near large cities for months or even for one or two years.

> **What do you think is the object of this custom?** (*See Textbook*, page 364.) **What classes of society are benefited?**

Beef sometimes is dried, canned, corned, or preserved in salt, saltpeter, boric acid, benzoate of soda, wood smoke, etc. (*See Textbook*, page 365.)

> **What is the cost of these preparations of meat as compared with fresh meats, and what is the advantage of preserving meat?**

As you observe the great pieces of beef unloaded at the retail butchers' shops you will notice marks on the surface made by rubber stamps.

> **What do you read in these marks, and what do they signify?**

In 1906 Congress enacted a law creating a thorough system of federal meat inspection and a general pure food law. But federal meat inspection had been in existence for fifteen years before that time.

1. **What are some of the reasons for having inspection of meat?** (For one point read the *Textbook*, page 31–32.)
2. **What can be done with meat that is found to be impure?**

There are a great many by-products of the meat industry. Among them are gelatin, beef extracts, glue, tallow, tripe, rennet, leather, hair, horn, fertilizer.

> **Tell what these various materials are, and something of the processes of preparing them.**

Scientific study of the different cuts of beef show that the cheaper cuts are as valuable pound for pound, and in some cases more valuable from the standpoint of protein content and energy, than are the higher priced cuts.

In purchasing beef for protein primarily, the neck, shanks and shoulder clod have been found to be the most economical cuts, and the rib, loin and round the most expensive.

> **Since authorities in this matter have estimated that the average family expends one third of its weekly food bill on meat, how much could a family save in a week through purchasing the cheaper meat cuts?**

Some authorities urge that the family meat bill be reduced to one sixth of the whole food bill in the interest of improved health conditions.

> **What is the basis of this advice?** (*See Textbook*, pages 354–360.)

Textbook, pages 188–191, 312–313.

LABORATORY STUDY 39

MILK

Milk is a natural food; it requires no artificial manufacturing process for its preparation. All female mammalian animals secrete milk in mammary glands for their young. Long experience has taught us that the milk of cows is highly nutritious for human beings. Choice breeds of cows produce more milk than their own young require.

I. THE COMPOSITION OF MILK

Examine a test tube of fresh milk that has stood a few hours in a cool place.

1. **What do you find at the top?**
2. **Why does it lie at the top?**

Pour the top substance into another test tube, place a small quantity on a piece of white paper, and compare the mark left with the spot left by a piece of lard or olive oil.

What do you find out?

Drop into the test tube of the skimmed milk a quantity of acetic acid or vinegar. For comparison take a test tube of skimmed milk that has become sour naturally. Test the two with litmus paper, and compare the reaction with that of fresh milk. Filter the milk artificially curdled. Wash the curd with water to clear out the acid.

Apply the nitric-acid-ammonia test (*see* page 13) **to the curd and note the result and its meaning.**

The watery remainder is called *whey*. Boil a quantity to evaporate most of the acid, and pour in some Fehling's Solution.

What is shown by this test?

Boil down the remainder of the whey in a crucible. When the water is evaporated and all the burnable contents are consumed,

What is left?

II. HOW MILK IS PRODUCED AND PROTECTED

Every farmer has a few cows for the use of his family. In sections where it is profitable to maintain dairies large numbers of cows are kept.

In what sections of the country are there likely to be large dairies? Why?

The dairy industry has become so important that the best breeds of milch cows are kept. They produce the best milk and the largest quantity.

What conditions do you think would favor the production of good quality and large quantity in milk?

The traditional way of milking by hand is now being largely displaced by the mechanical milker operated by a gasoline engine.

What advantages are to be gained by this change?

Before milking, the utensils are scalded with boiling water and the udders and flanks of the cows are washed with a moist cloth. The hands of the milk handlers are cleaned. The milk is strained through sterile cotton or cloth into a mixing tank over a metal cooler, and kept cool at 50° to 55° Fahr. until it is delivered to the consumer.

Explain the purpose of all this care and the biological principles involved.

The laws of most states require that dairy barns be kept clean, well lighted and ventilated, and free from dust, and that the health of the cows be looked after. Inspectors from the city boards of health visit the farms and the large receiving stations to inspect the conditions and the milk.

Tests are made to determine the richness in fat and protein of the milk by the *lactometer* which gauges the specific gravity or weight of the milk as compared with water. Tests also are made of the purity of the milk by analysis to see if adulterants have been put in. Other tests are made to determine the number and kinds of bacteria present. The best of milk contains bacteria that cause souring. Milk is also *pasteurized* by being heated for twenty to thirty minutes at a temperature of 140° to 145° Fahr. to destroy bacteria of any communicable disease that may be present; typhoid fever, scarlet fever, diphtheria, or tuberculosis.

How, in your judgment, has all this expense been justified?

III. PRODUCTS OF MILK

The important products obtained from such milk as is not sent as "whole" milk to the market are butter, cheese and sugar of milk.

Learn something about the manufacture of each of these products.

Textbook, pages 313–315.

LABORATORY STUDY 40

THE RELATIONS OF ORGANISMS IN A LIMITED ENVIRONMENT

In Chapters XVII and XXV of the textbook that accompanies this Manual certain important general conceptions in biology are presented and discussed. The study which the authors offer here is intended as a suggestion to students to think of life in terms of relations, for, as the chapters referred to clearly show, no organism lives isolated from others.

I. A SMALL POND IN THE WOODS

There is a bit of charming mystery about a pond in the woods. Its very attractiveness is a manifestation of the simple and quiet adjustment between life and the environment.

1. From your own first-hand observation of such places, what influence do the conditions of light have on the amount of vegetation about the margin?

2. If there are trees growing within the pond, is the pond temporary or permanent? Explain. Is there any other reason why you think the pond is temporary or permanent?

3. If there is green vegetation in or upon the pond, where is it, near the margin or in the middle? Explain.
4. Is there vegetation that has root in the mud, cat-tails, pond lilies or pickerel weed, or vegetation that floats on the surface, such as hyacinth or duckweed or both?
5. Is the pond connected with a brook, or has it an outlet in the form of a brook? If a brook connects with it, what difference do you notice between the bottom vegetation (Spirogyra, etc., *see Text-book*, page 215) in the pond and in the brook?

II. LIFE RELATIONS

1. Examine the bottom green vegetation where the sun shines for an hour or more, and note whether it ever floats to the top, apparently enclosing bubbles of air or gas.
2. If gas collects, what kind may it be?
3. When gas is formed by plants, is it of any use to other organisms?

There may be insects flying over the pond. Doubtless there are numerous specimens of larval forms of certain insects crawling about on the bottom. Besides, there are probably adult insects on the surface, water striders and whirligig-beetles, and some burly diving beetles that sound the depths if they need to.

1. What lace-winged insects are flying about above the surface whose young crawl beneath?
2. What do they appear to be looking for? Do they capture anything?
3. What about frogs and tadpoles? What are they living on? You must be patient to find out.
4. And the pond snails: watch them as they crawl up and down on submerged blades of grass or on stones, and tell what you think they are living on.
5. Are there other forms of animal life that ought to be mentioned?

There are probably at or near the pond rotting logs and fungi of many kinds living on dead and decaying vegetation, slowly but steadily disintegrating and returning to inorganic nature the substances that at one time were part of a living thing.

1. Which of these inorganic substances would plants use again?

2. What do you see that seems to fall under this description?

Textbook, Chapters XVII and XXV.

LABORATORY STUDY 41

BACTERIA

Bacteria, or "germs" as they are often erroneously called, are the simplest and most widely distributed forms of life known. They cannot be seen with the naked eye, and so for the most part people still fail to connect the results of their activities with the terms "germs" and bacteria. Because they are usually thought of in connection with disease, the whole group suffers an unjustified condemnation. In reality a large number of species by their activities serve mankind by aiding in the complete disposal of his débris and by enriching the soil from which he gains his sustenance. By doing the following experiments you will obtain a more intimate acquaintance with these forms of plant life and their activities.

I. DISTRIBUTION

(NOTE. For this experiment use petri dishes containing sterilized agar-agar that is slightly alkaline.)

1. Expose a petri dish containing sterilized agar-agar to the laboratory air for five minutes. Cover the dish, label it, and set it aside at room temperature.

2. Expose another dish to the air out of doors for five minutes. Cover the dish, label it, and set it aside as before.
3. Rub the tips of your fingers gently over the surface of the sterilized agar in another petri dish. Cover the dish, label it, and set it aside.
4. Place a fly in a petri dish and let it walk across the surface of the sterilized agar-agar. Cover the dish, label it, and set it aside.
5. Place a little milk in a petri dish containing sterilized agar-agar and pour off any excess fluid. Cover, label, and set aside.
6. Flood the surface of the agar-agar in a petri dish with water from the tap and pour off the excess water. Cover, label, and set aside.
7. Place a dish of sterilized agar-agar with the rest of the dishes to serve as check.

Examine the petri dishes daily and note the appearance of little dots on the culture medium. Where do they appear first? Where do they appear in the greatest numbers? These dots are colonies of bacteria, and each one represents the progeny of one bacterium.

What do these experiments show you concerning the distribution of bacteria?

II. FOODS PREFERRED BY BACTERIA

Place the following materials in test tubes and add a little water to each: (1) raw or cooked meat, (2) the white of an egg, (3) some crushed beans, (4) some sugar or molasses, (5) a bit of bread, (6) some melted butter. Place these tubes in a warm place and keep watch of them for two or three days. Notice any changes in the appearance and odor of the foods. Bacterial growth in foods causes putrefaction. Do you find putrefaction occurring in any of the tubes? In which does it seem to be greatest?

What conclusions do you draw from this experiment concerning the kinds of food preferred by bacteria?

III. EFFECT OF MOISTURE ON BACTERIA

Place in two sets of test tubes bits of the following foods: (1) crushed beans, (2) dry bread, (3) dried egg albumen, (4) cracker, (5) flour. To one set of the test tubes add a little water to their contents. Leave the other set dry. Set all the tubes aside in a warm place and watch daily as directed in the preceding experiment.

What effect does moisture have upon the growth of bacteria?

IV. EFFECT OF TEMPERATURE ON BACTERIA

Into each of four test tubes place a bit of meat and some water, or a solution of Liebig's Extract of Beef may be used. Close all tubes with plugs of absorbent cotton. Place one tube in the refrigerator, one in a warm place, as near a radiator, one in a place at ordinary room temperature; boil one for a few minutes and place it with the one at ordinary room temperature. Examine these tubes daily and note the rapidity of putrefaction in each tube.

What effect has temperature upon the growth of bacteria as shown by the results of your experiment?

V. EFFECT OF PRESERVATIVES ON BACTERIAL GROWTH

Fill each of ten test tubes about one third full of a solution of Liebig's Beef Extract. To the tubes add the following materials: # 1, ½ gram of salt; # 2, one gram of salt; # 3, one gram of sugar; # 4, five grams of sugar; # 5, two drops of formalin; # 6, five drops of formalin; # 7, a few drops of a saturated solution of boric acid; # 8, one spoonful of vinegar;

9, one spoonful of alcohol; # 10, no addition. Set all of the test tubes aside in a warm place and examine daily.

A preservative is an agent that is supposed to retard or prevent bacterial growth. Notice the extent to which the various preservatives prevent decay. Tabulate your results.

Which of the substances used do you judge to be the most effective preservatives?

Textbook, pages 222–227, 458–460, 491–496.

LABORATORY STUDY 42

YEAST

When anything containing a large amount of sugar spoils, the sugar is changed to carbon dioxide gas and alcohol, and we say that fermentation has taken place. This process is caused by countless numbers of tiny yeast plants growing in the solution. Incidentally the same process is used in the raising of bread and in the production of alcoholic beverages.

I. FERMENTATION

To 100 cc. of water add 10 cc. of molasses and one half of a fresh yeast cake. Pour some of this mixture into a fermentation tube until the arm is full then plug the tube with cotton and place the rest in a flask with a delivery tube leading from it into a test tube of lime water. Set both pieces of apparatus in a warm place and leave over night. Examine the fermentation tube and account for what has happened. What color is the lime water? What does this show as to the gas that was given off? Smell of the contents of the flask. What characteristic odor is present?

What is fermentation? What causes it? What are the results of fermentation?

II. CONDITIONS OF FERMENTATION

Fill three fermentation tubes with a mixture of molasses, water, and yeast. Boil the contents of one of the fermentation tubes, place it along with one of the other tubes in a warm place. Place the third tube in the refrigerator. Let these tubes stand for a couple of days and then examine them for the presence of carbon dioxide and alcohol. In which tube did the yeast grow most rapidly? How do you know? In which did it grow the least?

Under what conditions is fermentation most likely to occur? What effect does boiling have on the growth of yeast? What effect does cooling have on the growth of yeast?

III. SOURCE OF YEAST PLANTS

Place a mixture of molasses and water in a large beaker or a shallow dish and leave it exposed to the air for a day or so. Now pour the solution into a fermentation tube, plug with cotton, and set in a warm place. Examine in a day or so for the presence of yeast. Has fermentation taken place?

How do yeasts get into foods?

IV. STRUCTURE OF YEAST PLANT

Remove a few drops from the bottom of a solution of molasses, water, and yeast in which fermentation is taking place by means of a pipette or glass tube and place a drop on a microscopic slide. Add a drop of iodine (the starch is stained blue and the yeast cells unstained). Cover with a cover-glass and examine under the high power of the compound microscope. What is the shape of the yeast plants? Do you find a nucleus? Do you find any cells that are *budding* (one cell growing out of another in the shape of a small bud). This is the common method of reproduction of yeast plants.

Make a drawing of a few yeast cells (one half to one quarter inch in diameter) showing the process of budding.

Textbook, pages 227–229.

LABORATORY STUDY 43

PLEUROCOCCUS

Many of the most primitive green plants are found in a group called Algae. One common member of this group is the green coating on the north side of trees and wooden posts. It is known as pleurococcus, and all the plant activities are carried on in a single cell.

Examine a specimen of pleurococcus under the microscope and locate the different parts of the cell. You will find several of these cells together in a small group. Why is this?

Make a sketch of pleurococcus and label the cell wall, the nucleus, the cytoplasm, and the chlorophyll.

Be sure that you know how the life activities of this plant are carried on.

Textbook, pages 214–215.

LABORATORY STUDY 44

MOLD

When any food such as bread, cheese, meat, jelly, etc., is left exposed to the air for a time it becomes covered with a fuzzy, powdery growth of mold. The mold grows best under certain conditions, and it is often advantageous to be familiar with these conditions in order to keep foods from spoiling. The following study should reveal the conditions necessary for the appearance and steady growth of mold.

Take five pieces of dry bread and moisten four of them. Expose all five pieces to the air of the laboratory for about thirty minutes, then place each in a sterilized jar or wide mouth bottle and plug the mouths of the bottles with cotton. Place the jar containing the dry bread (# 1) and one of the jars containing moist bread (# 2) in a dark place in the laboratory so as to be exposed to ordinary room temperature. Place another jar (# 3) in the refrigerator and another (# 4) in a warm place such as above or near a radiator. The last jar (# 5), cotton plug in place, should be placed in a pan or beaker of water; the water boiled for ten minutes and then the jar placed near # 1 and # 2. Watch the jars daily for any changes that occur and for one week keep a daily record of each jar in your notebook

Where does mold come from?
In what jars did the greatest growth of mold occur?
In what jars did the least growth of mold occur?
What conditions are necessary for a luxuriant growth of mold?

STRUCTURE

Remove some of the thread-like structure (*mycelium*) and place it in a drop of water on a slide and examine under the microscope. The little knobs on the ends of some of the *hyphæ* (each thread is called a hypha) are *sporangia* and contain *spores.* Do you see many sporangia. Look for some of those that have broken open and notice the great number of spores that are coming out. Each mold spore under favorable conditions will germinate into a new mold. Explain the significance of the great number of sporangia and spores. The hyphæ that penetrate the bread and absorb food are called *rhizoids.*

Make a labeled sketch of the structure of a mold showing the method of branching of the mycelium, the sporangia and rhizoids.

Textbook, pages 229–231.

LABORATORY STUDY 45

MUSHROOMS

Mushrooms are *fungi*. Fungi are without green coloring matter or *chlorophyll* in their tissues. Hence they are unable to create food out of inorganic material, and must live on other organic matter, living or partly decayed.

I. WHERE MUSHROOMS LIVE

But mushrooms exist solely on decayed vegetation. In soil made rich by the disintegrated particles of leaves, sticks and other organic material, they spring into existence from their spores that have been dropped by currents of air in damp spots. Mushrooms live also under cultivation in cellars or in underground places that contain soil fertilized by various organic substances.

When have you seen mushrooms spring up in places where you had not observed them before? Explain.

Some mushrooms are known to contain poisonous substances, fatal if consumed by human beings even in small quantities. These poisonous forms are called "toadstools," although their structure is the same as the eatable kind.

On the basis of the cost of mushrooms and the best information obtainable as to their value, are mushrooms cheap as food, or not?

II. THEIR BIOLOGICAL SIGNIFICANCE

We have studied the constructive process of photosynthesis, page 96, and realize the difference between green plants and fungi which do not construct or build up food. Since mushrooms consume organic substance they maintain a relation toward matter similar to that held by animals.

1. **In what way may mushrooms, even the poisonous ones, serve a biological function in nature?**
2. **If there were a lack of organisms that help to destroy life, what would happen in nature?**
3. **Logically, must we cease to destroy the fungi of human disease, or plant diseases? When, if ever?**

Textbook, pages 232–234.

LABORATORY STUDY 46

SPIROGYRA

The Algæ are the lowest of all green plants. They are nearly all aquatic forms, although a few are found in moist places. One of the common forms of fresh water Algæ is *Spirogyra*, a green pond scum that is found floating in slimy mats in ponds and sluggish streams.

Examine some living Spirogyra from the laboratory aquarium. What color is it? How does it feel when you take some of it out of the water? Place a few threads on a slide in a drop of water, cover with a cover-glass and examine under the high power of the microscope. Do the threads branch? Of what are they composed? Notice the *chlorophyll* bands and the cell *nucleus*. The latter will be stained brown if a drop of iodine is placed on the slide and drawn under the cover-glass by means of a bit of blotting paper. The clear cell sap fills the interior of the cell.

Make a drawing of a few cells of Spirogyra, labeling the parts that you have seen.

If you search the slide carefully you may see little projections growing toward each other on two filaments that are lying close together. This is the early stage of a sexual form of reproduction called *conjugation*. In other filaments you may see that these projections have joined together and that the cell contents have united to form a dark ellipsoidal *zygospore* which is found within one of the cells, the other cell remaining empty.

Make a labeled drawing showing two filaments of spirogyra conjugating.

Textbook, pages 215–218.

LABORATORY STUDY 47

A MOSS

When coming upon some green mossy bank in the woods you may have wondered what the slender reddish stalks with their pointed caps were for, and why there was such a profusion of the tiny plants. In the following study you will see that the story of the life of a moss, or its life-cycle, is quite as complicated and no less interesting than the life-cycle of the frog or the moth.

Examine with the aid of a hand lens, a fresh specimen of a moss plant on which the fruit has developed. The fruit is represented by the slender reddish stem with the *spore-capsule* on the end, the whole thing growing from the top of a leafy female moss plant. This is known as the *sporophyte*. How are the leaves arranged on the stem? Is the stem branched? What kind of a root system is present? Remove the *cap* or *hood* from the *capsule* and notice the little lid that holds the spores in the capsule. This lid comes off when the spores are ripe. If you remove it you will see a row of little teeth-like structures around the edge of the capsule through which the spores shake out.

Examine some spores under the high power of the microscope. From a prepared slide or a chart find out what the spores develop into.

The little moss plants develop from buds on this tiny thread (*protonema*) some becoming male plants with *antheridia* (pollen bearing organs) at the top of the plant, and others female plants with *archegònia* (where the ovules are produced) also at the top. Examine male and female moss plants and notice the differences between them. If possible examine prepared slides or charts showing these structures. Hence the leafy plant represents the sexual stage of the moss or the *gametophyte*.

> **Make a drawing of your plant showing both the sporophyte and gametophyte stages and label all parts.**
>
> **Which generation of the moss is the most commonly seen, the asexual or sexual?**

Textbook, pages 235–238.

LABORATORY STUDY 48

FERNS

Ferns are among the highest of the non-flowering plants. Familiar as ferns are to us, the method of reproduction of ferns and other non-flowering plants was for a long time unknown even to the biologists. For that reason they applied to all non-flowering plants the name *Cryptogams*, which means *secret* or *unknown reproduction*.

I. WHERE FERNS LIVE

As a rule, ferns live in shady places, and where the soil is damp and rich. Masses of the large *brakes*, however, often grow in the open light along the borders of forests.

1. **What is the most conspicuous part of the fern plant, and what are the details of its structure?**
2. **From your own observation, what do you think is the reason a fern environment is considered beautiful?**
3. **What part of a fern plant is new every year, and what part is perennial or continuous?**

II. THE LIFE HISTORY OF FERNS

Whenever you see on the under surface of the *frond* or leaf of a fern a series of small regularly placed brown specks you may know that the plant has begun its annual cycle of changes, at the end of which two kinds of fern plants will have made their appearance. The little brown specks, called *sori* (sing. *sorus*) are coverings of many extremely small *spore cases* containing still smaller *spores*.

1. **Break open one of the sori under the objective of a compound microscope, separate and open a spore case in a drop of water on a glass slide, and observe the form and appearance of fern spores.**
2. **Since it is said that a single fern plant may produce 50 million spores, what tends to prevent the actual existence of so many plants?**

The spores of ferns are thrown by the bursting of the spore cases (called *Sporangia*) over an area of a few square feet. If the spore falls in a favorable situation it produces a small thread, called the *protonema*, as in the mosses. From this comes the small heart-shaped *prothallus*.

Search about the surface of fern flower-pots and moist frames in a greenhouse for some prothalli, and place one on a glass slide in water for examination with the low power of the compound microscope.

Examine top and bottom until you find the archegonia and antheridia described in the textbook. Give a description of what you see.

The prothallus is the *sexual generation* of the fern. The drawings on the textbook indicate the form and the details of structure of the reproductive organs. Search among your specimens of prothalli for one that shows a stage of development comparable to one of the figures on page 241 of the textbook.

What is there about the specimen that indicates that the cycle of alternation of generations has been completed?

At the base of the little plant the prothallus is absorbed and a permanent *rootstock* is developed. This is the part you dig up for putting in the pot, and the one from which the fronds in nature spring up each year, looking like a bishop's crozier.

Textbook, pages 238–242.

LABORATORY STUDY 49

SOIL IN RELATION TO THE GROWTH OF PLANTS

Wherever we are, most of us get used to seeing plants with which we are familiar growing in the soil. We may not know whether they would grow better in a different soil. By improving the soil by natural or artificial fertilizer, farmers and gardeners add greatly to the productivity of the land.

I. GROWTH IN NATIVE SOIL

In some soils certain plants do better than others. In part this is due to a difference in the mineral needs of plants, in part to a difference in the temperature, and in part to a difference in the water needs of plants.

Prepare four to six flower pots of soil native to the vicinity, and, so far as is known, unfertilized. Plant in separate pots seeds of peas, corn, oats, radishes and as many others as you have pots to provide for. Water, and place in as favorable a situation as possible. This experiment should be going on while other work is being planned and carried out.

Report results for a series of weeks. State your conclusions on the facts.

II. COMPARISON OF GROWTH IN SOILS OF DIFFERENT ORIGIN

Prepare flower pots of similar size, one with sand; a second with clay if obtainable; a third with black soil obtained from near the bases of trees where leaves have collected and rotted; a fourth a mixture of sand and black soil, and if obtainable, mixed with clay also. For this experiment select seeds which, like the radish, grow quickly and give a good basis for comparison in the size of the root formed.

Make observations on the results, and state your conclusions after carrying the experiment two or three weeks.

Textbook, pages 256, 287–289.

LABORATORY STUDY 50

THE RESPONSE OF ROOTS TO EARTH AND WATER

It seems natural for roots to grow into the earth and for stems to grow away from it. But we may not know that, under certain circumstances, roots will overcome many obstacles to go directly into the soil, and under other circumstances, actually grow away from it.

I. RESPONSE TO THE EARTH

Obtain two small glass plates about 4″ x 5″. Cut a piece of absorbent cotton to fit between them. Soak up the cotton in water, and lay a row of seeds across the middle that have been soaked twenty-four hours. Have the seeds pointing in all possible directions. Space out the top glass with pieces of stick to give the seedlings room to grow. Bind the whole together across the ends with two rubber bands. Stand the "set-up" on edge and mark with a label. Moisten the cotton when needed, and after the seeds have started to germinate turn the plates one-fourth around. Keep on turning every twenty-four hours.

Describe what has happened to the roots, and make a sketch of the entire experiment, indicating the results.

II. RESPONSE TO WATER

Prepare another set of plates, cotton, and soaked seeds. Place diagonally across one plate a series of chips of cork, leaving spaces large enough for roots to pass between. Cut a triangular piece of cotton to fit between the plates above the pieces of cork. Lay a few soaked seeds on the cotton alongside the pieces of cork. Bind the plates together with rubber bands, and stand the "set-up" on edge, vacant space down, in a shallow dish containing a little water. Keep the cotton moist and watch for results.

1. At the end of four or five days after the germination of the seeds has begun make a sketch of the apparatus, indicating the results.
2. Will roots cross an air space to reach a larger supply of water than is available nearer at hand? If not, why not?
3. So far as the tests show, which response, to earth or to water, is the stronger in roots?
4. Is it possible that roots solve their whole problem in obtaining water? If so, how?

Textbook, page 246.

LABORATORY STUDY 51

THE RESPONSE OF PLANTS TO LIGHT

Everyone has noticed that light has a considerable influence on plants. And from our study of the work of leaves we have learned that light is essential to one of the chief functions of those organs, the manufacture of carbohydrates. But not until we observe plants closely do we realize how great is the apparent effort of plants to adjust themselves to the source of light itself.

I. THE RESPONSE OF SEEDLINGS

It might well be supposed that seedlings, being unformed as they emerge from the ground, would respond readily to the light.

Start growing near a window, boxes or pots of bean or corn seedlings. After the seedlings have grown above the ground three days, note their positions from the perpendicular, and note the positions especially of the leaves.

Mark the side of the container that is away from the window with a label and turn it 180° and indicate the date.

1. **How long is it before the seedling has again grown over toward the light?**
2. **Turn it 180° a second time, and make note of whether any part of the plant begins to grow vertically instead of bending toward the light.**

II. THE RESPONSE OF POTTED PLANTS TO THE LIGHT

Potted plants, of course, are older than seedlings. Most potted plants have woody stems, and may have grown in an environment where the light was more equally distributed than it is in a laboratory window. Take a potted hydrangea, coleus or geranium that has not been changed from its position recently.

1. **Turn the plant 180° and label with date. Describe the position of the leaves as compared with those that were on the room side.**
2. **Describe what happens in a few days to the leaves that have just been turned to the room side. What part of the leaf seems to be most active in bringing about the changed position?**
3. **At the end of a week turn the plant 180° again, and note what has happened.**

III. LIGHT RELATIONS IN A FOREST

If a forest or "wood lot" is not accessible, study the conditions found in a park where there are trees fairly close together as well as some widely separated.

What difference in general form do you note between trees of the same species that grow close together and one that grows by itself, no obstruction being near? Explain.

Where a good many trees grow close together, whether of the same species or not, many of the lowermost branches are likely to be dead.

Why is this?

In going along a road through the woods you must have noticed the greater number of branches of trees extending over the road than into the forest.

How could you distinguish a newly made wood road from one that had existed a long time?

Textbook, pages 268, 273, 274.

LABORATORY STUDY 52

ROOTS

Roots are definite organs of the plant. In general they are the part of the plant that exists in the soil, though there are roots that exist in the air, and there are parts of plants found in the soil that are not roots. But wherever roots exist, they perform much the same function of holding the plant in place or taking up water and its contents for the use of the plant.

I. KINDS OF ROOTS

There are two classes of roots, *normal roots* which extend into the soil or water directly from the base of the stem. There are also *adventitious roots* which occupy *unusual* positions. An example of a normal root are the fibrous roots of grass. An example of adventitious roots are the roots that branch out from the lowest joints of the stem of the corn plant.

Name two other plants that have normal roots and one that has adventitious roots.

Among normal roots there are single, long, and slender *tap roots*, thick, soft, or *fleshy roots*, and thick, spongy roots of plants that grow in the water but do not reach the bottom. Among adventitious roots there are roots that come from the drooping branches of certain small fruit shrubs, and roots that penetrate the stem tissues of other plants, drawing sustenance therefrom.

Give the names of examples of as many of these kinds as you can.

II. THE FUNCTIONS OF ROOTS

Roots are capable of adjusting themselves to widely varying conditions. They respond readily to conditions in their environment (see Laboratory Study 50). And they are capable of overcoming serious handicaps in making their way through the soil.

There are four important functions that may be carried on by roots; but not all roots do carry on all four functions. All roots absorb water and minerals in solution from the soil, and occasionally from the air. All roots aid in supporting or holding the plant to a definite spot, even those roots that extend into the water only. Thirdly, roots store up food which the leaves manufacture, some holding large quantities. A fourth function is the occasional one of propagating or starting a new plant.

1. **Which of these functions do the following plants manifest? Take them in turn and discuss. (a) The oak; (b) the bean; (c) the carrot; (d) the raspberry; (e) the water hyacinth.**
2. **Describe briefly the work of root-hairs.**

(*See Textbook*, pages 246, 258, and the study of Osmosis, in *Manual*, page 8.)

III. ADAPTATIONS IN ROOTS

The particular adaptations seen in roots are adjustments of form to the functions which are being carried on. Here are a few facts about roots which the student is asked to explain on the basis of *adaptation* to *function* or *use*.

1. Roots have no leaves or flowers.
2. Roots have a thimble-like cap on the growing tip of the young roots.
3. Roots have microscopic single-cell, thin-walled root-hairs near the tips of roots, but none in older parts of the roots.
4. Roots show a more definite response to the presence of water than to anything else.
5. Roots spread over a great area of ground and penetrate many feet vertically.
6. Roots are far more flexible than stems.
7. Roots are plentifully supplied with bast fibers which are very tough.
8. Many plants that live two years are capable of storing large amounts of food in their roots.

Good explanations of these facts will insure a clear understanding of the subject of roots.

Textbook, pages 246, 258.

LABORATORY STUDY 53

STEMS

The stem is a conspicuous organ of the higher type of plant. On its parts or branches it bears buds, leaves, flowers, and fruits. From its buds it develops additional branches, and by means of certain interior cells it adds to the amount of living plant material year after year.

I. KINDS OF STEMS

There are several more or less clearly distinguishable types of stems, the features of which are indicated in the form of the whole plant. There are the slender stem, the spreading stem, the creeping stem, the climbing stem and the underground stem. Examples of all of these will occur to the student, except perhaps the underground stems. The white potato, the onion, and the horse radish are underground, condensed stems. They fit into the description of stems in that they have buds, leaves and branches.

Give an example of each of the other kinds of stems.

II. FUNCTIONS OF STEMS

Some of the functions of stems are obvious, and others have to be ascertained by experimentation.

What are the obvious functions of stems?

To determine the less apparent functions of stems, cut two willow twigs a foot or more in length. Strip from each a band of bark about an inch long. Pour water into a jar so that the water will stand below the level of the band of bare wood. Keep the surface of the water at this point.

Watch the willow twigs for a few weeks. Report what you see, and state your conclusions.

III. TISSUES OF STEMS

Cross-sections of stems or twigs of an oak, or other common tree, and of many thousands of species of smaller plants, will show a certain definite arrangement of tissues or groups of cells. A cross-section of the stem of a corn plant shows entirely different arrangement of kinds of cells. Stems of the first kind are characteristic of dicotyledonous plants. Those of the second kind belong to monocotyledonous plants. Chapter XXII on the bean shows two stages in the development of a dicotyledonous stem. Chapter XXI shows the structure and arrangement of the tissues in a monocotyledonous stem.

1. Identify the tissues beginning at the center, and give some notion of the function of each.

2. **Cut cross-sections of twigs of trees and determine the age of each by noting the number of annual rings.**

Textbook, pages 247–249, 258–260.

LABORATORY STUDY 54

LEAVES

Nothing in nature brings us quite so much joy as does the coming of the green leaves in spring. During the summer months we continue to appreciate their verdure and shade, and an autumn landscape again brings exclamations of praise from our lips. While the beauty of leaves escapes none, the fact that we and all animal life are dependent upon them for our existence is not so generally recognized. The truth of this statement will be obvious when you have completed the following studies.

I. LEAF FORMS AND THE PARTS OF A LEAF

1. **Make a sketch of the leaf of a maple or of an oak, and label the blade, the midrib, the veins, and the petiole, or leaf stalk.**
2. **Sketch also the leaf of a lily or corn plant.**

In what respect does the leaf described in # 2, differ from the leaf of the maple or oak? In what respects is it similar? The maple and oak leaves are called *dicotyledons* (plants having two small leaves in their seeds), and the corn and lily leaves are called *monocotyledons* (plants having one small leaf in their seeds).

To which group do most of the plants with which you are familiar belong?

Examine and sketch a compound leaf such as a horse-chestnut or an ash. How does it resemble and differ from those you have already drawn?

What are the functions of the veins? How does the broad thin shape of the leaf fit it for the work it has to do?

II. STRUCTURE

Examine under the microscope a prepared slide of a cross section of a leaf. Observe carefully the following parts: the upper layer of cells or *epidermis* beneath which is a row of elongate cells, the *palisade layer*, which contain *chlorophyll;* the spongy *parenchyma*, which is made up of the irregular cells beneath the palisade layer and which also contain chlorophyll; air spaces; a cross-section of a vein; the lower epidermis where you will find the openings of *stomata*, or breathing pores.

(Optional.) Make a drawing showing the cross-section of a leaf.

How does the leaf get its water? Its carbon dioxide?

III. PHOTOSYNTHESIS

Cover a portion of a leaf of a hydrangea or coleus top and bottom by pinning on pieces of sheet cork, spacing out with very narrow pieces of cork to permit the circulation of air under the cork. Leave the plant in the sunlight about forty-eight hours. Then remove the leaf and dip it in boiling water to kill the living protoplasm inside. Now place the leaf in wood alcohol until the green chlorophyll has been removed. Soak out the alcohol and test the leaf with iodine for starch. Record your results. Repeat this experiment, using the leaves of similar plants which have been kept in the dark for a day or longer.

Prepare another experiment by smearing vaseline in spots above and below the middle of a leaf. What factor are you experimenting with?

What substance is manufactured by green leaves and what conditions are necessary for the process? What does the chlorophyll do? What are the air spaces in the leaf for?

Starch is a basic organic food substance and cannot be formed in any way but the one described. Place a large glass funnel over some water plant (such as elodea) submerged in water in a tall battery jar. Fill a test tube with water and invert it over the end of the funnel so that any gas that is given off will displace the water. Set this material in the sun for a few days and keep careful watch to note the results.

What gas collects in the test tube? Test with a glowing splinter in the test tube.

Where did the gas come from? Of what process is it a by-product? What can you say of the importance of photosynthesis to man?

IV. TRANSPIRATION

Place a small branch with a good many leaves on it through a large hole rubber stopper that fits a wide mouth bottle. Pour some water in such a bottle and place it on a glass plate. Stopper the bottle and leave the end of the branch in the water. Seal the branch in the hole in the stopper with paraffin and place a bell jar over the plant and bottle. The bell jar should be sealed to the glass plate with vaseline and the whole apparatus set in the sunlight in as cool a place as possible. Observe the jar in a day or so and account for any change in its appearance.

Where do plants get their water? Why do they need it? Explain fully. What would be the result if plants did not give off this excess of water?

This process of giving off water by plants is called *transpiration.*

Textbook, pages 243–264.

LABORATORY STUDY 55

THE PARTS OF A FLOWERING PLANT

As we have seen, man is ultimately dependent upon green plants for his food supply. Most green plants in order to carry on their species must produce seeds. Without flowers there can be no seeds, so we may say that in an important sense man owes his continued existence to the flowers.

THE PLANT

Examine a complete specimen of a buttercup, or other flowering plant, that you may obtain. Notice that the plant is divided into four important parts: the roots, the stem, the leaves, and the flower. These are the organs of a flowering plant.

THE ROOTS

How does the size of the root system compare with the rest of the plant that is above the ground? What is the character of the roots: are they *fleshy*, like those of the beet, carrot, and turnip; *fibrous*, thread-like as those of grasses?

Of what service to the plant would the roots be in a wind storm? In what other ways would roots be of service?

THE STEM

Is the stem smooth or hairy? Is it strong? Describe its method of branching. What is the arrangement of the leaves on the branches? How does the stem aid the leaves in receiving a large amount of light? At what places on the stem are the flowers found? Tell as many uses of stem as you can.

THE LEAVES

Are there many leaves on your specimen? Are the leaves *simple* (the blades united into one piece) or *compound* (the blades deeply cut and the *leaflets* as the divisions of the leaf are called are attached to the *petiole* or leaf stalk or to the midrib)? Is the leaf hairy or smooth? parallel-veined or netted-veined (the veins branching so as to form a network)?

THE FLOWER AND ITS PARTS

How many flowers are there on your specimen? Where are they located? What are their colors? Working from the outside toward the center of the flower, find a circle of pale yellow *sepals* which together make up the *calyx*. How many sepals are there? Proceeding toward the center you will notice a circle of brilliant yellow *petals* which together make up the *corolla*. How many petals do you find? What is the function of the calyx? What is the function of the corolla? Inside the corolla you will find a whorl of *stamens*. How many stamens do you find? The slender stalk of the stamen is called the *filament* and at the end you will find the *anther*, a little case where the *pollen* is produced. The pollen is the powdery-like substance that you see on the anthers. Examine some pollen grains under the microscope and make a sketch of them. In the center of the flower you will see the pale green *pistil*. The pistil is composed of three parts: the broad round base which contains the *ovary* inside of which are found the *ovules*, the slender stalk called the *style*, and the *stigma* at the top of the style. The stamens and pistils are the most important parts of the flower. Can you tell why?

THE FRUIT

Examine the fruit of the buttercup or of the flower that you have studied. What parts of the flower make up the fruit? How many seeds do you find in the fruit?

Make a drawing of the plant showing all parts.

Make a drawing of the flower, labeling the parts you have seen.

Make a drawing of a single stamen, labeling all the parts.

Make a drawing of the pistil, labeling all parts.

Make a drawing of a fruit and a single seed.

Textbook, pages 208–213.

LABORATORY STUDY 56

THE POLLINATION OF FLOWERS

We have already learned that the pistil and stamens are the most important parts of the flower. If the pistil is removed, or if the stamens are removed and the pistil covered with a paper bag, no seeds will be produced. When this is proved it is sufficient evidence that the pollen and the pistil are necessary for the production of seeds. Pollen must in some way or other get to the stigma. We shall see that the adaptations of plants to this end are remarkable.

INSECT POLLINATION

Examine a buttercup (or other flower) and note the arrangement of the flower parts, particularly the stamens and pistils. Pull off a petal and with the aid of a hand lens examine the pointed base. What do you observe? Taste this part.

What would happen when a bee or some other insect in search of nectar visits this flower? Would self-pollination be likely to occur in the buttercup?

Examine a tulip and note the arrangement of the flower parts. What are the relative lengths of the pistil and stamens? Is the pollen sticky? The nectar is found at the base of the pistil.

What would happen when a bee visits a tulip in search of nectar after having previously paid visits to other tulips?

Examine a nasturtium, and notice the arrangement of the stamens and pistil. (If the anthers hold pollen, the pistil is below them, while if the stamens have given up all their pollen, the pistil projects up into the entrance of the flower with its three-pronged stigma outspread.) Bite off the end of the calyx tube and taste the nectar.

Tell what would happen if a bee seeking nectar visits a nasturtium when the stamens contain pollen. What would happen if the stamens had shed their pollen?

Examine a specimen of "butter-and-eggs" and notice the tubular two-lipped corolla. Look inside for the stamens and pistil, and find the nectaries. Bees in search of nectar alight upon the lower lip of the corolla and the weight of the insect forces the lip down and makes an entrance into the corolla tube.

What would happen when a bee covered with pollen from another flower of butter-and-eggs makes its way into the corolla tube?

Examine carefully the flower parts of salvia. Notice particularly the arrangement of the stamens. How are they adapted to dusting their pollen on the back of a bee in search of nectar at the base of the pistil? Would the stigma receive the pollen as the bee goes into the corolla tube or as it backs out?

Describe just what would happen when a bee visits salvia in search of nectar.

WIND POLLINATION

Examine the catkins of an oak tree, with the aid of a hand lens, when the anthers are shedding their pollen. Are all of the organs of the flower present? Shake a catkin gently over a piece of paper. What is the substance that falls upon the paper? Does it appear to be abundant? Is it as sticky as the pollen of the buttercup? The catkins are the staminate flowers (flowers with stamens); the pistilate flowers (flowers with pistils) are less conspicuous and are found in the axils of the leaves. Examine some pistilate flowers with a lens and determine if the calyx and corolla are present. What is the shape of the pistils? Is it well adapted to the work that it has to do? Why would not the flowers of the oak be pollinated by means of insects?

How are the flowers of the oak tree pollinated?

The flowers of the elm, birch, hickory, walnut, corn, and many other plants are also pollinated by the wind. Some of these may be brought into the laboratory and examined after the manner of the oak blossoms.

What is meant by pollination?

What adaptation do flowers possess that depend upon insects for pollination?

What adaptations do flowers possess that depend upon the wind for pollination?

Textbook, pages 211–213, 261–264.

LABORATORY STUDY 57

FERTILIZATION

Pollination we have learned is the transfer of pollen from the stamens of one flower to the stigma of another. Fertilization begins where pollination leaves off and is completed when the nucleus of the male cell (the pollen grain) unites with that of the egg cell in the ovule.

You may perform an experiment to see how this process of fertilization is begun. Shake the pollen from a tulip on a 3 per cent solution of cane sugar in a concave slide, cover with a cover glass and examine with the low power of the microscope. Now place the slide under a small bell jar with wet blotting paper or a moist sponge to prevent the evaporation of the sugar solution. Try narcissus pollen on a 5 per cent solution and sweet pea pollen on a 15 per cent solution. If other kinds of pollen are available try them on solutions of different strengths.

Examine after a day or so with the low power of the microscope. The small tubes growing out from the pollen grains are *pollen tubes.*

Make a sketch of a few pollen grains showing the pollen tube.

The pollen grains on the stigma put forth these pollen tubes which grow down the pistil into the ovule and which serve as a pathway for the male nucleus. You can best get an idea as to the path taken by the pollen tube by a careful study of Figure 131 in the textbook.

From the study of fertilization, what organs of the flower appear to be most important?

Write a short story about pollination and fertilization, being careful to distinguish between them.

Textbook, pages 261-264.

LABORATORY STUDY 58

FRUITS AND SEEDS AND THEIR DISPERSAL

Fruits come after the flowers. Often it is possible to identify accurately the part of the flower that develops directly into the fruit. The word fruit suggests something eatable, but a great many fruits are neither eatable nor, in fact, conspicuous in any way. But all fruits have the same biological function to perform. Can you suggest what this function is?

I. THE RELATION OF FRUITS TO FLOWERS

What part of the flower of the bean plant or the pea becomes the fruit? Explain.

The familiar apple is one of the most complicated of fruits, relative to its development from the flower. Examine the dried objects at the end of the apple opposite the stem. The minute outside parts are the tips of the five sepals (see page 99). At the center are sometimes to be found the dried stamens and the stigma of the old pistil. A longitudinal section and a cross-section of apples show at the middle the seeds joining at the base of the ovary and protected by the tough ("core") inner wall of the ovary. Next comes the soft eatable outer ovary wall, and, separated by a ring of ducts, the outside fleshy basal portion of the calyx.

Do you know of other fruits that are constructed in a similar way?

Most fruits consist of the ovary wall hardened, or softened, and the seed or seeds contained within.

Describe three examples of this type of structure.

II. THE ADAPTATIONS OF FRUITS AND SEEDS TO DISPERSAL

In all cases of fruit or seed dispersal it is well to remember that neither the plant nor the animal that may take part in any act of dispersal knows the meaning of its participation in the phenomenon. Even human beings who wander through the woods, and, on finding their clothing covered with "pitch-forks" or "stick-tights" scrape them off and throw them on the ground, are acting as much without thought of the favor they are doing the species of weed as does the cow that beats her tail against the fencepost, loosening a few of the clinging fruits.

What is the advantage to the various species of plants of having adaptations to dispersal?

The following are means to dispersal of fruits and seeds: the wind, edibility, minute clinging hooks, explosion (pods popping open), and the fitness for floating on water.

What are the adaptations to dispersal characteristic of the following fruits? Describe each adaptation in detail, and tell how the dispersal is carried out: The milkweed; the maple; the cockle bur; the hickory nut; the sedge; the wild geranium; the violet; the touch-me-not; the apple; the tomato.

Textbook, pages 290, 291.

LABORATORY STUDY 59

THE GERMINATION OF SEEDS

We have all noticed that stored seeds remain for a long period of time unchanged. Under certain conditions seeds will quickly show signs of life, and the miniature plant, hidden within, will unfold and manifest the characteristics of the species. Analysis and experimentation with essential factors in the environment of growing seeds will disclose the importance of each factor.

I. WATER AND GERMINATION

Prepare a series of five or six bottles holding about eight fluid ounces, bottles that can be closed with a stopper and sealed with melted paraffin. Crumple up an equal number of pieces of blotter or filter paper, and place them in the bottoms of all the bottles.

Take a small handful of sun-dried, not kiln-dried, pea seeds (grocery store seeds will not do), weigh out ten to twelve seeds, and pour them into each bottle. Use metric system scales if you weigh the seeds.

Next measure out with a graduated cubic centimeter cylinder varying quantities of water. Since one gram is equal to one cubic centimeter of water, you can definitely relate a known quantity of seeds to varying quantities of water. If you have no metric scales, measure quantities of seeds and water in any small container.

Arrange the series to have a small quantity of water at one end and a large quantity at the other end, where the seeds should be immersed in more water than they can absorb. Seal the bottle and set them aside under the same exterior conditions. Why seal the bottles?

1. **What are the conditions, exterior and interior, that are the same?**
2. **What is the importance of being careful to keep all these conditions similar while varying the conditions of moisture?**
3. **Carry the experiment through four to six days, observing and noting each day what has happened.**
4. **At the end of that time what is your conclusion relative to the influence of water in germination, expressed in terms of percentage, if possible?**

II. AIR AND GERMINATION

The special inquiry we can make relative to the influence of air on germination concerns the particular part of air that furthers the process.

First, soak some sun-dried pea seeds for twenty-four hours. Prepare four eight-ounce bottles with stoppers. Collect in one pure oxygen (see page 3), in a second pure nitrogen (see page 6), in a third carbon dioxide (see page 131), and in a fourth air. The bottles should be equipped with some crumpled blotter or filter paper and what appears from the experiment under Section 1 of this study to be a favorable amount of water. The stoppers of the bottles should have a plugged opening in each, large enough to receive the ten to twelve seeds when you are ready to drop them in.

1. **Carry out further necessary steps in the experiment, and report what you have done.**
2. **Observe the experiment four to six days, report results noted, and give your conclusions concerning the part of air which aids seeds to germinate.**

III. HEAT AND GERMINATION

We come now to a third factor which may be supposed to operate in bringing about the germination of seeds. In a general way we know that seeds are not germinating out of doors in winter, at least in the latitude of our northern States. Do they germinate when the weather is the hottest?

Prepare another set of eight-ounce bottles, with clean blotter or filter paper in the bottom, and with what you regard as a favorable amount of water in each. Drop into each ten to twelve sun-dried pea seeds. These may be closed in with plugs of absorbent cotton to prevent rapid evaporation and to permit some air to enter. Find at least four places where the temperature is fairly constant but different from other situations included in the experiment.

1. **Find such situations, take note of the degree at which the temperature is constant, and report.**
2. **Make observations and take note of results for four to six days.**
3. **What are your conclusions as to the most favorable temperature for the germination of pea seeds?**

Textbook, pages 253, 258.

LABORATORY STUDY 60

COTYLEDONS AND ENDOSPERMS IN GERMINATION

Seeds of various kinds form an important portion of the food of many kinds of animals, including man. The germ or embryo of seeds is often a small part of the whole seed. The material constituting the remainder of the seed, whether it is separate from the embryo or stored within a part of it, is nutritious. The probability is that this material is useful also to the plant which produces it. An experiment will help us to ascertain the facts.

I. THE COTYLEDON IN GERMINATION

Start several pea seeds growing in a box of sawdust. When the stems are one to two inches high, take up a few seedlings carefully and cut one cotyledon from two seedlings, and both cotyledons from two others, leaving two specimens uncut.

Cover a tumbler of water with netting, binding it about the edge with a string. Poke holes through the netting large enough to admit the roots, and small enough to retain the cotyledons above the water. Adjust in place the six pea seedlings, and keep in place with the glass filled with water. Observe for four to six days or longer.

Report on the facts, and state your conclusion on the importance of the cotyledons of the pea seed in germination and early development.

II. THE ENDOSPERM IN GERMINATION

Grow corn seedlings in moistened sawdust. When the stems have begun to appear above the surface, remove six seedlings carefully. Prepare a tumbler of water as in Section 1 of this study.

Cut vertically from two corn seedlings one half the endosperm, being careful not to disturb the remainder. Cut away the entire endosperm from two others, leaving the cotyledon whole. Keep two seedlings unchanged. Thrust the roots of all six through holes in the netting, and set aside as in Section 1.

Report on the facts, and state your conclusion on the importance of the endosperm of the corn seed in the process of germination and early development.

Textbook, pages 253, 254; for comparison, *see also* page 258.

LABORATORY STUDY 61

REGIONS OF RAPID GROWTH IN PLANTS

Plants make phenomenal growth in a single season, and even in a single day. Do you know whether two nails driven into a tree a foot apart will in the course of time grow farther apart? To locate the region of growth in an old plant, and to find the point or region of the greatest growth in a plant of any age, is a process worth investigating.

I. SEEDLINGS

Take a few two to three-inch pea seedlings grown in moist sawdust, and make equidistant marks with a fine brush and India ink on the entire root and stem. Cover a tumbler with a netting and poke holes large enough to admit the roots.

1. **Observe the development for four to six days, and describe the results.**
2. **Does any part of the stem or root attain an appar-**

ently maximum length, or is the growth in length continuous?

II. OLDER PLANTS

Select a favorable stem on a potted plant such as a coleus or a geranium. With a brush and India ink make marks exactly one inch apart from the base of the stem to the tip of a prominent branch.

Observe the plant for one to two weeks, and describe the results. Is the stem of an older plant fixed in length at any point?

LABORATORY STUDY 62

CORN

Corn is a native of this Continent, but is now grown widely over the world in improved varieties. One-third of our cultivated land is used for growing corn, and over three billion bushels are produced yearly. No food plant we have produces so enormously. Yet we ourselves eat little of it. Nevertheless, it is excellent food, and it is cheap.

I. THE CORN PLANT

The seeds of the corn plant are planted in hills of a few seeds each in the spring in temperate to hot portions of the country. The plant grows rapidly and blossoms in the months of May, June and July, depending on the latitude.

Describe the process of pollination in the corn plant and the result of that process. (*See textbook*, page 253.)

The corn plant matures or ripens in late summer or early fall, when the whole plant becomes yellow and the grains hard.

1. Examine an ear of corn and describe what you see.

2. Section a grain of soaked corn lengthwise while it lies flat, and examine the parts you discover. Identify endosperm and embryo and parts.
3. Try the nutrient tests to discover the facts that may justify the statement that corn is an important food plant.

II. CULTIVATING AND HARVESTING CORN

Corn is grown in rich soil where a plentiful supply of water is available. Deep plowing and harrowing improve the chances of the plants. Before the young plants have appeared above the ground, and during the entire time of their growth, various enemies attack them; first, the crows, then cutworms, army worms, grasshoppers, and a parasitic plant, called smut, that grows in a black lumpy mass on the ears.

What is done to check the ravages of some of these enemies of the corn plant?

Soon after the plants have grown a few inches cultivation begins, and continues until the tassels of staminate flowers have appeared.

What is the benefit to be derived from cultivating plants?

Sweet corn is mature enough to eat in July. Field corn must harden to be fit for its uses.

How is the harvesting of field corn carried on?

III. DISPOSING OF THE PRODUCT

From 85 to 90 per cent of the field corn never leaves the farms where it is produced. The remainder is shipped to the market, and is distributed about the world for various purposes.

What happens to the corn that never leaves the farm? Why?

Corn bread is made from corn meal, ground after the bran and the embryo have been removed. The old process of grinding eliminated only the bran.

What nutrient of the grain in general is left out of corn meal now?

Beside corn meal, other corn products are corn starch, corn syrup or commercial glucose, and oil. From the oil a valuable cooking oil is obtained. Oil is transformed into soap, into a tanning material, into a substitute for rubber, and into water-proofing and insulating material. The oil cake remaining after the oil is extracted from the embryo is fed to livestock.

1. **What branch of human knowledge has made these discoveries possible?**
2. **Make a longitudinal section through the embryo as the grain lies flat. Draw X 3. Label the parts.**
3. **Make a transverse section through the middle. Draw X 3. Label the parts.**

Textbook, chapter XXI and pages 297–299 at end of study.

IV. DEVELOPMENT

Prepare a moist chamber of a wide flat-bottomed, covered jar, with two layers of moistened filter or blotting paper and a little excess water. Soak corn seeds twenty-four hours. Drop into the moist chamber a dozen or more soaked seeds.

1. **Identify the plumule and the radicle in development, telling what they are developing into.**
2. **When the root-hairs appear make a drawing of the whole seedling.**

LABORATORY STUDY 63

THE BEAN

Beans are common in temperate and tropical regions throughout the world. They are cultivated and cared for because they are nutritious. In most places they are cheap, and unlike most plants their growth in the soil improves the condition of the soil itself.

I. THE PLANT AND ITS PARTS

Because beans may be grown indoors, it is possible to provide at least small plants at various seasons. But in early spring better plants may be obtained. Seeds planted at different times will yield maturing plants during a long period. Dig up bean plants for the laboratory study, wash off the roots and lay them out for examination.

1. Sketch in outline the entire plant, noting the arrangement of the leaves on the stem, the veining of the leaves, the form and branching of the stem, the root system and the tubercles of nitrogen-fixing bacteria on the roots.
2. Take a blossoming plant for the study of the flower. Identify and observe the parts in the calyx, the corolla, the stamens and the pistil.
3. Make a careful drawing of a flower.
4. What adaptations do you observe in the flower to pollination by insects?
5. What parts of the flower in the older blossoms are developing into the fruit?
6. Open a young fruit and describe what you see.

II. BEANS AS FOOD

The widespread use of beans for food is evidence of value. But food tests will give us definite information.

1. Apply the nitric acid-ammonia test to some seeds that have been soaked several hours, and state

whether the protein content seems to be high or low.

2. Apply also the starch test, stating the conclusion you draw from it.
3. Do you find glucose and oil in the bean seeds?
4. What other food is frequently eaten with beans? Why?

We may have bean seeds all the year round, and green beans in the summer time. But in large cities and in some tropical countries green beans may be obtained continuously. The green beans are shipped from the South to the cities.

What additional needs of our bodies do green beans supply?

III. THE DEVELOPMENT

Plant some sun-dried bean seeds in moistened sawdust or soil. Soak another lot for twenty-four hours. Place some of this lot in a moist chamber on damp filter or blotter paper, and leave until they germinate. Take other soaked seeds and examine the structure of the seed and the embryo contained in it.

1. **Open a seed along the convex edge with the point of a knife, lay out the halves and identify the seed coats, the cotyledons, the delicate plumule and the radicle.**
2. **Make a sketch of the embryo in place.**
3. **From your examination of the germination stages appearing in the moist chamber specimens, describe the early changes in the plumule and the radicle.**

If you are watching the course of development in the planted seeds you may see a loop of the young seedling that is pushing its way up through the crust. This is a portion of the new stem that develops from a minute region called the *hypocotyl* that lies near the junction of plumule and radicle below the point where the cotyledons are attached.

1. **Do you see an adaptation to use in the doubling of the hypocotyl on its way to the light and air?**
2. **What appearance develops in the cotyledons after their emergence that gives a notion of their function?**
3. **What happens to the cotyledons later on that shows their function in development?**
4. **What is the meaning of the large amount of rich food in the bean seed for the young plant itself?**

Textbook, chapter XXII and pages 348, 354.

LABORATORY STUDY 64

WHEAT

Wheat is grown in considerable quantity in forty-three of the states of the Union. In the year 1923 we produced 781,737,000 bushels. 100,000,000 bushels of this went into the production of macaroni. Wheat is the most important grain food we consume. The amount of labor and the wealth concerned in the care of wheat and in the creation of its chief product, flour, are tremendous.

I. THE WHEAT PLANT

In the most northern states and in Canada varieties of "spring" wheat are grown, while the states south of this district grow more "winter" wheat. Spring wheat is sown in early spring, and winter wheat is sown in the autumn. Both reach maturity in June and July.

Why should the two kinds be sown?

Wheat is a member of the grass family of plants. The flowers are inconspicuous, and the pollination is carried on chiefly by the wind blowing pollen from one wheat plant to another. Examine a "head" of a wheat plant.

1. **How are the grains situated, and how are they protected in development and during harvesting?**
2. **Crack open a grain and describe what you see.**
3. **Examine a particle of the interior on a glass slide in water with the compound microscope, and describe what you see.**

II. CULTIVATING AND HARVESTING WHEAT

Wheat grows in fertile soil with a light mixture of clay and lime. The top soil must be fairly deep to maintain the supply of nitrogen and other elements used in large quantities by the plants. Plowing and harrowing prepare the ground for the drill. With the drill, drawn by horses, the grains of wheat are sown in shallow trenches a few inches apart, the machine covering the seeds as it goes along.

Why is no further cultivation possible or necessary during the growth of the plants?

During the growth of the plants numerous enemies attack it. Among them are the wheat rust (see page 231 of the textbook) and the insects, the chinch bug and the Hessian fly.

Ascertain the extent of the damage done by these enemies, and the means being taken to eliminate them.

When the wheat begins to turn yellow, or to ripen, harvesting is on. The farm implements used in this process are the old-fashioned "cradle," the old reaper, the newer reaper and binder, and the harvester that clips off the tops only. When the grains in the heads are thoroughly dried or "cured," threshing of the wheat follows.

From current-events discussion, recall and mention the proposals that have been made, or have been put

into effect, to prevent waste and exploitation in handling and disposing of wheat to the flour mills.

III. THE MANUFACTURE OF BREAD

Wheat bread is doubtless the most important single article of food among civilized peoples.

Why is this so?

The manufacture of flour is more centralized in certain cities of the country.

What are the cities, and what are the factors that have brought this about?

The baking of bread has also become industrialized in large centers.

Do you think the results have been beneficial on the whole? How?

Textbook, pages 230, 292, 301–303.

LABORATORY STUDY 65

THE HUMAN MOUTH

Have you thought of the number of functions with which the human mouth is concerned — eating, tasting, feeling, breathing, speaking? The mouth is the most primitive of all the organs of the body, the place where animals take in food. In ourselves we realize still more the importance of the mouth when we begin to consider the result of not taking care of it.

I. PARTS WITHIN THE MOUTH CAVITY

With a small hand mirror much can be learned about the mouth cavity. Open wide the mouth to the light and identify the teeth of the upper and the lower jaws, the *incisors*, the *canines*, the *premolars*, and the *molars*. Is the tongue attached to the upper or to the lower jaw? When the mouth opens and closes which jaw moves? What parts form the side walls of the mouth cavity? Looking far back into the cavity, identify the passage into the pharynx, the *uvula* or soft palate, extending tremulously from above, and the red *tonsils* at the sides of the passage.

What adaptations of structure to function can you discover in the arrangement of the parts in the mouth cavity?

II. THE TEETH

The teeth are a part of the digestive system. Let us see why they are so called.

When you take a bite of food, which teeth cut off the piece? If the food is something that you pull or tear apart, which teeth are called upon to do most of the work? Try it at meal time and see. If you are eating nuts or other hard food, which teeth do the work of chewing? How many of each kind of tooth have you in upper and lower jaws?

How is each kind of tooth adapted to the work it does?

While you were looking at the teeth, did you notice any cavities, or did you see where any teeth had been filled? Have you lost any teeth? And do you notice whether any white food matter has collected about the bases of your teeth, or between the teeth? Where do most of the cavities occur in teeth? Why? What is the best way to brush the teeth?

Write an account of the reasons for taking care of the teeth, and of how to do it.

Close your teeth together, spread your lips away from the teeth as far as possible, and look to see if teeth of upper and lower jaws strike one another. If they do, you are less liable to have trouble in later years with receding gums or *pyorrhea*. If teeth do not strike their opposing teeth, try to have an *orthodontist* (a dentist who sets teeth straight) adjust them for you. Remember the infection in pyorrhea is a result of receding gums, not a cause of receding.

What may a good set of teeth have to do with good digestion?

III. THE TONGUE

The tongue is composed of muscular tissue. On the surface near the tip are many delicate sense organs of touch. On top are many sense organs of taste.

1. **Do you see any advantage in the location of these two sets of sense organs?**
2. **How does the tongue aid in the work of the teeth?**

Sometimes the tongue is coated brown. This is an indication of indigestion.

Do you know of other indications of indigestion, and do you know how indigestion may be avoided?

IV. THE SALIVARY GLANDS

Spread the jaws enough to permit the tip of the tongue to be extended out to the inner surface of the cheek muscles. Feel about until the tongue touches a noticeable lump, one on either cheek. These are the *papillae* on which one pair of salivary glands open, they are called the *parotid glands*. Two other pairs of salivary glands open beneath the tongue. When your mouth "waters" these glands are secreting large amounts of saliva. In the course of time tartar from this secretion collects about the bases especially of the lower front teeth. This is incidental to the chief work of the saliva.

Under what conditions have you noticed your mouth "watering"?
What is the meaning of the watering?

Try placing a strip of litmus paper into the mouth to ascertain the chemical reaction of the saliva.

V. THE CONNECTING PASSAGES

From the mouth cavity there are passages through the *pharynx* to the nostrils, and also to the middle ear cavities by way of the *Eustachian tubes.*

Have you ever had experiences indicating that this statement could be verified? What were they?

The pharynx may carry infection to the *alimentary canal*, as in *typhoid fever.* Or it may carry infection up the Eustachian tube, causing pus to collect in the middle ear, from which infection may extend to the mastoid bone behind the ears.

What care can be taken at the mouth to prevent typhoid fever infection and the infection of the Eustachian tubes?

Textbook, Chapter XXXIII.

LABORATORY STUDY 66

FOODS IN HEALTHFUL LIVING

Food is our first necessity. We take it instinctively for continued existence, and along afterward, perhaps, think over the matter of why we do it, and under what conditions it should be done. Intelligent persons are anxious to give careful attention to a problem that is bound up so closely with their personal safety from day to day, and with their happy and efficient activity in a long life.

I. FOODS THAT FURNISH THE NECESSITIES

At first through experience, and later more definitely through scientific knowledge, we learn that there are important classes of food which our bodies absolutely require. Without a little of all these classes we should not be able to continue alive at all. They are the *carbohydrates* (sugars and starch), *protein*, *fats*, *mineral salts*, *vitamins* and *water*. Our laboratory study on the Tests for the Organic Nutrients, page 12, has made us acquainted with the means of detecting the presence of the first three. We know water, but less of mineral salts or vitamins.

1. **Let us add to our knowledge by testing for carbohydrates the following foods, if we have not already done so: potato, bread, carrot, cereal.**
2. **Which of the following contain glucose (grape sugar): potato, carrot, apple?**
3. **Do the following foods contain protein: beans, cheese, cereal?**
4. **Is there oil in these: meat, some green vegetable, oatmeal?**

These are some of the many foods of which we consume a great deal. But we should know just why we eat them. Study of the textbook makes it clear that we derive energy for the body and its organs from the carbohydrates.

In order to have a variety of sources of energy, let us make a list of five foods from which carbohydrates may be obtained (*see textbook*, pages 342, 343).

We consume protein to have material for repairing the small amount of muscle and nerve tissue that is worn out each day. While we are growing, a considerable amount of the protein we eat goes directly to the building of protoplasm in the new living cells. One food containing an abundance of protein will supply this need.

What foods would supply this protein (*see textbook*, pages 345, 346)?

Fat is not turned into fat on being consumed and digested, but is oxidized for energy.

What foods may supply this energy from fat (*see textbook*, pages 344, 345)?

The other nutrients which have definite uses are mineral salts, vitamins and water. The mineral salts furnish bone material and substances useful in correcting the bodily functions.

> **A list of the foods containing these nutrients should be given here** (*see textbook*, pages 346, 347).

The vitamins are the newly discovered essentials for healthful living.

> **Make memoranda to show their uses and their origin** (*see textbook*, pages 348–350).

Water is present everywhere, and is needed to keep the protoplasm fluid and alive.

II. AMOUNTS AND CONDITIONS FOR EATING

Even a furnace has to be supplied intelligently with burnable material. If you throw into the furnace, or into the human body, a considerable amount of material at once it will seem to be enough, when it really will not be. In the case of the furnace, and in the case of ourselves, we are deceived.

1. **What precautions in this matter will set us right?**
2. **What other effect have you noticed resulting from rapid eating?**
3. **What effect have you noticed from actual over-eating?**
4. **Have you ever had experiences like those described in the textbook, page 383? If so, what would you suggest as a means to establishing good conditions for eating?**

Many persons are puzzled to know how much they should eat. It is difficult to estimate the amount to eat, on a mathematical basis. If the habit of eating three times a day only is established, and the habit of eating slowly, and chewing the food well, the appetite itself is a good leader.

A suggested limit on eating, however, is offered in the following for the principal meal of the day:

One dish rich in protein.
One dish rich in starch.
One dish rich in sugar.
One dish rich in fat.
One dish rich in mineral salts.
One harmless beverage.
Fruit.

On this basis suggest a meal, and compare it with what you commonly eat.

III. THE HYGIENE OF DIGESTION

Food having been consumed under favorable conditions, and in suitable amounts, it is necessary that the digestion proceed under good conditions. Sometimes we have headaches, dizziness, bad taste, foul breath and acute pains in the abdomen. Added to these the skin may appear sallow. These are signs of constipation or a clogging up of the whole digestive system. Fresh fruits are valuable aids in setting the digestive system right in difficulties of this kind.

1. **What actual experience have you had bearing on these points?**
2. **What have you noticed in your experience to be the effect of vigorous exercise on the satisfactory completion of digestion?**
3. **Have you ever planned to avoid the necessity of complaining about your digestion, a misfortune of many older persons?**

Textbook, Chapters XXVIII, XXIX, XXX.

LABORATORY STUDY 67

THE DIGESTION OF STARCH

We learned in the study on Osmosis, page 8, that starch cannot pass through a membrane. In the same study we learned something about the solubility of various substances. We realize from these studies that the change in the chemical composition of foods is a necessity before living things can make use of them. The process by which these changes are brought about is called *digestion*. It is a fundamental process for all animals and all plants.

I. DIGESTION IN THE MOUTH

Have several clean test tubes ready. Set out some Fehling's solution for the glucose test and some iodine solution for the starch test.

To see what happens to soda crackers on being chewed, chew a piece for two or three minutes. Place a small portion in each of two test tubes with a little water. Into two other test tubes containing water drop pieces of dry cracker. Apply the starch test to the contents of a tube containing the dry cracker, and to the other dry cracker apply the glucose test.

What is the result in each case?

Next apply the starch test to one lot of chewed cracker, and the glucose test to the other.

Describe the results in these cases, and state what seems to be proved.

But may it be that the saliva itself may be giving some reaction to one of these tests? Therefore, rid the mouth of cracker, and test some saliva for starch and for glucose.

What is your final conclusion from all these tests?

II. DIGESTION IN THE SMALL INTESTINE

The pancreas, a digestive organ lying under the stomach, by the first fold of the small intestine, has very important functions. Prepare some pancreatin solution from the manufactured product of an animal's pancreas.

Place a piece of soda cracker in a test tube and pour in some pancreatin solution. Set in an incubator or an oven of about 100° Fahr. for twenty-four hours.

Carry out the glucose test on the cracker in the test tube, and also on some pancreatin solution, and state your conclusion.

III. DIGESTION IN PLANTS

Plants, of course, contain starch; they also contain glucose. Let us see if there is digestion of starch in plants. Cut some soaked grains of corn lengthwise and apply the starch test. Also to other specimens apply the glucose test.

Describe what happens in each case.

Next take from the laboratory stock a few corn seedlings with stems three or four inches high. Remove stems and roots. Section longitudinally and test two of these seeds for starch and two others for glucose.

Describe the results and state your conclusion.

Textbook, pages 250, 343.

LABORATORY STUDY 68

THE DIGESTION OF PROTEIN

In the experiments under Osmosis, page 8, we learned that white of egg, a typical protein, will not pass through a membrane. Therefore, protein cannot be absorbed from the intestine of an animal eating the white of egg.

Cut pieces of cooked white of egg and drop into four clean test tubes. Prepare cotton plugs for closing the tubes. Into the first tube pour water to cover the egg, into the second pour a solution of fresh saliva, into the third, a solution of prepared pepsin, and into the fourth a solution of prepared pancreatin.

Close the test tubes with cotton. Place the four test tubes in a warming oven of about 100° Fahr., and look for changes indicating progressive dissolving of the egg.

1. **Record results daily for four to six days.**
2. **According to these results, where in the digestive system does protein digestion begin, and where is it completed?**

Textbook, pages 384–385.

LABORATORY STUDY 69

THE DIGESTION OF OIL OR FAT

We now know that oil or fat occurs in small or large quantities in a great many foods. Like other organic nutrients it can be digested, and for the same reason it must be.

Set up four test tubes with a small lump of butter in each. Into the first pour water, into the second pour saliva, into the third a solution of pepsin, and into the fourth a solution of pancreatin. Place all in an oven of about 100° Fahr. for two or three days.

1. **What happens in the several tubes?**
2. **Supposing that you know the source of pancreatin, where in our digestive system would fat or oil be digested?**

Textbook, pages 384, 385.

LABORATORY STUDY 70

THE BALANCED MEALS OF A DAY

Even thoughtless persons will not deliberately try to make a meal on a single kind of food, except under necessity. No single food contains what we need in the ratio satisfactory to man.

I. THE BALANCING WORKED OUT IN HUMAN EXPERIENCE

There are certain food combinations which we eat from long habit, like meat and potatoes, bread and butter, etc., etc.

> **Name five other natural combinations, and tell what organic nutrients are brought together in the balanced ration.**

II. WHAT SCIENCE HAS ADDED IN COMPLETING THE BALANCE

Although it appears to be natural for children to adopt the balanced rations, bread and butter, meat and potatoes, and others, it is not natural for them to like another class of food which science has shown to be necessary. This is green vegetables.

1. **What is the scientific basis for the advice to eat green vegetables** (*see textbook*, pages 347, 349, 350)**?**
2. **What green vegetables were you yourself obliged to learn to like?**

III. THE DAILY BALANCE

There is considerable variation in the needs of adults in the daily supply of food; some hard-working men require three times as much as other men. Among children and adolescents, however, the actual needs are similar for each age group. And the amount required by a young person in school is not very different from the amount needed by a grown person working at a profession.

Experience has shown that at breakfast our needs are not as great as they were thought to be at one time. The menus given on pages 356, 357 in the textbook are said on competent authority to be enough.

1. **Take up the breakfast menu suggested, and tell what nutrients this would provide for the consumer.**
2. **Do the same with the menu for lunch.**
3. **Do the same with the menu for dinner.**

Textbook, pages 356–360.

LABORATORY STUDY 71

THE CIRCULATORY SYSTEM

The circulatory system of man is a good example of a system of organs that has closely connected relations with several other systems. Among these are the digestive system, the nervous system, the respiratory system and the excretory system. A way of stating the importance of the circulatory system is to say that it stands in a key position in *metabolism*, the whole series of chemical and physical processes which the living body carries on.

I. THE EXTERNAL PHENOMENA OF THE CIRCULATORY SYSTEM

The best known of the external activities of the blood system is the "pulse." There are several places on the surface of the body where the rate of beat of the heart can be determined by counting the pulsations in an artery. The easiest point at which to locate the pulse is perhaps the small artery that runs in front of the ear (see textbook, page 390).

1. **Let each member of the class count his pulse for one minute while remaining seated.**
2. **Count again while standing.**
3. **Let the members of the class hop up and down rapidly for one minute and then count again.**
4. **Rest two minutes, and count once more, and count until the normal standing rate is recovered.**
5. **Compare the rapidity of recovery of normal standing rate among the members of the class.**

The most superficial blood vessels are veins. Note the distribution of some of the veins on the inner surface of the forearm. Grasp the right arm with the left hand at a point above the elbow. Press down until the veins swell to considerable size.

1. **What causes the swelling of the veins?**
2. **When the pressure is released what happens?**
3. **Is there a pulse in the veins? Explain.**

One of the most important conditions of the blood system to know about is the blood pressure. It is now within the power of nearly everyone to have this information about himself. The information may be obtained by means of the *sphygmometer* (pulse measurer). This instrument consists of a syringe pump which in the hands of an operator forces air into a rubber bag bound about a person's arm. The pressure exerted by the blood is checked against the pressure exerted by the pump, and is indicated by a column of mercury, or by a dial gauge. If the blood pressure is high it means that the body is using a large amount of energy to carry blood through arteries that have become inelastic, probably as a result of chronic constipation or of the excessive eating of food.

1. **What would seem to be the risk involved in permitting the blood pressure to become high?**
2. **What can be done to prevent high blood pressure?**

II. THE INTERNAL PHENOMENA OF THE CIRCULATORY SYSTEM

The center of the circulatory system is of course the heart. Its periodic contraction and relaxation is in the control of the *autonomic nervous system* (see textbook, page 423), but the rate of contraction is adjustable to needs in other systems.

1. **What systems especially are supplying increased needs during an athletic contest?**
2. **To what organs are these needs transported?**
3. **Study the work of the red blood corpuscles, and state their function** (*see textbook*, page 394).

To understand another function of the circulatory system we must consider what is likely to happen to the food the digestion of which is being completed in the intestine. The blood vessels penetrate the wall of the intestine, and lie on one side of membranes on the other side of which is digested food.

Recalling the experiments on Osmosis, page **8, what now happens to the digested food?**

In a later study we shall find some of this food stored in the liver, and some of it will be distributed over the whole body, a little to be stored in the muscles, a little to be used up at once to supply energy, and some to be transformed by assimilation into protoplasm of living cells.

1. **By what process would certain portions of the food be used up to supply energy?**
2. **Study the connection of the lymph system** (*see textbook*, page 395) **and give your idea of the way digested food reaches the cells, and the wastes are carried back into the circulatory system.**
3. **On page 394, textbook, you will read the interesting story of the white blood corpuscles. Tell**

what each person can do to give these "eating cells" their best support in protecting us.

Textbook, pages 328–330 and Chapter XXXIV.

LABORATORY STUDY 72

RESPIRATION

Respiration or breathing is a function that brings every animal and every plant into contact every second with the most generally present substance in existence, — air. Thus, respiration and its attendant process, oxidation, become in an important sense the most fundamental process in life.

I. HOW RESPIRATION IS FUNDAMENTAL

We are accustomed to saying that plants breathe *in* what we breathe *out*. This is a contradiction in the meaning of the term, breathing. The word is used scientifically to apply to the process of taking in oxygen and giving out carbon dioxide, and to nothing else. But plants also use carbon dioxide as described in the study of Leaves (page 95).

We found in the study of Oxygen and Oxidation (page 3) that oxygen will combine with any one of several elements.

1. What element or elements are present in the bodies of plants and animals that may combine with oxygen?
2. What is the source of these elements?

Borrow from the chemical laboratory the carbon dioxide generator. Fill it with blocks of marble and dilute hydrochloric acid. Collect a quantity of the carbon dioxide obtained from the splitting up of the lime in the marble, and mix it with clear lime water. Take note of the milky precipitate (sediment) formed.

> **For comparison blow your own breath through a glass tube into another glass of clear lime water, and say what you think the result means.**

Next take two large glass-covered jars of equal size. Put into each equal quantities of moistened filter paper and small open vessels of lime water. Into one of the jars place a number of fresh cuttings from a coleus or other convenient "fleshy" stem and leaves. Keep the other jar without leaves as a check. Cover both jars carefully.

> **In twenty-four hours note results, and tell what they mean.**

We found also in the study of Oxygen and Oxidation that energy is set free during oxidation.

1. **Is there evidence that energy is set free in the animal body? If so, what kind or kinds of energy?** *(Remember that any kind of work being done is evidence of the manifestation of energy.)*
2. **Do plants show evidence of energy being set free?**

II. THE HYGIENE OF BREATHING

We realize the importance of the lungs in providing oxygen for the body in quantity sufficient to maintain all bodily functions. In the average person the amount of air entering the lungs is about one eighth of their entire capacity. "Shallow" breathers, careless folk, have no more than one half this amount of what is called *tidal air*. Thus, the red blood corpuscles carry from the lungs only a portion of the oxygen they could carry.

1. **What is bound to be the effect of the reduced supply of oxygen on the degree of activity of the organs of the body?**

2. **By taking in a large amount of tidal air, what organs and tissues of the body may be directly benefited? How?**

Colds are traced to mucous membranes of the throat and lungs that are weakened and made susceptible to the attacks of bacteria.

Why may a person who lives indoors most of the time have more colds than one who spends his days out of doors?

Textbook, pages 251, 259, 336, 401.

LABORATORY STUDY 73

VENTILATION

We live immersed in an ocean of air. But sometimes we appear to have difficulty in getting enough air to breathe. Why this should seem to be so is certainly worthy of study. The first thing to do in dealing with a problem that appears to be difficult is to try to analyze or take apart its elements. Let us, therefore, examine the air. We find, as already noted in the textbook (page 407), and from the studies on Oxygen and Oxidation, and on Nitrogen (pages 3, 6) that air is composed of oxygen one-fifth part, and of nitrogen nearly four-fifths part, a little carbon dioxide and about one per cent of *argon*, and other little known gases.

1. **In a body of air from day to day, and in different localities, what other substances are there present in air?**
2. **How would temperature affect the amount in the air?**

It used to be thought that the amount of carbon dioxide given off from the lungs of a number of persons in a close room is the cause of the discomfort noticed. Scientific experiments have shown that this inference was incorrect. The familiar bad odor has also been shown not to be the cause of the discomfort. In order to trace the source of the discomfort, let us imagine ourselves in the open air on a warm day.

1. **Are the days on which we suffer most in the summer the days that show the highest temperature?**
2. **Do we suffer most when we have the most perspiration on the skin?**
3. **How is it that on certain days when the temperature as shown by the thermometer is high we seem to perspire little?**
4. **How does the humidity of the air as shown by the weather reports relate to this situation?**

Now let us return to our ill-ventilated room in order to find out what to do about it. Evidently the moisture in such a room has some relation to the discomfort we feel.

1. **What is the source of the moisture in this case?**
2. **What is the effect of an amount of moisture present in the air of a room on additional moisture sent out into it?**
3. **When water is evaporating from a boiling pot, or from your own skin, what goes out with the water?**
4. **Why is it when water (perspiration) escapes into the air readily you feel more comfortable than you do when it passes off slowly?**
5. **What, then, should be done with an ill-ventilated room?**

Textbook, page 407.

LABORATORY STUDY 74

EXCRETION

Through the biological process of excretion materials that have been a portion of the body are sent out as waste. Since the foods that animals consume are in general complex, the wastes produced by a breaking down process are relatively simple in chemical composition. Plants, too, give off as waste simple compounds. These are few in number.

I. ORGANS OF EXCRETION

For human beings the chief organs of excretion are the kidneys, the liver, the lungs and the skin. The same organs serve the function of excretion in all the vertebrate animals down to the Amphibia, for a part of their existence. The skin of the thick-shell reptiles, however, is impervious to gases and liquids.

The organs of excretion in plants are the *stomata*, minute pores on the leaves and on the younger portion of the bark.

> **What explanation occurs to you for the existence of the greater number of kinds of excretory organs in animals?**

The function of the kidneys is to separate from the blood the wastes of urea, uric acid, minerals and water. This waste passes from the kidneys through tubes to the bladder from which it is expelled from the body.

The liver has several functions, two of which are connected with excretion. In the first place, it takes some of the waste products of the protein substances in the body and builds them up into a less dangerous product, urea. The blood carries the urea finally to the kidneys where it is separated from the blood. The other function in excretion is the separation from the blood of the broken down red corpuscles, which are sent into the secretion, *bile*, later to be expelled into the intestine.

It has already been explained that the lungs excrete carbon dioxide after the process of oxidation is finished.

The skin excretes perspiration which contains water, urea and mineral salts, with a minimum of urea in health. Incidental to the elimination of perspiration excess heat is given off.

The functions of the stomata of plants is the elimination of carbon dioxide after oxidation, and the elimination of oxygen after photosynthesis. Excess water is also sent out from the stomata.

What systems of organs in the body seem to be connected with building-up processes while the ones mentioned in this study are removing wastes?

II. THE HYGIENE OF THE ORGANS OF EXCRETION

It is worth while to note that the heathfulness of every organ of the body is promoted if the general health is good. This is just as true of the deep-seated excretory organs, the liver, the kidneys and the lungs as it is of the skin. But the kidneys and the liver are especially susceptible to injury from over-eating. Both organs are much stronger in persons who eat a small amount of meat and plentifully of green vegetables and fruit, and exercise in the open air in loose clothing. Jaundice, a disease of the liver, comes from the clogging up of the bile wastes.

1. **On the basis of what has been said, give advice for the hygienic care of the lungs and the skin.**
2. **Knowing the functions of the skin, can you say what part baths play in its hygiene?**
3. **From your own experience, what are the effects of warm and cold baths on the general tone of the body?**

Textbook, pages 266, 329–330, 372, 399, 401–403, 405.

LABORATORY STUDY 75

THE HUMAN EYE

Our eyes are rightly considered the most important of our organs of sense. This is true chiefly because the eyes make things outside ourselves seem real. Without the power to see few things, except what we feel, would appear to exist.

I. THE PARTS OF THE EYE

You will notice that everything about the eye is marvellously adapted to particular uses, and that the protection of the eye is the outcome of all these adaptations.

1. **What is done by the eye-lids and the eye-lashes that bears on this point?**
2. **Examine the human skull and tell how it is adapted to protecting the eye.**
3. **Compare the convex surface of the cornea of the eye with the convex surface of a reading glass, and tell what each does with the rays of light that pass through.**
4. **With a mirror watch the change in the blue, gray or brown iris of the eye on first awaking in the morning, or on coming from a dark room, and explain what you see.**

II. WHAT THE EYE DOES

We don't have to think much to make the eye do its work. For the most part, the activities of the eye are carried on by reflex action (see page 415), and in accordance with certain laws of light. Rays of light reflected from surfaces enter the pupil of the eye, and are brought to a focus on the retina at the back of the eye by the corneal lens in front of the iris and the crystalline lens back of it. The optic nerve on the retina transmits the stimulus to the optic lobes of the brain — and we see.

1. **What must the eye do to see things at one side, or in looking from one object to another at a different distance?**
2. **Try closing each eye alternately while looking at an object with angular sides a few feet away, and tell the advantage two eyes give you.**
3. **When you have been using your eyes for a long time, where do you feel pain? What is the use of this information?**

III. THE CARE OF THE EYES

Sometimes in cases of serious eye trouble the sufferer may feel pain or weakness apparently having no connection with the eyes. Thus, information on the condition of the eyes must be secured from time to time by means of certain tests. Among these are the tests easily provided by the "Snellen Cards."

1. **While looking at an object first with one eye and then with the other, do your eyes see differently? If so, what does this mean?**
2. **If one holds a book close to the eyes what is the trouble, and what can be done about it?**
3. **Have you known of persons whose lines of vision for the eyes seem to cross at times? What is the meaning of this, and what can be done?**
4. **Why should we not read in weak light, or with the light falling into our eyes?**
5. **What general principle of health is involved in practicing with our eyes before a Snellen Card, covering our eyes with the palms of the hands for some minutes, and looking at various letters without straining?**
6. **What are the possible uses of the eye-cup in caring for and protecting the eye?**

Textbook, pages 435–437.

LABORATORY STUDY 76

THE HUMAN EAR

Next to the eyes, the ears are probably the most important of our sense organs. It is difficult to calculate the deprivation a person suffers who loses the sense of hearing.

I. THE STRUCTURE OF THE EAR

The ear is made up of three parts, the convoluted *outer ear*, which collects the waves of sound and permits their passage along the short canal to the *tympanum* or *drum*, a membrane cutting off the outer ear from the *middle ear*. In the middle ear are three small bones, which carry the waves of sound across to the nerve endings in the *inner ear*. The *auditory* or *hearing nerve* transmits the stimulus to the brain which gives us the sensation of hearing.

In our study of the Mouth, page 117, we came upon the term *Eustachian tube* which is the name of the passageway connecting the pharynx at the back of the mouth with the middle ear.

1. **Through which organ, the eye or the ear, may information reach the brain the more quickly? Explain.**
2. **Propose an experiment, or describe one already tried, which shows how long it may take for sound to reach the ear.**
3. **How accurate is the ear in locating sound? Blindfold a person and hold a watch in different positions above, behind, in front, and at both sides of the head.**

II. SOURCES OF TROUBLE IN THE EARS

Have you ever passed through a tunnel under a river, or have you been carried to a great height suddenly, and, in the process, have you felt uncomfortable pressure in the ears? If you have not had either of these experiences, perhaps you have had the same feeling during the time you have suffered from a cold in the head.

Can you suggest an explanation of these sensations?

You may know the cases of men who have belonged to the army and have difficulty in hearing.

What is the cause of the difficulty?

In childhood especially a great many persons have had trouble with "running ears." In all such cases the ear drum has burst because of inflammation in the middle ear and the collection of pus.

1. **How may the middle ear have become infected?**
2. **What may a person do to avoid at least some of the trouble from this source?**

Sometimes a person passing through an attack of measles "catches cold." Inflammation develops in the middle ear, and the inflammation may extend through the mastoid bone behind the ear. Through this and other colds *mastoiditis* may develop, in which case a serious operation is imperative. Frequent examination of the ear drum by a physician may help in avoiding mastoiditis.

1. **What does an earache mean, and what should be done if the earache is continuous?**
2. **What harm may a person do in trying to "pick" his ears? Have you tried cleaning the dirt out with a thick absorbent cotton swab on the end of a blunt stick?**

Textbook, pages 436, 437.

LABORATORY STUDY 77

THE CARE OF THE BONES

There are more things to concern ourselves about in the care of our bones than to see that we do not break them. Consider the skulls of the Flathead Indians, flattened down by a board in babyhood, the crippled feet of the old-time Chinese ladies, and the cramped ribs of our own American ladies of the era of 1880. Have we stopped such foolishness? For answer, examine the picture in the textbook on page 441. Besides, we must feed our bones.

I. THINGS TO WATCH

The bones of young persons and adolescents are quite hard, and cannot easily be pressed out of their natural shapes. But the pads of cartilage at all the movable joints may be compressed. Wrongly applied pressure on the cartilage will force the bones out of place.

Observe the habits of your neighbors, as well as of yourself, and note down the things you see which in your opinion may induce physical defects in the skeleton.

II. THE PHYSICAL PROTECTION OF THE SKELETON

Perhaps you have noticed that most of the avoidable troubles that persons have with their skeletons is in the trunk of the body. That being the case, it is economical of time and thought if we can find a remedy that is fundamental and easy to apply. Try to take a deep breath, and see what happens. Up goes your head, shoulders and entire trunk. Inhale and exhale several times at the rate of about eight times a minute for the whole process — no faster.

1. **How do you feel?**
2. **Write a list of the things probably happening now in your body that were not happening well when you began this exercise.**

There is one point that you may overlook in this study unless attention is called to it. Bad posture is not due entirely to carelessness. It may be due to weak muscles. The muscles may have become weak through carelessness. Probably lack of use has something to do with it.

What can be done to strengthen weak muscles?

But no matter how much we exercise in the open air, incidentally breathing deeply because we cannot avoid it then, we cannot correct defects as long as we are carrying around with us the cause of more trouble, such as tight clothing and heels narrow and more than one inch high.

Mention other foot troubles, and tell how to correct them.

III. AVOID STARVING THE BONES

Have you wondered how a small animal like the clam or mussel could surround itself with so much hard protective material? All this lime compound must come from the food which the animal consumes. Similarly, the lime and phosphorus compounds must be set aside by the protoplasm of the human body and organized as framework. This is a chemical process of great complexity.

Have you noticed children with bent legs? Are they little or large for their ages?

These troubles of little children are due to lack of food containing sufficient quantities of lime and phosphorus compounds and also to lack of vitamins (*see textbook*, page 348).

Examine the statement made on pages 348–350 and say whether in all particulars you are doing full duty to your bones and to your general growth.

Textbook, pages 348–350, 440–442.

LABORATORY STUDY 78

ATHLETICS

Athletics are new activities in our civilization, although men have always amused themselves in games in which one matches his wits and muscular prowess against the skill of another. But today physical exercises as games are highly organized and varied, and constitute an important phase of our education.

I. KINDS OF ATHLETIC ACTIVITY

At first athletics were developed only for boys and men. But now we have organized physical activities for girls and women.

1. **What are the athletic activities most popular in this country for boys and for girls?**
2. **What countries were represented in the last Olympic Games?**
3. **Which of these countries showed supremacy in the various branches of athletics?**
4. **What benefits of any kind can be traced to the Olympic Games?**
5. **What forms of athletics are adaptable to persons of widely different ages? Why?**

II. WHY ATHLETICS ARE POPULAR

Athletics are popular everywhere. A great deal of time, money and organizing energy go into the work of providing opportunity for boys and girls to take part in athletic games.

1. **Consider an athletic contest you have witnessed, and tell why you enjoyed being there.**
2. **Consider a form of athletics that is not usually engaged in before large audiences, and tell why you think the game is liked.**

III. THE PRACTICAL VALUE OF ATHLETICS

An enterprise which is merely popular might even be injurious. In athletics we find wise and experienced persons giving time and money to the development of athletics. There must be a practical reason for this.

1. **Do you see any practical value in athletic contests to persons who do not actually engage in them?**
2. **Have you known cases in which some bodily weakness or lack of development has been corrected through athletic exercises? If so, tell about it.**
3. **How does athletic exercise improve the bodily functions of circulation, respiration and the removal of wastes?**
4. **Is there a practical advantage in being proficient in a number of athletic activities? If so, what is it?**

Textbook, pages 445–447.