BIOLOGY MANUAL

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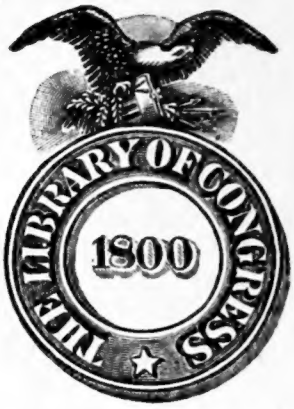

Class QH317

Book .B2

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LABORATORY MANUAL

TO ACCOMPANY

SMALLWOOD, REVELEY, AND BAILEY'S

BIOLOGY FOR HIGH SCHOOLS

BY

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AND

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GENESEO, NEW YORK

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no 1

"The invariable adaptation of an animal to the life it leads is one of nature's most instructive lessons, and can be discovered and appreciated by every pupil, but never through oral teaching or from reading of books. Better a child should learn to handle one animal, to see and know its structure and how it lives and moves, than to go through the whole animal kingdom with the best text-book under the best teacher, aided by the best charts ever made. The former would have learned what real knowledge is and how to get it, while the latter would have simply learned how to pass at his school examination."

— Alpheus Hyatt.

PREFACE

This manual is intended to bring to the pupil's attention the adaptations of plants and animals to the place they hold in the organic world. We do not intend to substitute laboratory work for class room work, but to reënforce the work of the class room with a study of the actual forms in the laboratory or in the field.

Whatever may be the ideal method of teaching biology from a theoretical point of view, practical school men know that biology must be fitted into a crowded curriculum and that often certain adjustments must be made that are not in keeping with the most approved methods. This book has been written with the realization that pupils have other classes to attend and that in many schools consecutive laboratory periods are not practical.

To equip a modern biology laboratory with all the desirable biologic aids called for in any text-book is beyond the means of the average high school. So we have endeavored to make use of those aids most easily and economically available.

For schools which have not enough compound microscopes to accommodate each pupil we have directed attention, as a substitute, to lantern slides made from actual photographs of the subject. Where these slides are not obtainable the laboratory study of accurate charts is recommended.

The use of the microscope is a highly technical problem. Too often the pupil's time is consumed in looking *for* the thing rather than in looking *at* it. The use of slides and charts enables the teacher to call attention to the important

thing to be emphasized and much valuable time may be saved.

We have aimed to cover all the work required by the average syllabus of biology and yet to keep away from what seems too technical without omitting important and significant topics.

Adaptation has been the dominant word in the minds of the authors, and *structure* has been treated to show adaptation. Without trying to convey the idea that there is a reason for everything or that if the human mind were penetrating enough it could find a use for everything, we have tried to direct the pupil to inquire how structures are adapted so as to enable the animal to survive in the pitiless struggle for existence.

G. A. B.
R. A. G.

February, 1922

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INTRODUCTION

Biology in the high school is a newer expression than zoölogy or botany or human physiology. These subjects were formerly treated in ten or thirteen weeks, and too often were considered as separate and unrelated subjects. As a matter of fact they are all intimately related, and it is the appreciation of this relationship that gives the greatest value to the newer term, biology.

Botany, plant study, taken with zoölogy, animal study, and both kept in mind as we consider man in his material surroundings, gives us an idea of biology. Human physiology alone is hardly what we mean, for we turn our attention to man's adaptation to the life he leads. We consider sanitation and the cause and prevention of disease. These hardly belong to human physiology.

Whether it is man, the highest type of animal, or the amoeba of the lowest group, or whether it is the big tree or the lowly moss, there are terms to which all may be reduced. The first of these common terms is *motion,* for in some way or other there is motion of some form in all kinds of living things. A second common term is *nutrition,* for food in some form and in some way must be supplied to all living things. A third common term is *respiration,* for all forms seem to require oxygen in order to live and derive energy. A fourth term is *excretion,* for all organic forms give us waste products either in gaseous form or liquid or solid. In some plants the waste is held as crystals in the tissues. A fifth common term is *sensa-*

tion. All animals and plants have a way of responding to some exciting causes (stimuli) to a greater or lesser degree. Lastly there is the common term of *reproduction,* whereby forms of life reproduce their kinds, and thus make good, in a measure, the inroads of disease, accident, and violence on their numbers.

So we have six common terms to be sought for in every animal or plant that lives or has ever lived. The laboratory enables us to see many of these terms as they are worked out on the table. We may see how a plant gives off a waste, carbonic acid gas. We may see how an amoeba takes in food (a part of nutrition). The flower when reduced to these terms becomes a device for the production of seeds (reproduction). A kernel of wheat may be food for man, but in our scheme of common terms it becomes an agent of reproduction for the wheat plant.

The geranium turns its leaves towards the window, and this is an example of sensation. So we might go over the whole list of plants and animals and inquire for each of the common terms. The laboratory gives us the opportunity to start the investigation, and then the whole wide world may become our laboratory in which to inquire as long as we live.

ANIMAL BIOLOGY

THE GRASSHOPPER

TAKE a field trip into a pasture or a field and secure as many grasshoppers of all sizes as possible. Each student should have a large adult specimen which has been preserved in formaldehyde, and a wire cage containing sods should receive the living grasshoppers. This should be placed where it may be observed by the class as they study this animal.

Examine the preserved specimen closely.

1. How long is your specimen?

2. What is its color?

3. Describe the place where it was found.

4. How is it protectively colored?

5. What kind of skeleton does the grasshopper possess?

6. Can you see any advantage in this?

7. How many distinct regions of the body can you find? Name them.

8. What is the shape of the head? Is it movable?

9. Is there a neck?

10. How many large eyes do you find?

11. Examine one under a hand lens or compound microscope. Is it made up of one or many parts? Such eyes are said to be compound.

12. The grasshopper also has three small eyes which are simple (not compound). One is located in the middle of the forehead and one near each compound eye. Describe what you can see of one.

13. Locate them with reference to the compound eyes.

14. How many antennae does the insect have?

15. Compare their length with the body length of the specimen.

16. Are they movable? Explain.

17. How many distinct mouth-parts are there?

18. The upper lip is called the labrum. Describe it as to shape and size. Is it movable? See text for other mouth-parts.

19. The jaws are called mandibles. How do they work?

20. What is the food of the grasshopper?

21. How are the mouth-parts specially adapted for this kind of food?

22. Show exactly what happens when a grasshopper feeds.

23. Make a drawing (×5, that is, five times the natural size) of the head as seen from the front, and label compound eyes, simple eyes, antennae, labrum, and mandibles.

24. The thorax is divided into three parts, the pro-thorax (front), the meso-thorax (middle), and the meta-thorax (back). Their boundaries are not always clear. Try to distinguish them.

25. How many appendages for locomotion can you find?

26. To which part of the thorax is each appendage attached?

27. How many pairs of wings are there?

28. How are they carried when the grasshopper is resting?

29. Which pair is most useful in flying?

30. What function does the smaller pair perform?

31. Describe each pair as to size, shape, and texture.

32. How many legs has the insect?

33. Which legs are used most for walking?

34. How are they adapted for this use?

35. After watching a live grasshopper, explain carefully how it walks.

36. What legs are used for jumping? How are they fitted for this function?

37. Examine the jumping leg closely. Of how many parts is it composed?

38. The part nearest the body is called the trochanter; the long muscular part, the femur; the slender spiny part, the tibia; and the three sections of the foot, the tarsus.

39. Describe each part as to relative size, shape, color, and special adaptations which fit it to perform its special function.

40. Explain just exactly how the grasshopper jumps.

41. Make a drawing (×3) of the jumping leg of the grasshopper. labeling all parts.

42. How many segments in the abdomen?

43. Most of the spiracles or breathing pores are located in the segments on each side of the abdomen. How many spiracles do you find in each segment?

44. What is the depression and membrane in the first abdominal segment?

45. Watch closely the abdomen of a living grasshopper. Describe any movements you may observe.

46. The female may be distinguished by a pair of blunt spines called the ovipositor at the tip of the abdomen. Determine the sex of your specimen.

47. For what purpose does the female use the ovipositor?

48. In what ways does the nymph (immature form) differ from the adult?

49. What kind of metamorphosis does the grasshopper illustrate?

50. Of what economic importance is this insect?

51. Name some of the other common members of this same family.

52. Write a complete life history of the grasshopper.

53. Make a drawing (×5) of the entire grasshopper, labeling all parts.

THE CABBAGE BUTTERFLY

(*Pieris Rapae*)

Stages of Development

A visit to a cabbage patch will usually provide the class with a wealth of material. Secure cabbage leaves with eggs on them and as many cabbage "worms" of all sizes as possible. Possibly you may find pupae hanging to the leaves. Put the cabbage leaves and specimens into a wire cage where they may be frequently observed. Feed the larvae fresh cabbage leaves daily.

The Egg

Examine the eggs of the cabbage butterfly without removing them from the leaf.

1. Describe an egg as to size, shape, and color.

2. On which surface of the leaf are the eggs commonly deposited?

3. Are they deposited singly or in a cluster?

4. How are the eggs protected?

5. Make a drawing (×5) showing a few eggs attached to a cabbage leaf.

These eggs will hatch later, or larvae secured from the field may be observed.

The Larva

6. Are the larvae ("worms") all the same size? Why?

7. How many distinct body regions can you see?

8. How many segments in your specimen?

9. Can you see any evidence of spiracles?

10. How many pairs of legs has the larva?

11. Where are they located?

12. What is the food of the larva?

13. Observe it eating. For what kind of work is its mouth fitted?

14. Make a labeled drawing (×2) of the larva.

15. Can you find any larva wagging its head from side to side spinning a tangle of silk? It is preparing to change its form.

The Pupa

If the larvae are left in a warm, well-lighted room and fed fresh cabbage leaves every day, they will soon molt and pupate.

16. If you have found a chrysalis in the garden, describe the exact place where you found it. If the caged larvae have pupated, in what part of the cage do you find the pupal cases?

17. Describe the chrysalis as to size, color, and texture.

18. How is it held in place?

19. How is it protected?

20. Make a drawing (×2) to show the shape and means of attachment of a chrysalis.

Each student should have a preserved specimen, and there should be several living butterflies caged where they may be observed by the class. Examine a cabbage butterfly closely.

1. Measure the body length of your specimen.

2. How does it compare with that of the grasshopper?

3. Into how many parts is the body divided? Name them.

4. How many eyes can you find?

5. Are they simple or compound?

6. Describe an antenna as to length and flexibility.

7. What structure do you find at the end of the antenna? This is peculiar to butterflies; moths never have it.

8. Spread them apart and disclose the mouth-parts. The two jaws or mandibles are long and fit together to form a tube called the proboscis.

9. Measure its length. How does the butterfly carry the proboscis?

10. What is the food of the butterfly?

11. How is the proboscis especially adapted to secure this kind of food?

12. If you have a living butterfly place it near some sweetened water or honey and describe the way it feeds.

13. How many pairs of wings does the butterfly have?

14. To what body region are they attached?

15. What is the main color of the wings? Are there other marking colors?

16. Is the animal protectively colored? Explain.

17. The female has two or more black spots besides the tip on each fore-wing, the male but one. Determine the sex of your specimen.

18. Which pair of wings is the larger?

19. What are the uses of the veins which you see in the wings?

20. How are the wings carried when the butterfly is not flying?

21. Observe a wing with a hand lens or compound microscope. With what is it covered?

22. What evidences can you see of the way in which the butterfly breathes?

23. Make a drawing (× 3) of the cabbage butterfly, labeling eyes, proboscis, antennae, wings, legs, and abdominal segments.

THE HONEY-BEE

Each student should be provided with a preserved specimen of the worker bee. If possible have an observation hive with glass sides in the schoolroom; if not, ask some bee keeper in the vicinity to show the class the bees in a movable frame hive.

1. The body of the honey-bee is divided into how many sections?

2. How does the body-covering of the bee compare with that of the grasshopper?

3. Compare the antennae of the bee and the grasshopper as to length and shape.

4. Describe the compound eyes as to number and position.

5. Use a hand lens and describe the simple eyes in number and position.

6. Note that the mouth-parts are composed of a couple of crude jaws and a long proboscis containing a hairy tongue. How long is the proboscis?

7. For what type of food do these parts seem fitted?

8. What is the natural food of the honey-bee?

9. Where is this food found?

10. How is the bee's mouth specially adapted for securing this food?

11. How many legs do you find? On what region are they borne?

12. How are they adapted for the bee's special purpose?

13. The blade part of the hind leg is called the scraper. What does it scrape?

14. Make a drawing of the hind leg (× 4) of the bee, showing the scraper with ball of pollen attached.

15. Examine the wings. To what region are they attached?

16. Compare the front with the hind wings.

17. How many segments are in the abdomen?

18. How does the bee respire?

19. The stinger is located at the tip of the abdomen. Describe it as to size and function.

20. What kind of metamorphosis does the honey-bee illustrate?

21. Write a life history of a worker bee.

22. Of what economic importance are these insects to man?

23. Draw a lateral view of the honey-bee (× 5), labeling all parts.

THE HOUSE-FLY

Each student should have a preserved specimen of the animal. If some raw meat be placed where flies may reach it, it will, in the course of a few days, furnish materials for the study of the fly development.

Study your specimen carefully.

1. Describe the fly as to size and color.

2. Into how many regions is the body divided? Name them.

3. How many compound eyes can you find?

4. Examine one with a hand lens or compound microscope and make a drawing to show the shape and arrangement of the parts of the eye.

5. Describe the proboscis as to size, shape, length, and color.

6. What is the food of the house-fly?

7. Where is the proboscis when the fly is not eating?

8 To what part of the body are the legs and wings attached?

9. How many true wings does the fly have?

10. Compare the position of the wings when at rest with the flying position.

11. Look back of each wing for small membranes called winglets. Are they separate or connected with the wings?

12. The knobbed stalks back of the wings are called balancers. How many are there?

13. How many legs has the fly?

14. Are they all of the same length?

15. Is the abdomen segmented?

16. Describe the surface of the thorax and abdomen.

17. Is the house-fly a friend or an enemy to man?

18. How may a fly spread disease?

19. What methods may be employed to exterminate them?

20. Name any other flies you may know. Are they harmful or beneficial?

21. After examining a piece of flesh which has been "blown" by flies and contains "maggots," write a complete life history of the house-fly.

22. Make a complete drawing ($\times 5$) of the side view of the house-fly, labeling all parts.

THE MOSQUITO

The class should make an excursion to a low, swampy region known to be infested with culex mosquitoes. Secure floating egg-masses if possible and a good number of "wigglers" and keep them in the schoolroom in jars of the same water in which they were found living. If adults are to be kept for any length of time, small pieces of banana should be put in the jars with them.

The Egg

1. If you are fortunate enough to find the floating egg mass of the mosquito, observe the arrangement of the eggs.

2. Can you make the egg mass sink?

3. About how many eggs are there in the mass?

4. Usually the eggs will hatch in from twelve to twenty-four hours after they are laid. From which end of the egg will the larva emerge?

5. Draw the egg mass (×10).

The Larva

6. How does the larva or "wiggler" move about?

7. How does it breathe?

8. Can you find any special organ for breathing?

9. Can the larvae see? Support your answer.

10. Near the head are bunches of hair which sweep currents of water containing food to the animal's mouth. How many such tufts can you see?

11. How many antennae can you distinguish?

12. Make a labeled drawing of the larva (×5).

The Pupa

13. After a few days the animal passes into its pupal stage. How has the shape changed?

14. Is the pupa as active as the larva?

15. Try to determine the number of body regions.

16. The two hornlike projections are breathing tubes. How are they used?

17. The pupa does not eat. Can you see any traces of legs or wings?

18. Make a drawing of the pupa (× 5).

The Adult

After being in the pupal stage two or three days, the mosquito again changes its form. Try to observe this trans-

formation from pupa to adult. Adult specimens should be killed and provided for each student.

19. How many body regions does the mosquito have?

20. Male mosquitoes have long, bushy antennae, females short ones with few hairs. Determine the sex of your specimen.

21. What is the natural food of the mosquito?

22. How are the mouth-parts adapted for securing this food?

23. How many wings does the mosquito have?

24. How many legs?

25. Of what importance are mosquitoes to man?

26. Where are mosquitoes most commonly found?

27. How may they be kept under control?

28. Write a complete life history of the mosquito.

29. Make a drawing of the left side of the mosquito ($\times$ 5), labeling all parts.

THE BEETLE

May beetles, or "June bugs," as they are sometimes called, are perhaps the best beetles to study on account of their size. If these are not obtainable, the potato beetle ("bug") or any of the many beetles commonly found on goldenrod and milkweed in the summer and autumn may be used. Each student should have a preserved specimen, and a few live ones should be kept and observed by the class. If possible secure some of the larvae ("grubs," "wire worms," or "borers") of the beetle family.

1. Describe the beetle as to size, shape, and coloring.

2. Describe the outer covering of the beetle.

3. Into what regions is the body divided?

4. How many eyes does it have? Simple or compound?

5. Locate the antennae. Are they segmented?

6. What is the food of the beetle?

7. For what type of work are the mouth-parts adapted?

8. Two wing covers protect the wings. Describe them as to size, shape, and texture.

9. How do they fit together?

10. How are they held during the flight?

11. Lift up the covers and describe the wings found beneath.

12. How many legs has the beetle?

13. To what body region are they joined?

14. For what are they used? Do you find any special adaptations for this use?

15. How many segments in the abdomen?

16. What are "grubs," "wire worms," and "borers"?

17. Are beetles in general beneficial or harmful to man?

18. Write a complete life history of the special beetle which you have studied.

19. Make a drawing ($\times 5$) of the entire beetle from the left side, labeling all parts.

GENERAL STUDY OF INSECTS

A collection of preserved specimens of the insect group should be available or the class may make a collection of living specimens. Let the group include as many as possible of the following: beetles, grasshoppers, dragon flies, bees, butterflies, moths, cicadas, true bugs, and flies.

Answer each of the following questions for each insect studied. If preferred, the data may be recorded in tabular form.

1. What is the insect's natural habitat?

2. How many legs has it?

3. How are they adapted for its special use?

4. How many wings?

5. How are they specially fitted to perform their work?

6. What is the food of the animal?

7. How are the mouth-parts adapted to secure this food?

8. What kind of metamorphosis does the insect have?

9. How does it escape its enemies?

10. Is it harmful or helpful to man?

THE CRAYFISH

Several live specimens should be caught by the students and put in aquaria in the laboratory where they may be observed and studied. Preserved specimens may also be used for some parts of the exercise.

1. Describe the natural habitat of the crayfish.

2. Where do they make their burrow? Why?

3. What is the color of the living crayfish?

4. Explain the value of this to the animal.

5. Where is the skeleton of the crayfish?

6. Of what advantage is this? What disadvantage?

7. How may a crayfish grow?

8. How many body regions can you find?

9. The anterior region is called the head-thorax and the posterior region the abdomen.

10. Describe the bony covering of the head-thorax which is called the carapace.

11. Is the body of the crayfish segmented?

12. How many segments are there in the abdomen?

13. In what directions are they movable?

14. What is the last segment used for?

15. How is it adapted for this work?

16. How many pairs of legs are there?

17. How many pairs have pincers?

18. For what purpose does the crayfish use the first pair?

19. How are they adapted for this purpose?

20. What methods of locomotion does the crayfish employ?

21. Which is best for food-gathering? For escaping enemies? Why?

22. The long "feelers" of the head are called antennae and the short ones antennules.

23. How many of each does the crayfish have?

24. Are they solid or segmented?

25. Locate them with respect to the eyes.

26. What seems to be their function?

27. Are the eyes simple or compound?

28. Touch one with a needle. What happens?

29. Of what advantage is this to the crayfish?

30. What is the natural food of the crayfish and how is it secured?

31. Feed the animal some little pieces of liver or fish and observe him eat.

32. Locate the mouth.

33. How many pairs of appendages do you find that aid in the eating process?

34. Name and describe each pair.

35. On the ventral side of the abdomen are located the swimmerets.

36. How many pairs are there?

37. For what are they used?

38. Does the crayfish reproduce sexually or asexually?

39. The first two pairs of swimmerets are long in the male and small in the female. Determine the sex of your specimen.

40. With a medicine dropper let fall a few drops of carmine solution near the side of the crayfish just above the legs.

41. What becomes of the carmine?

42. Where does it reappear?

43. What organ is responsible for this circulation?

44. Describe it as to structure, shape, and attachment.

45. What benefit does the animal get from this current of water?

46. Why are crayfish commonly found with their heads down stream?

47. Make a drawing (×2), labeling all body divisions and appendages.

48. Name some other animals closely related to the crayfish?

49. Of what economic importance is this group to man?

Dissection of the Crayfish

Large preserved specimens should be provided for class use. If the lesson is to be a demonstration, a lobster would be preferable on account of size.

1. The head-thorax is covered by a saddle-shaped bone called the carapace.

2. Where is this attached?

3. Carefully remove this, bringing to view the gills and gill chamber.

4. What appendages have gills attached?

5. How many gills are in each chamber?

6. Describe a gill as to form, structure, and functions.

7. Are the gills outside or inside the body cavity?

8. Make a drawing of the side view of the head-thorax with carapace removed, showing the legs with gills attached.

9. Remove the body wall just back of the antennae and expose the two kidneys or green glands.

10. Describe them as to shape and color.

11. Where is the external opening?

12. Remove the dorsal part of the body wall, taking care not to injure the heart, which lies just beneath.

13. Describe the heart as to size, color, location, and function.

14. Can you find any tubes running from the heart?

15. What is their purpose?

16. Remove the heart and observe the organs of the digestive system.

17. Describe the size, shape, position, and function of

a. Mouth

b. Oesophagus

c. Stomach (two chambers)

d. Intestine

18. Make a labeled drawing of the body cavity (×2) containing all observed organs.

19. Remove these organs and note the ventral nerve cord.

20. Describe it as to length, size, and color.

THE FISH

Small perch or goldfish in jars should be placed where every student may observe and study them.

1. The fish is a vertebrate animal. What does this mean?

2. With what is a fish's body covered?

3. How are these parts arranged?

4. Name the distinct body regions of the fish.

5. Locate the mouth.

6. What is the fish's food?

7. Do all fish have teeth? Do they chew their food?

8. Can a fish taste? Test with sand and fish-food.

9. How many nostrils has a fish?

10. For what are they used?

11. Describe the eyes as to number and location.

12. Are they movable?

13. Does the fish have eyelids? May the eyes be closed?

14. How are the eyes protected?

15. Do the fish appear to hear?

16. Locate and describe the operculum or gill cover.

17. Under these covers are the gill chambers, in each of which there are usually four red gills. Each gill is an arch of bone covered with a fleshy fringe.

18. Why does the fish continually open and close its mouth?

19. Where does the water thus taken in escape?

20. Explain fully how a fish respires.

21. How many organs of locomotion can you find?

22. How many are in pairs and how many single?

23. Locate each of the following fins: Pectoral, pelvic, dorsal, anal, and caudal.

24. After studying your specimens try to determine what the special use of each one is.

25. Which is largest? Why?

26. Which is used most? Least?

27. Can a fish remain motionless in the water?

28. How is the fish protected from its enemies?

29. Of what economic importance are fish?

30. Name some fish common in your locality?

31. How are the state and federal governments trying to protect fish?

32. Write a complete life history of a native fish.

33. Make a drawing of the left side of a fish, labeling all parts.

If possible secure a large fresh fish at a market and remove the operculum carefully and expose the gill chamber and gills.

34. How many gills can you see?

35. Are they all alike?

36. Describe one as to size, shape, color, and position.

37. How do gills secure oxygen from the water?

38. Why do fish commonly lie in a brook with their head upstream?

39. Make a drawing of the head with operculum removed, labeling all parts. Show by means of arrows the path taken by water through the gill chamber.

THE FROG

Live frogs should be captured and kept in a moist box in the school-room. Each student should be provided with a specimen which has been chloroformed or preserved in a 5% formaldehyde solution. The complete life history may be observed if frogs and tadpoles are secured in the spring and kept in an aquarium.

Examine a live frog.

1. What is the habitat of the frog?

2. Describe the color of the frog. Is this an advantage or disadvantage?

3. How is the ventral side colored? Why?

4. How does the frog feel when it is handled? What causes this?

5. What methods of locomotion does the frog employ?

6. Are the eyes movable?

7. How many eyelids can you find? Try touching the eyeball with a pencil.

8. Why does the skin under the mouth move?

9. Can the frog hear? Make a test.

10. Put some insects (flies, grasshoppers, or bees) in the cage and describe the way the frog secures its food.

Study the preserved specimen closely.

11. How many body regions can you distinguish?

12. Open the mouth. How does it compare in size with mouths of other animals we have studied?

13. Draw out the tongue. What is its shape?

14. Where is it fastened?

15. Can you find any teeth in the frog's mouth?

16. Make a drawing ($\times 2$) showing the lower jaw and tongue.

17. Locate the nostrils. For what are they used?

18. Using a horsehair or probe, determine whether or not they open into the mouth.

19. Explain exactly how the frog breathes.

20. How many toes are on the front foot?

21. Are there the same number on the hind foot?

22. For what purpose is the front leg used?

23. Why should the hind legs be better developed?

24. Describe the special adaptations of the hind leg for leaping. For swimming.

25. Make a drawing, natural size, of the fore leg and the hind leg of a frog extended.

26. Write a complete life history of a frog, giving in detail the stages of development and their accompanying changes in form, manner of breathing, and so forth.

Dissection of a Frog

With the scissors carefully cut around and remove the skin on the ventral side of the abdomen. Then with the scalpel and scissors very carefully remove the entire muscular wall on the ventral side, being careful not to injure the organs lying just beneath.

27. Is the body cavity of the frog divided by a muscular partition or diaphragm?

28. Locate and describe the lungs and the heart in the anterior end of the body cavity.

29. The large reddish brown organ lying close to the lungs is the liver. Into how many parts or lobes is it divided?

30. Describe it as to size, shape, color, and location.

Carefully remove these parts and dissect out the entire alimentary canal.

31. Describe each part of the canal as to relative size, shape, color, and function.

32. Open the stomach and note the contents.

33. What is the food of the frog?

34. Is the frog harmful or beneficial to man?

35. Make a labeled drawing, natural size, of the frog with the entire ventral side removed, showing all the organs in place.

MOUNTED BIRD

1. Examine a mounted specimen of a bird. With what is it covered?

2. What advantage have feathers over scales as a covering for birds?

3. How are feathers a good protection against cold weather?

4. Notice the shape of the bird's body.

5. Is this shape favorable for flying? How?

6. Notice the beak. What kind of food is it fitted for handling?

7. Notice the wings. Are they placed advantageously for flying? How?

8. Notice the tail. In what way is a tail similar to a rudder on a boat?

9. Is a rudder necessary for a flying machine? Why?

10. Show how a bird is like a flying machine.

11. Show how a bird is different from a flying machine.

12. Notice the feet. How are they adapted for perching? For offense? For defense? For food-taking?

13. Sketch a side view of a bird, labeling beak, nostril, eye, ear (no external shell present), and feet.

14. Compare the beaks of different birds, such as hawks, sparrows, herons, kingfishers.

15. Compare feet of different birds, such as a hen, duck, hawk, canary, and crow.

16. Name some birds that are excellent fliers. Are their wings long?

17. Name some birds that are good runners. Are their legs long and strong?

FIELD TRIP TO STUDY BIRDS

NOTE TO TEACHER. No better way of studying birds is offered than by field trips. The best time to study birds is early in the morning from 4 to 6 or from 5 to 7. Another good time is in the afternoon from 5 to 7. On these trips a report should be made out by each pupil, giving the information called for. Modifications of the following forms will afford material for several trips.

Plate A. REPORT FOR IDENTIFICATION OF BIRDS

	Where observed	Apparent Food	Size as compared with Robin	color of head	Color of breast	Color of wing	Color of tail	Color of back	Tail forked or rounded	Beak strong or weak	Special Markings
Oriole											
Purple Finch											
Swift											
Golden Crowned Kinglet											
Bluebird											
Flicker											
Robin											
?*											
?											

* What birds have the characteristics given in these two rows?

Plate B— — Report for feeding station —

	Food	Drive away birds	Store away food	Line of flight towards food	Method of approaching Food—	Manner of — coming to food — Singly —	In pairs —	In a group —	Sing while feeding	Number of different Notes	Easily approached
Downy Woodpecker											
Hairy Woodpecker											
Nuthatch											
Chickadee											
Brown Creeper											
Song Sparrow											
House or English Sparrow											
Robin											
Grackle											

Plate C— — Report for Birds in Nesting Season —

	Nesting Site	Material	Arrangement	Eggs			Adults		Young		Opened Mouths	Shrink down
				Number —	Color —	Size —	Bold —	Timid —	Large —	Small —		
Robin												
Chipping Sparrow												
Oriole												
Grackle												
Meadow Lark												
Phoebe												
Cat Bird												
Mourning Dove												
House Sparrow												

Plate D— — Report on a single pair of Birds feeding their young —

	Time —	Male fed —	Female fed —	Nature of food —	Number of times each Nestling is fed — Nestling № 1	№ 2	№ 3	№ 4	Direction from which Adults approach nest — East —	West —	North —	South —	Food supply —	Cleaned Nest	Brooded Young
9:15															
9:20															
9:21															
9:28															
9:30															
9:40															
9:45															
9:47															
9:53															

Plate E. — Report for Seasonal Activities of Birds —

	First Arrival	Does Male Precede ?	When Common ?	Began Nesting	First seen with Young	Color of Young — Head	Breast	Wings	Tail	Color of Adult — Head	Breast	Wings	Tail	Young Independent
Robin														
Bluebird														
Chipping Sparrow														
Gold Finch														
Cedar Bird														
Bobolink														
Song Sparrow														
Sandpiper														
House Sparrow														

MAMMALS

From a skeleton or chart of a skeleton study the dog or cat.

1. Notice the framework of bones. Of what use to the living is this framework?

2. Notice the attachment of the legs. Of what use are these legs to the living animal? How are they united to the framework?

3. Notice the forms of bones that may be classed as long bones, flat bones, and irregular bones. Name uses of each class of bones.

4. Which class is best adapted for protection? Name some of these.

5. Which class is best adapted for attachment of large muscles? Name some of these.

6. Which is best adapted for attachment of small muscles? Name some of these.

7. Compare the bones of front and hind legs as to number, general form, and use.

8. How can you account for the difference between the shape of some of these bones that occupy the same relative position in a front and a hind leg?

9. Notice the inside toe of each front foot. How does it compare in strength with the other toes of the same foot? Is this inside toe (thumb) of any use to the living animal for supporting weight or holding food?

10. Look for the corresponding toe of the hind foot. Do you find it? If not, how would you account for its absence? Is there a tendency for useless structures to disappear from animals?

11. Examine the teeth of the upper and lower jaw. How does the number on each jaw compare? How do the forms of opposing teeth compare? Compare the front teeth (incisors) with the molars. How would use account for any differences you find?

12. Examine the eye teeth (canines) just outside the incisors. Show for what these teeth are adapted.

13. Compare the vertebrae of the neck and tail. How would use account for the difference in size?

14. What adaptation of the skeleton in general can you make out that gives the animal speed in travel?

15. In how many ways is the human skeleton like the skeleton you have just studied?

THE PARAMECIUM

A. Reaction to Stimuli

Paramecium or slipper animals may be seen by the naked eye in a hay infusion as tiny white specks moving rapidly through the water. Deposit a drop of the infusion containing the animal on a glass slide and examine under the compound microscope. While the paramecium has no sense organs or nervous system, it will react to a variety of stimuli. Watch an individual as it swims about.

1. What happens when it bumps into a grain of sand?

2. Is there a different response if it comes in contact with a piece of vegetable matter? What does the animal do?

3. Slightly jar the slide. What change occurs in the animal?

4. How does the paramecium react wnen a warm needle point is brought near it?

5. By reflecting a strong shaft of light from a mirror, try to discover whether or not the paramecium is affected by ordinary light.

6. What difference can you discover in the reactions to gentle and severe stimuli?

7. Make a drawing showing by arrows what happens when a paramecium runs into an obstacle.

B. Food-taking

Deposit a drop of infusion containing a paramecium on a glass slide and carefully push a wisp of cotton fibers into the drop before putting on the cover glass. These will prevent the free swimming of the paramecium, and it may be studied more closely. Locate an animal near the center of the field and carefully drop some finely powdered carmine into the drop of water with it. It will be seen that the pigment circulates with certain water currents.

1. Trace the course the carmine takes.

2. Describe the body structure for taking in food.

3. What creates these currents?

4. How are these an aid in food-getting?

5. What is the natural food of the paramecium?

6. Can the paramecium recognize food from sand?

7. What are food vacuoles?

8. How many can you find?

9. In what part of the body are they located?

10. Why are they not all of the same color?

C. Excretion

Continue the examination of the paramecium as described in *B*. Look for clear, round spots of considerable size called contractile vacuoles.

1. How many do you find?

2. In what part of the body are they found?

3. Is this location permanent?

4. What relation do they bear to food vacuoles?

5. Explain how they get rid of contents.

6. Watch one for several minutes. How many times does it contract per minute?

D. Cell Structure

Locate and examine a paramecium under the high power of the compound microscope.

1. Has the paramecium a definite shape?

2. May the animal alter its shape?

3. Can you find any divisions or partitions in the animal?

4. Of how many cells, then, is it composed?

5. Has the paramecium a definite cell wall?

6. What do you find covering the whole body? Describe them

7. Are they longer on any particular part than elsewhere?

8. What is the groove used for?

9. How is it specially adapted to this function?

10. How many kinds of vacuoles can you find?

11. Compare them as to number, size, location, and purpose.

12. The nucleus will be visible if some stain is dropped into the infusion.

13. Describe the shape of the nucleus.

14. The paramecium is a typical protozoön. Name its essential characteristics.

15. Make a drawing (4″ long) of the paramecium, labeling cell wall, cilia, food groove, nucleus, contractile vacuole, and food vacuole.

THE SPONGE

Examine a specimen of the sponge called grantia, which may be secured from dealers in biological supplies. This is one of the simpler animals composed of many cells.

1. What is the length of the grantia?

2. How does this compare with the width?

3. What is the shape of the body?

4. Notice the sharp, needle-like structures which project from the body. They are called spicules.

5. Of what mineral substance are they composed?

6. Of what use are they to the sponge?

7. Observe the shapes of some spicules under a compound microscope, and make several drawings of the shapes observed.

8. One end of the sponge is always attached to a rock or other object. Can you see where your specimen was torn loose?

9. Describe the other or free end of the animal.

10. With a sharp knife cut the specimen in two lengthwise, making a longitudinal section. The hollow space or cavity is called the cloaca.

11. Can you see any pores in the side of the body?

12. Water flows continually through these pores into the cloaca and out through the opening in the free end called the osculum.

13. Of what use is this water current to the sponge?

14. What creates these currents?

15. What is the food of the grantia?

16. Describe any evidence of budding which you may find in your specimen.

17. The animal sometimes reproduces sexually.

18. Of what economic value is this animal family?

19. Make a drawing, actual size, of a grantia.

20. Draw a longitudinal section of the sponge ($\times 5$) labeling cloaca, pores, osculum, and spicules. Show the water currents by means of arrows.

HYDRA

Living hydras may be found clinging to the submerged stems of water plants in most localities that have shallow ponds. Look at a specimen which has not been disturbed for some time.

1. How long is it?

2. Touch it lightly. What change occurs?

3. How great is the difference in size?

4. At the free end of the body may be found "arms" or tentacles.

5. How many does the animal have?

6. How are they arranged?

7. For what are these tentacles used?

8. Describe their movements.

9. The mouth is in the center of the group of tentacles and leads to the hollow interior of the body.

10. What is the natural food of the hydra?

11. The body wall is composed of three layers: an outer, a middle, and an inner.

12. In which layer must digestion occur?

13. How do the cells of the other layers feed?

14. What is meant by "division of labor"?

15. What becomes of the unused part of the food?

16. Can you distinguish any signs of reproduction by budding?

17. The hydra also reproduces sexually. Look for ovaries and spermaries, which may be seen as little lumps on the side of the body, the spermary usually being nearest the free end.

18. If you can find them, describe them as to shape, size, and location.

19. What is the difference between sexual reproduction and budding? Explain.

20. How does the hydra differ from the grantia?

21. How may a hydra protect itself from its enemies?

22. Make a drawing (×4) of a hydra extended, and label base, mouth, tentacles, body cavity, budding hydra, and spermary and ovary, if found. Trace by means of arrows the path of food eaten by the animal.

23. Draw to the same scale the same hydra contracted.

THE EARTHWORM

Take a short trip into a meadow to obtain living earthworms. As specimens are found, study the natural habitat.

1. How can you recognize earthworm burrows?

2. How deep did you dig to find them?

3. In what kind of soil did you find most worms?

4. Why are they so common after rains?

5. How do they offer resistance when dragged from their burrows?

The specimens secured should be placed in a pail of moist (not wet) earth and carried to the class room. Place each worm on a piece of wet blotting paper and study it.

6. Distinguish the anterior and posterior ends and the dorsal and ventral surfaces.

7. What is the general shape of the body?

8. What is the difference in shape between the anterior and posterior ends?

9. How does the anterior end differ from the posterior end as to size and color?

10. By touching it with a needle, determine which end is most sensitive to touch.

11. What is the general color of the worm?

12. Is this an advantage or a disadvantage? Explain.

13. Bodies composed of ring-like parts are said to be segmented. Is the earthworm segmented?

14. Are all segments the same size?

15. How many segments does your specimen have?

16. Is this number the same in all earthworms?

17. When the animal moves what is the action of the segments?

18. How many setae or bristles on each segment?

19. How are they arranged?

20. Explain how they assist in locomotion.

21. Does the same end always go forward?

22. Of what advantage is the body slime?

23. What is the food of the animal?

24. Locate the mouth. Of what advantage is this position?

25. Has the worm hard jaws? Why?

26. The enlarged band about the worm is called the clitellum. It forms a case for the eggs when they are laid.

27. Nearest which end is the clitellum located?

28. Of how many segments is it composed?

29. Does it form a complete ring?

30. Do all the specimens you have secured have a clitellum?

31. Does the earthworm reproduce sexually or asexually?

32. Work out a scheme to discover whether earthworms prefer light or darkness.

33. How is the earthworm protected from its enemies?

34. Why cannot earthworms survive drying?

35. Where are they in very hot, dry weather?

36. How do worms benefit the soil?

37. Do they injure plants or animals?

38. Write a complete life history of the earthworm.

39. Make a drawing showing a lateral view (×2) of the earthworm, labeling mouth, segments, setae, and clitellum.

Dissection of the Earthworm.

Place the preserved specimen in a shallow dissecting pan partly filled with water.

1. With the scissors cut along the middle of the ventral surface from the anterior end to the posterior.

2. Pin the anterior end down to the wax and, working under water, carefully pull back the body wall and pin it back to the wax from the anterior to the posterior end, thus disclosing all body organs.

3. Describe the tiny ventral nerve cord.

4. What is the color and relative size of the ventral blood vessel?

5. Remove these and notice the various organs of the digestive system.

6. Briefly describe the size, shape, position, and functions of

a. Mouth cavity

b. Pharynx

c. Oesophagus

d. Crop

e. Gizzard

f. Stomach-intestine

7. Make a drawing (×4) of the dissection at this stage, showing all organs labeled and in place.

8. Remove the digestive organs and note the large, dorsal blood vessel.

9. Is it larger or smaller than the ventral vessel?

10. How many loops or "hearts" can you discover?

THE STARFISH

Secure at the seashore or through a dealer enough specimens of the starfish so that each student may have one. These may either be preserved in formaldehyde solution or dried, and if carefully handled will last for years.

1. Describe your specimen accurately as to size, shape, color, and general appearance.

2. How many arms or rays does your specimen have?

3. Compare with other specimens used by the class.

4. How do you account for the differences in size of the rays on some specimens?

5. Define "regeneration of parts."

6. What kind of skeleton does the starfish have?

7. Describe the outer covering of the animal.

8. What difference do you notice between the dorsal and ventral surfaces?

9. The central part of the starfish is called the disk. On the dorsal surface of the disk may be found a wart-like growth called the madreporic body. Describe it as to location, size, shape, and color.

10. Does it appear to be solid or porous?

11. Suggest a possible use to the animal.

12. Note the groove on the ventral surface of each ray. It contains the tube feet. Describe these as to number, size, and shape.

13. With what are the sides of the groove covered?

14. Why do the tube feet need so great a protection?

15. How does the starfish move from place to place?

16. Try to distinguish an eye spot at the end of each ray. What are the advantages of this location?

17. In the center of the ventral surface is the mouth. How is it protected?

18. Possibly you can see inside a gray bag, the stomach. How does the food get into the stomach?

19. What is the food of the starfish?

20. Describe in detail how a starfish would kill and eat its prey.

21. Of what economic importance is this animal to man?

22. Suggest ways to check the destruction caused by the starfish.

23. Make a drawing, natural size, of the ventral surface of the starfish and label rays, spines, tube feet, eye spot, mouth, and stomach.

FRESH-WATER CLAM

Secure from local streams or through a dealer several specimens of fresh-water clams or mussels. Put each specimen in a jar of water in which there are several inches of sand and leave undisturbed for several hours before using.

1. What is the habitat of the fresh-water clam?

2. Describe a specimen as to approximate size, shape, color, and position.

3. How many parts (called valves) do you find in the exoskeleton?

4. They are hinged together; locate the hinge when the animal is in a natural position.

5. Can you see any evidence that the clam has moved about in the jar?

6. How are clams fitted for locomotion?

7. Let one of the class quickly lift a clam from its resting place. Describe the foot as to size and color.

8. Near one end of the shell opening you will observe some exterior openings; how many?

9. These are called siphons. By releasing a drop of red ink with a glass tube near the siphons determine the direction of flow of any possible water currents.

10. Why does the clam need water?

11. Of what does the clam's food consist?

12. How is the clam protected?

13. Name some relatives of the fresh-water clam.

14. Of what economic importance is this group to man?

15. Draw (×2) the lateral view of the fresh-water clam, labeling valve, hinge, foot, inhalent siphon, and exhalent siphon.

INTERRELATIONS OF PLANTS AND ANIMALS

THE BALANCED AQUARIUM

A BALANCED aquarium may be made by the class. If the school does not possess regular aquaria, these may be made as a class project[1] or battery jars may be used. The bottom of the aquarium should be covered with sand, and such water plants as are common in the locality should be planted in it. Eel-grass, bladderwort, watercress, the stoneworts, and others are common in New York. A plant called parrot's feather, commonly used in fish globes, may be obtained from a florist and used to advantage. Duckweed may later be placed on the surface of the water. Having planted these, the sand should be covered with small stones or gravel and water carefully added.

A field trip to a pond or sluggish stream will provide plenty of animal life. Water beetles, pond snails, crayfish, polliwogs, and small minnows may be used and goldfish may be added if desired.

In a properly balanced aquarium it will be necessary only to add water on account of loss by evaporation.

Study closely the life processes occurring in a balanced aquarium.

1. What gas do animals require for respiration?

2. When this has been used and changed by the body, it is given off as what gas?

[1] Cornell Teachers Leaflet No. 11, May, 1898.

3. In a balanced aquarium what becomes of this product?

4. What raw materials are necessary for the plant to manufacture starch?

5. On a sunny day look for tiny bubbles on the surfaces of the plants. What gas is this?

6. By what organism is it utilized in the aquarium?

7. As the animals live and grow, from what source can they secure their food?

8. What becomes of the nitrogenous wastes of the animals?

9. If a plant or animal chances to die, how is it disposed of, naturally?

10. Define symbiosis.

11. Is it present in a balanced aquarium?

12. Explain how plants, other than aquaria plants, depend upon animals.

13. In what ways are animals dependent upon plants?

14. Make a diagram showing a plant and an animal of a balanced aquarium and by means of labeled arrows show the interchange of essential materials.

THE HAY INFUSION

Gather a small bunch of dry grass or hay and put it to soak in a glass of water. Leave this in a warm room for several days and then examine carefully. By allowing the water to evaporate, a productive infusion may be kept and used from year to year by adding water to the dried hay and scum.

1. What apparent changes have occurred in the water?

Examine a drop containing a bit of the hay under the compound microscope. Great numbers of small one-celled plants called *bacteria* will be seen.

2. How did they get into the infusion?

3. What do they appear to be doing?

Search carefully and find some simple one-celled animals called *protozoa*.

4. How many different kinds can you find?

5. Where could they have come from?

6. Try to see one eat. Of what does its food consist?

7. Describe its activities.

8. How do the protozoa compare with the bacteria as to size and number?

9. By examining a drop from the infusion at intervals of several days determine whether or not the numbers of the protozoa are increasing.

10. Suggest reasons why this is true.

11. What effect does this have on the numbers of the bacteria?

12. How might a balance of life in a hay infusion be secured?

PLANT BIOLOGY

FLOWERS

Fall Study

Parts of a Flower

Material: Select nasturtium blossoms if possible when the study is undertaken in the fall.

1. Notice the outer parts, sepals. How many are there?

2. Examine the inner, more highly colored parts, petals. How many are there?

3. Compare the shape of the different petals. Compare the upper two and the lower three. Notice the fringe.

4. What advantage might this fringe be to the flower in offering a barrier to crawling insects?

5. Notice the stripes on the upper petals. Towards what do they converge? Examine this long tube, the nectar spur.

6. What advantage is there to the flower in having the nectar at the bottom of a long nectar spur? Think of this in connection with short-tongued and long-tongued insects.

7. Make a sketch to show side view of nasturtium flower. Label all parts.

8. Notice the thatched form of sepals and petals over the top of the flower. How might this arrangement assist in keeping rain from the nectar spur?

9. Remove sepals and petals from (1) a flower just opened, (2) a flower in prime condition, and (3) a faded flower. Notice the number of stamens in each. How many? Notice the anthers in each of the flowers. In which flowers do you find the largest anthers? Do all the anthers mature at the same time? If they do not, how would this assist in gaining pollination?

10. Compare the pistils in each of the flowers just examined. In which of the flowers do you find the three-pronged stigma? If more than one stage shows a three-pronged stigma, which one has the freshest looking stigma?

11. Do anthers apparently shed their pollen before or after the three-pronged stigma is developed?

12. When the anthers and stigma mature at different times we have an illustration of dichogamy.

13. Make a sketch to show the three conditions of stamens and pistils as found in the different nasturtium flowers just examined.

THE COMPOSITE FAMILY

The Dandelion

Note to Teacher.—Explain the composite family to the class before the laboratory period and emphasize the main differences between the dandelion type and the sunflower type.

1. On a sunny day, just before the laboratory period, bring in a quantity of dandelion heads in different stages of development. Select some just opening, others in full bloom, and others beginning to open.

2. Examine a head that is beginning to open.

3. Notice the center cluster of unopened florets (the individual flowers of the head). How do they compare with the florets around them in form?

4. Remove a floret from the outer border and examine. Find the small, strap-shaped corolla with small teeth at the upper end. Use a hand lens and count these teeth. How many do you find?

5. Above the attachment of the corolla to the floret, notice the cylindrical form (the hollow cylinder of united stamens with anthers inside. This is difficult for the beginner to determine.

6. Above the stamens look for the T-shaped stigma and part of the style. The style continues through the hollow cylinder of stamens to the ovary.

7. Note the ovule at the bottom and above it the group of small hairs, the calyx. Later this calyx becomes the pappus of the fruit.

8. We now have the complete flower: the corolla (the united petals), the stamens (the united cylinder of the center), the pistil with the T-shaped stigma, style, and ovary (ovule), and the hairy calyx.

9. In the younger florets in the center what parts named above can you make out?

10. Select different stages in the development of florets, beginning with the younger ones of the unopened center and ending with the florets that show an elongation between ovary and old corolla. Make a selection of five or six in different stages of development.

11. Sketch the series above and label all parts that you can make out.

12. Another composite is the sunflower. Compare the corolla of the dandelion with the corolla of a sunflower floret. Notice that the corolla of the sunflower is not on one side as in the dandelion, but surrounds the floret. How many tips to the sunflower corolla?

13. Notice stamens. How do they compare with those of the dandelion?

14. Notice pistils. Compare those of the dandelion with those of the sunflower. In what ways are they alike? What are their differences?

15. What takes the place in the sunflower of the hairy calyx of the dandelion?

16. Compare the outer florets of the sunflower, that is, the ones that bear the colored ray flowers, with the outer flower of the dandelion head. What is the difference?

17. Compare the other composites like the wild asters, goldenrod, wild sunflowers, china asters, marigolds, cosmos, bachelor's buttons, etc., to see if they are more like the sunflower or dandelion in the form of their heads.

INSECT–POLLINATED FLOWERS

Spring Study

To study flowers of cherry:

1. Examine the flower. Notice the green outer envelope of sepals that make the calyx. How many are there?

2. Find these sepals in the bud of a flower. What purpose do they appear to serve?

3. How many petals (the row of parts just inside the calyx) do you find? Examine several cherry blossoms. Do you find any with four or six petals? It is not unusual to find such variation.

4. Examine the next group of parts inside the corolla (the name given to the petals taken together). These are stamens. How many would you estimate there were of these? They vary in number. Examine a stamen with a hand lens. Make out the knobbed end at the top, known as the anther, and the slender stem that supports it, the filament.

5. By using a hand lens are you able to tell how the anther opens to let out the pollen?

6. Examine the central part of the flower, the pistil. This is made up of three parts; the upper end is the stigma. The slender stem that supports is the style, and the small forming cherry at the lower part is called the ovary in the flower.

7. Examine several cherry blossoms to see if the stigma is glistening with moisture at the same time the pollen is seen on the anthers. When the stigma glistens, it can germinate pollen grains — this is the beginning of fertilization. If the pollen that touched the stigma came from the same blossom it would be self-pollinated. Are cherry blossoms self-pollinated? Give reasons for your answer.

8. If the stigma and anthers mature at different times, the flowers are dichogamous. Are cherries dichogamous? Can dichogamous flowers be self-pollinated? Give reasons for your answer.

9. If cherries are cross-pollinated are they pollinated by insects or wind? Give reasons for your answer.

10. Compare blossoms of plum, peach, or apricot with the cherry blossom. What are the main differences?

STUDY OF WIND POLLINATION

1. Select catkins from the staminate cottonwood (a dioecious form). These are reddish in color and short.

2. Examine the catkin to determine the anthers. How are they arranged on the catkins?

3. Make a sketch to show the staminate catkins leaf buds and other features of the cottonwood stem.

4. Select catkins from the pistillate cottonwood. These are slenderer than staminate catkins and are greenish in color.

5. Examine these catkins to determine the pistils. Make out stigma, style, and ovary.

6. Do you find calyx or corolla on either kind of catkins? What advantage in this?

7. Are these catkins adapted for wind pollination or insect pollination? Give reasons for your answer.

8. Do these catkins have a strong odor? Would a strong odor be of any use in pollination?

9. Have these catkins any striking coloration? Would striking colors aid in pollination?

10. Is pollen abundant? Is it dry and dusty? What advantage in pollination?

11. Is the stigma large and sticky? What advantage in pollination?

WIND–POLLINATED FLOWERS

Spring Study

The Oak, a Monoecious Form

1. In the oak the staminate flowers appear early in the form of catkins. The pistillate flowers are not made out as easily nor as early in the season.

2. Examine the catkins of oak as soon as they are powdery (pollen forming).

3. How are the anthers attached? Do you find calyx or corolla? Remembering the purpose that the corolla serves in pollination, how is it that the oak blossoms do not have a corolla?

4. Sketch a cluster of catkins. (Use a hand lens to make out details.)

5. Look on the newer parts of the season's growth for pistillate flowers. These flowers are really the small acorn with the stigmata and styles attached.

6. How many parts are there to the stigma?

7. What advantage in pollination is there in having a large, feathery surface for the stigma?

8. Examine the surface of the stigma and describe it.

9. What advantage in pollination in having dry, abundant pollen? What chance of waste of pollen in such a case?

10. Is the pollen dry or sticky? Under what circumstances would sticky pollen be advantageous?

11. Make a sketch to show the form of the pistillate blossom. Label all parts.

12. Compare blossoms of pignut, hickory, black walnut, or English walnut with the blossoms of the oak. What are the main differences?

13. What advantage have trees that are wind pollinated over trees that are insect pollinated?

14. How do you account for the lack of striking colors or fragrance in the wind-pollinated flowers?

15. What advantage is there in having the blossoms form before the leaves are fully developed?

SEEDS AND FRUITS

1. Compare a number of selected dry marrow beans. (Any other large bean will do.)

2. In what respects are they all alike?

3. In what respects do they differ?

4. Outside features:
   a. Notice the scar, hilum, where the bean was attached to pod.
   b. Near the hilum notice a small opening. (Use hand lens.) This is the micropyle.
   c. A raised portion of the surface near the hilum indicates a union of the seed coats. This is the chalaza.
   d. A line or ridge joins the hilum with the chalaza. This is the raphe.

5. Soak in water over night enough beans for class use.

6. Make a sketch to show the outside features of the bean, labeling hilum, micropyle, chalaza, and raphe.

7. Remove the peel. Notice the two parts inside. These are the cotyledons. These cotyledons hold the loosely attached embryo. The sprout is the hypocotyl and the leaf-like part is the plumule. Separate the cotyledons.

8. Sketch one of the cotyledons with its attached embryo. Label cotyledon, hypocotyl, and plumule. Use a lens to show the veining of the plumule.

9. Examine some beans that have been germinating for several days. Does the plumule or the hypocotyl form the leaves? The stem? The roots?

10. If time permits, germinate the scarlet runner beans, lima beans, and others. Compare the hypocotyls and plumules of each.

11. Make a study of soaked peas following the questions and directions for beans.

Castor Bean (Ricinus)

1. Examine castor beans and compare with marrow beans.

Note: Castor beans and marrow beans are not closely related. In fact peas and beans belong to the same family (pulse family), while castor beans are in another family (spurge family).

2. How do the different castor beans compare in color and markings?

3. Examine the surface markings of castor beans.
   a. Notice the thickened extension like a small handle. This is the caruncle. (See Beal's *Seed Dispersal*, page 70.)
   b. Find the hilum near the caruncle where the castor bean is attached.
   c. Find the chalaza near the end opposite the caruncle.
   d. Trace the faint line from hilum to caruncle. This is the raphe.

4. Sketch a view of the castor bean to show caruncle, hilum, chalaza, and raphe.

5. Compare this drawing with the similar drawing of the bean.

6. Remove the peel (testa) and notice the delicate, white inner-lining, the endopleura. How does this feature differ from the bean?

7. Open up the interior. Can you find the embryo? Compare with marrow bean.

8. Notice, if possible, the faintly veined plumule covering the cotyledon. Compare this feature with marrow bean.

9. Notice short straight hypocotyl at one end.

10. Note that in the castor bean the cotyledon has the veining and in the marrow bean the plumule has the veining.

11. The bulk of the castor bean that holds the food is the endosperm.

12. What holds the food in marrow bean?

Dent Corn

1. Examine several kernels of dent corn.

Note: Dent corn has long kernels. It is sometimes called western corn. There is a dent in the broad end of the kernel.

2. Compare the two broad sides of several kernels of corn. How do they differ?

3. Examine the corn to find the silk scar near the broad end.

NOTE: This can be made out best by looking at an ear of green corn and tracing the silk thread to the attachment of the kernel on the cob.

4. Under the depression on the broad side is the scutellum or cotyledon.

NOTE: This can best be seen when the kernel is cut. Make out the embryo in the center of the depression.

5. The hilum is not present, but the seed stalk at the lower end of the kernel takes its place.

6. Make a sketch to show silk scar, embryo, scutellum, and seed stalk.

7. Cut in two a kernel of soaked corn. Cut this evenly through the depression.

8 Examine the cut edge and find directly under the depression the split scutellum. Notice behind this scutellum the light colored area. This is the endosperm.

9. In front of the scutellum notice the embryo made up of three parts: First the plumule pointing toward the broad end second the root sheath pointing toward the seed stalk, and third the hypocotyl near the attachment of embryo to scutellum.

NOTE: This is not easily seen, and the teacher may need to point this out in favorable specimens.

10. Make a sketch to show the cut edge of the kernel of corn and label endosperm, scutellum, plumule, hypocotyl, root sheath, and seed stalk.

STUDY OF GERMINATION

Direction: Place in soil, moss, moist sawdust or damp cotton, a few beans, peas, castor beans, squash seeds, corn, etc., at intervals of four or five days. At the end of a month you should have seedlings of each in various stages of development. Arrange the seedlings of each in a horizontal row in order of age or growth from left to right. Sketch each of these and label as follows: hypocotyl, arch of the hypocotyl, cotyledon, plumule, brace roots, primary root, secondary root.

NOTE: Use such of these terms or additional terms as are needed to label the drawing properly. See Figure 209, page 221, *Biology for High Schools*.

TESTS FOR FOODSTUFFS IN SEEDS AND FRUITS

Test for Grape Sugar (Dextrose)

Material: Fehling's solution, test tubes, gas or alcohol burner, mortar and pestle.

Experiment:

1. Crush five or six dry peas in the mortar (use late varieties, as they usually have more sugar).

2. Boil in a test tube with water for five minutes.

3. Heat about 10 cc. of Fehling's solution in another test tube. If no yellow color develops, the solution is probably in good condition.

4. Add the contents of the test tube that contains the boiled peas to the test tube of Fehling's solution.

Note: Keep the flame near the upper surface of the boiling mixture. If grape sugar is present in sufficient amount, a yellow color will develop in the mixture.

5. Repeat the experiment, using sweet corn, dent corn, beans, and any other seeds you may have.

6. Make out a list of these and write down in the order of sugar found.

Test for Starch

Materials: Iodine solution, test tubes, mortar and pestle, gas or alcohol lamp.

Experiment:

1. Crush five or six peas.

2. Boil in a test tube with water for five minutes.

3. Pour a few drops of this solution into a test tube, add water to make up to 10 cc.

4. Add a few drops of solution of iodine and boil.

5. The development of a blue color indicates starch.

6. Now use three or four times the quantity of solution used in (3). Add same amount of water. Add solution of iodine and boil. How does the blue color now compare in intensity with that obtained before? What do you conclude?

7. Repeat the experiment, using beans, corn, wheat, potatoes, etc.

Test for Protein

Materials: Strong nitric acid (c.p.), strong ammonia water (ammonium hydroxide).

Experiment:

1. Crush five or six peas.

2. Boil in test tube with 10 cc. of water. Cool by holding test tube in cold water.

3. Wipe off the water from the test tube. Add a few drops of nitric acid. Boil and again cool. If a yellow color develops, protein is indicated.

4. Add a few drops of ammonia water. If the yellow color deepens to orange, you have a further indication of protein.

5. Repeat the experiment, using beans, corn, wheat, and other seeds available.

Test for Oil

Materials: Walnut meats, sunflower seeds, brazil nuts, coconut, etc.

Experiment:

1. Crush walnut meats or sunflower seeds and put into a test tube. Add ether or benzine until test tube is two thirds full. Shake well. Let stand a few moments and shake again.

2. Filter and evaporate the filtrate; that is, the part that leaks through the paper.

3. Rub this substance that does not evaporate on writing paper and see if you get a translucent grease spot. A grease spot can be recognized in general by its appearance. This is not a very satisfactory test, but it is one that is usually accepted. There are complicated chemical tests for oil which are more accurate.

4. Repeat the experiment, using brazil nuts, coconut, whole-wheat flour, castor beans, or other seeds that may be available.

TO TEST SEEDS FOR GERMINATING QUALITIES

Corn Test

Materials: Moss, sawdust or blotters or seed-testing frame.

Experiment:

1. Get some ears of seed corn and select six kernels from each ear as follows: two kernels from opposite sides near the top of the ear, two kernels from the middle, and two from the bottom.

2. Soak the kernels for two hours in water and place them in moss or blotters or seed-testing frame. Keep the kernels from the same ear in a group. Keep these kernels where it is warm and moist. If kept too cool or too moist, the kernels will rot.

3. After five or six days examine the corn and count the number that have germinated.

4. Repeat this experiment, using beans, peas, carrots, parsnips, and other seeds that are to be planted the following spring.

TEST FOR VIABILITY OF SEEDS

Directions: Get some old seeds from home or from the store and find out as near as possible the age. Test in the same way as for corn, except that you may use ten or fifteen seeds of each kind. Use seeds of different kinds but of the same age for each experiment. The purpose of this experiment is to find what kind of seeds will grow after being kept two, three, four, or five years.

Fill out the following outline after having experimented on various kinds of old seeds.

KIND	1 YR.	2 YR.	3 YR.	4 YR.
Beans				
Peas				
etc.				

TO STUDY CONDITIONS NECESSARY FOR GERMINATION

A. Moisture

1. Soak a handful of peas in water over night.

2. Take three cups or tumblers and place a piece of blotting paper in the bottom of each.

3. Place ten soaked peas in each tumbler. Half fill one tumbler with water, sprinkle a little water on second bottle. Keep third dry. Cover each tumbler with a loose piece of cardboard.

4. Examine each day for ten days. Fill out the following report on the sixth, eighth, and tenth days:

	6th Day How Many Grew	8th Day How Many Grew	10th Day How Many Grew
Peas covered with water			
Moist peas			
Dry peas			

5. What can you say about the moisture condition necessary for germination?

B. Temperature

1. Soak a handful of peas in water over night.

2. Take three tumblers and put a piece of moist blotting paper in the bottom of each.

3. Into each put ten soaked peas and keep the moisture condition favorable for germination.

4. Now put one tumbler where it is hot, say near the heat source such as the radiator, register or stove. Put the second out on the window ledge or some other cold place. Put the third where the temperature will be about 70 degrees all the time. Put the same amount of water in each.

Note: An ideal place for germinating seeds would be an incubator where a temperature of 70 degrees could be constantly maintained. Such incubators are used in experimental stations where accuracy in observing germinating qualities is of great importance.

5. Fill out the following report:

Ear	Number Grown	Weak Growth	Strong Growth
No. 1			
2			
3			
4			

C. Oxygen

1. Put forty or fifty soaked peas in a wide-mouthed bottle.

2. Tip the bottle on one side and fill above and around peas with moist sand. Completely fill bottle and then seal with paraffin or sealing wax.

3. Now take same number of soaked peas and fill bottle half full of moist sand. Do not seal.

4. Let both bottles have same treatment otherwise, such as same heat and moisture.

5. Fill out the following report:

	Number Sprouted	Strong Growth	Weak Growth	Few Spoiled	Many Spoiled
Peas with sand and sealed					
Peas with less sand not sealed					

To Test Germinating Seeds for CO_2

1. Place in a bottle a handful of germinating peas.

2. Replace the stopper and after three days or so remove some of the air above the peas with a rubber bulb and glass tube.

3. Force this air through lime water. Do this three or four times.

4. What happens in the lime water?

Note: CO_2 forms a milky substance in lime water.

5. Hold a lighted stick in the bottle with the germinating peas. Does it burn less brightly? Does it go out?

Note: Oxygen is necessary to keep the stick burning. What is indicated from your observations with the lighted stick?

6. Breathe through a tube into lime water. Do you get a milky color in the lime water? What does this indicate?

7. Do germinating seeds give off CO_2? Does the human breath contain CO_2?

ROOTS

The Carrot

1. Cut a carrot in longitudional sections. Make out a central area, known as the central cylinder; outside of this a thicker area, the cortex; and surrounding it all the epidermis, the covering.

2. Make a sketch to show these regions. Label.

3. Make a cross-section of a carrot and identify the same regions.

4. Make a sketch to show these regions. Label.

5. Secondary roots may appear in these sections. To which region are they connected? Show this in your drawing.

6. Stand a cut end of the carrot in red ink for a few hours. Through which region does the ink rise?

7. Make a similar study of parsnip, beet, vegetable oyster or other roots.

The Onion Root

1. Select strong roots of growing onions and examine the natural ends. These are blunt and usually show the root-cap. Make thin, lon-

gitudinal sections through these ends and stain with methylene blue. Make out central cylinder, cortex, and epidermis. At the free end of the root should be found a cluster of cells known as the root-cap. Just back of the root-cap near the outer end of the central cylinder should be found a group of small cells, the growing region known as the meristem.

2. Make a sketch of longitudinal section of onion root to show central cylinder, cortex, epidermis, root-cap, and meristem.

Wheat Kernels

1. Place several kernels of wheat on moist blotting paper or cotton and invert a glass tumbler over them. After a few days the hypocotyl and roots should form. If the moisture condition in the tumbler is favorable, the roots will be covered with fine root hairs.

2. Make a sketch to show the roots, root hairs, and hypocotyl.

3. From a prepared slide showing cross-section of one of these roots, determine how the root hairs are formed and from what they are outgrowths.

4. Make a sketch to show this cross-section and label central cylinder, cortex, epidermis, and root hairs.

5. If the prepared slide is well stained and a careful examination made of the root hairs, the nuclei of the root hairs can be seen. Where are they located in relation to the epidermis?

Corn

1. Examine growing corn and look for roots that start above the ground and reach to the ground on all sides. These are brace roots. How is their development an advantage to the growing corn?

2. Make a sketch to show these brace roots in relation to the corn stem and the surrounding ground. Do they develop strong roots branching at their lower end?

Fibrous Roots

1. The carrot and parsnip are examples of tap roots. Some plants have fibrous roots. Select from the garden or lawn those weeds that do not have tap roots but have a branching system of small roots.

2. Make a sketch of one that shows a good distribution of roots and compare this root surface with the part of the plant above the ground.

3. Make a list of common weeds that you have gathered which show fibrous roots.

Fascicled Roots

1. The dahlia is a good example of a plant with fascicled roots. These roots are thickened and shortened for food storage.

2. Make a sketch to show a cluster of these roots. They serve as a means of propagation.

Aërial Roots

1. The Boston ivy has aërial roots growing along the stem. These roots penetrate tree trunks, brick walls, etc., and serve as holdfasts.

2. Make a sketch to show a portion of a stem with these roots attached.

STEMS

Spring or Late Fall

The Horse-Chestnut Stem

1. Examine the stems with strong buds.

2. Notice the large terminal bud.

3. What purpose does the gummy part of the bud serve?

4. What is the arrangement of the lateral buds in reference to each other?

5. Notice several pairs of adjacent buds. How are these pairs arranged in reference to each other?

6. Directly beneath the bud are the leaf scars where the leaves of other years have been attached.

7. Inside the leaf scar notice the row of small projections. These are bundle scars. Count them. How does the number compare in different leaf scars? How do these numbers compare with the number of leaflets of the compound leaves of the horse-chestnut?

8. Notice the small scars that encircle the stem at intervals. These are bud scale scars. They are formed by the bud scales of earlier years.

9. What does the space between the bud scale scars represent? Determine the age of the oldest growth in your specimen.

10. Notice the small points or marks on the bark of the new growth. These are lenticels. They connect with the inner portion of the stem. How may the stems get oxygen for respiration during the season the leaves are not functioning?

11. Notice the scars at the union of some lateral stems with the main stem or on the shoulders of the main stem. These are not numerous and you may have to examine several stems before you find one. They are the flower cluster scars and mark the place where the flower cluster was joined to the stem. Later the fruit was nourished through the same region. Why are they not numerous in comparison with leaf scars?

12. Examine the pith exposed by cutting the stem diagonally. Notice the layers of wood and bark outside the pith.

13. Make a sketch of a typical horse-chestnut stem, showing terminal and lateral buds, leaf scars, bundle scars, bud scale scars, year growths, lenticels, flower cluster scars, and the pith with surrounding layers of wood and bark.

Cross-section of a Woody Stem

Horse-chestnut

1. Compare the pith, the wood, and the bark. Which is firmer?

2. Examine a cross-section of an older stem of horse-chestnut. How does the size of the pith compare with the younger specimen?

3. Have you any reason to believe that the growing wood crowds up the pith?

4. Notice radiating lines running through the wood. These are medullary rays. They serve to convey materials from the pith to the outer layers.

5. Notice the concentric ring about the pith. Compare the number of these rings in the young stem with those in the old stem. These are rings of annual growth.

6. Notice the ends of tubes in the woody section. These carry materials from the root to the leaves and from the leaves to the root.

7. Pare off strips of the bark. Can you find strengthening fibers running up and down the stem? These are bast threads.

8. Examining the cross-section of the stem, tell which part gives it support?

9. Is there any relation between the hollow cylinder of wood and a solid cylinder of the same weight? Which is stronger? Would the horse-chestnut stem be stronger if the same amount of wood were arranged in a solid cylinder or in a hollow cylinder?

10. Take a horse-chestnut stem two or three inches long and place a cut end in red ink. Let it stand two or three hours and then make cross-sections, beginning with the upper end of the stem. In what portion of the stem do you find that the red ink has risen most? Try grape stems, elder, parsnip, carrot, etc.

11. Which ones seem to carry the ink highest in the same time?

12. What part of the stem, then, seems to carry fluids up?

13. Take several willow stems and put them in water until they root. After they have established good, long roots, cut a ring one half inch wide around the stem and remove the bark. Scrape the wood beneath the bark to be sure all of the bark is removed. Replace in the water

with the cut portion underneath the surface of the water. Observe for two or three weeks. What happens to the roots that were started earlier? What happens at the upper cut edge? Account for what happens.

Stems in Their Relation to Life

1. Take a plant such as a geranium or any house plant and place it in a window. Do the stems respond to the light? How?

2. Turn the plant halfway around. Leave for a few days. Have the stems changed position? How? What is the effect of light on stems?

3. Place some growing seedlings in the dark. Place some of the same age in a good light. Keep moisture and temperature conditions the same. After a week or ten days, compare the growth made under the two different conditions. What is the effect of darkness on the growing seedlings?

4. Does darkness stimulate growth? If a stem is unevenly lighted, that is, one side well lighted and the other poorly lighted, would this inequality explain why plants lean toward a window?

5. Sometimes a barrel is put over pie plant early in the spring. If the barrel is tight so that the interior is dark, what effect should this have on the growth of the pie plant? Why?

6. Potatoes left in the cellar or other dark place during the early summer will grow sprouts ten or twelve feet long. Is this in accordance with the action of other stems when grown in the dark?

7. What adaptation is shown here which would apply to buried stems or seeds planted too deeply? What does the stem gain naturally by having its growth stimulated by darkness?

Sunflower Stem

1. Cut very thin slices of a small sunflower stem in cross-section. Stain with methylene blue and examine with a low-power microscope.

2. Notice the row of bundles that extend around the stem just inside the bark. These are fibro-vascular bundles. They afford strength and also carry solutions. These bundles have three regions. The outer region is phloem and is the bark part. Next inside is the cambium region or growing region. Next inside is the xylem or the woody part of the bundle.

3. Make a sketch to show the arrangement of these bundles in relation to the whole stem and also roughly to show the general form.

4. Use a higher-power lens and make a sketch to show more in detail the appearance of a single fibro-vascular bundle. Label pith, xylem, cambium, phloem.

5. Review the make-up of these various regions and the other details of bundle structure in your text.

Corn Stem

1. Cut thin slices of a moderate-sized corn stem in cross-section. Stain with methylene blue and examine with a lower-power lens.

2. Find the areas scattered through the stem that are more deeply stained. These are the fibro-vascular bundles of the corn stem. Compare their arrangement with that of the sunflower bundles.

3. Examine with a higher power lens a single bundle and notice the arrangement of parts in comparison with the bundle of the sunflower stem. Surrounding the whole bundle are thick-walled cells known as the bundle sheath. Notice extra large openings inside the bundle. These are special conducting tubes. Notice thick-walled cells at the ends of the bundle. These are strengthening cells. Notice the other cells and by reference to your text determine the functions of the different kinds.

4. Make a sketch to show the arrangement of bundles in a corn stem, and also, by aid of a lens, a sketch to show the regions of a single bundle. Label to show pith, bundle sheath, woody cells, and conducting cells.

MODIFIED STEMS

The Potato

1. The potato is a modified stem for food storage. It has most of the features of an ordinary stem.

2. Select clean, white potatoes and notice the eyes. These eyes are buds. Below the eyes are small scales which may be considered dwarf leaves. The buds are, then, located in the axils of the leaves. Is this as it should be?

3. Notice the small projections on the surface of the potato. These are lenticels.

4. Make a cross-section of a potato and find the thickened areas that correspond to fibro-vascular bundles. These are poorly developed in the potato for the reason that the potato is a storage region rather than a conducting region.

5. Make a sketch to show a potato with the stem-like features labeled.

The Onion

1. The onion has a modified stem which is short and thick, surmounted by thickened leaves surrounding the buds. The roots are in a cluster from the lower end of the stem. In this case, the stem is reduced to its lowest terms while the bulk of the onion is thickened leaves and buds.

2. Make a sketch to show the appearance of an onion in cross-section. Label to show bud region (in some cases there will be two or more buds) and thickened leaves.

3. Make a sketch to show an onion in longitudinal section. Label to show thickened leaves, bud, stem, roots.

The Cabbage

1. The cabbage has a short, thick stem with thickened leaves closely set with buds in their axils.

2. Make a sketch to show a cabbage in longitudinal section, labeling stem, thickened leaves, and buds.

Other Stems

1. Stems are usually for support, for food storage, or to give the leaves favorable positions in the sunlight. Some stems are modified into thorns, as in the case of wild apple, honey locust, prickly ash, etc.

2. Select small branches of honey locust or wild apple and examine them to find out the form and arrangement of the thorns. Make a sketch to show the arrangement of the thorns and buds.

3. Do these thorns serve any useful purpose? It is sometimes said that thorns protect stems from being eaten. Does this seem a good explanation to you?

4. Quack grass has underground stems by means of which the grass extends its area and is a means of propagation. Select some quack grass with these underground stems carefully preserved. Make a sketch to show how these grow and the buds they form.

5. What other plants have underground stems? Do they serve the same purpose as in quack grass?

6. Examine runners of strawberries and notice how these stems likewise serve to extend the area of the plant. Examine some runners of strawberries and find out how many small plants may form on one runner.

7. Make a list of edible stems, including such stems as are found in stores or in neighboring gardens. Such stems are modified for food storage.

8. Make a list of stems that serve as means of propagation.

9. What is layering? Grafting? Budding? Slipping?

10. How are grapes propagated? Currants? Blackberries? Raspberries?

LEAVES

General Characters

1. Gather the leaves of twelve or fifteen kinds of trees. Examine them and note as many points of resemblance as you can find. These resemblances may include color, thickness, veining, petioles, and other resemblances.

2. In how many ways do they differ? These differences may include size, hairiness, margins, form, and such other differences as you may find.

3. Write a description of your observations summarizing the resemblances and differences of leaves.

The Maple Leaf

1. Select a wild form of maple leaf and make a sketch to show the whole leaf. Trace the outline if time does not permit of a free drawing.

2. Label petiole (the part that attaches the leaf-blade to the stem), midrib, and other prominent veins and leaf-blade.

3. Hold the leaf up to the light and notice the many fine branches of the larger vein.

4. Use hand lens to see the still smaller veins.

5. What is the function of the leaf?

6. What are the functions of the veins?

Leaf Forms

1. Gather leaves of elm, oak, lilac, horse-chestnut, and ash.

2. Make a sketch to show outline and venation (veining) of elm, oak, and lilac. The elm has a toothed margin, the oak a lobed margin, and the lilac has an entire margin. Label these leaves toothed, lobed, entire, respectively.

3. Compare the prominence of veins in each and notice how the lateral veins join the midrib. Show these characteristics in your drawings.

4. In what way is a river system suggestive of the system of veins in these leaves?

5. What relation do these veins have to the fibro-vascular bundles of the stem?

6. What advantage does a flat leaf derive from having its leaves broad and thin?

7. Make a sketch to show the compound leaves of horse-chestnut and ash.

8. How many leaflets in the horse-chestnut leaf have you sketched?

9. Count them in other leaves. Is the number always the same?

10. How do the numbers of leaflets compare in general with the number of bundle scars in the leaf scars of the horse-chestnut stem? What do you conclude?

11. How many leaflets in the ash leaf? Does this number vary in different ash leaves? Is there any relation between bundle scars of the ash leaf scar and the number of leaflets of the ash?

12. Does the midrib of the elm leaf divide it into two equal parts?

13. If you are uncertain about the elm leaf, fold it on the midrib.

14. Compare the oak and lilac with the elm leaf in this respect.

15. Which of these leaves has the most uneven sides?

Functions of Leaves

Respiration

1. Take some algae or other water plants that grow entirely in the water and place in a large glass jar. Place a funnel inverted in the jar and over the plants. Fill the jar with water so that the level of the water is above the opening of the funnel. Over the open end of the funnel invert a large test tube filled with water.

2. The purpose of this apparatus is to catch any gas given off by the plant that is not readily soluble in water.

3. Keep the apparatus in the dark or in a poorly lighted part of the room. Do you observe any gas collecting in the test tube?

4. Place the apparatus in the strong sunlight. Do you observe any gas bubbling up in the test tube?

5. If the plants are too densely crowded or are not numerous enough, you may have to repeat the experiment for a good result.

6. In case you get a quantity of gas, you may remove the test tube and quickly thrust in a glowing match.

7. In the presence of oxygen, the glowing match will burst into flame.

8. What happened in your case? What do you conclude?

9. If leaves give off oxygen, is it associated with respiration or photosynthesis?

10. Is the giving off of oxygen limited to water plants? What about the plants in the garden and woods?

11. Do plants give off carbonic acid gas (CO_2)?

12. Is carbonic acid gas soluble in water? What makes soda water bubble?

13. If carbonic acid gas is soluble in water, could this apparatus just used collect carbonic acid gas?

Transpiration

1. Take a small geranium plant or any other strong plant that is growing in a crock. Cover the crock with a cardboard and seal the opening around the plant and the split in the cardboard with modeling clay or gum. The idea is to prevent the water vapor from the crock getting above the cardboard.

2. Invert a glass jar over the plant and seal the lower edges with modeling clay or gum.

3. Place the plant just covered in the sunlight, preferably where a good breeze may strike it.

4. After a time the inside of the glass jar should show a change in appearance.

5. Account for any change that you see.

6. Transpiration in plants is the giving off of moisture through leaf tissue.

7. Why do plants need water?

8. How are plant foods from the soil, roots, and stems brought to the leaves? Consider this in relation to root hairs, fibro-vascular bundles, and veins.

9. If the leaves were obliged to retain all water brought to them by the veins, what would be the effect on the weight of the leaves? Their size? Their functioning?

Evaporation through Leaf Tissues

1. Take two large, thick leaves of even weight. If you cannot find two of the same weight, get two of nearly even weight and balance with

dry sand or small weights. Dip the cut ends of the petiole in melted paraffin.

2. The thicker and larger the leaves, the better results your experiment will give.

3. Cover the upper side of one leaf with butter or vaseline and cover the lower side of the other in the same way. Take care to keep one side absolutely free from oil. Put the leaves again on the scales and balance.

4. Place the scales in strong sunlight with the lower surface of each uppermost.

5. Do you find that they soon get out of balance? Which leaf is heavier?

6. Which surface evaporates the water faster, upper or lower?

7. Transpiration takes place more,— from which surface?

8. What advantage does the leaf derive in having the surfaces as you find them?

9. Some leaves do not have a normal upper and lower surface, as in the case of the onion.

10. Strip small shreds of epidermis from fresh leaves of growing onions. Mount in water and examine with a $\frac{2}{3}$ objective.

11. Do you find small pores or openings? These are stomata — small openings each surrounded by two guard cells. These guard cells regulate the size of the stomata and so control in a measure transpiration.

12. If possible, study a prepared slide showing these guard cells, stomata and epidermal cells of onion or other plant.

Leaves as Food Storage

1. Make a collection of all the different leaves that are used as food, such as celery, cabbage, spinach, lettuce, chard, endive, etc.

2. Compare these as to color. Which ones are green? Which are bleached or yellowish white?

3. How is celery bleached? What is the difference in appearance bleached and unbleached celery?

4. What change in taste when celery is bleached?

5. What gives leaves their bitter taste? What develops chlorophyll in leaves?

6. What plants do you know that lack green color?

7. What is the color of the cabbage leaf in the head near the stem?

8. Are cabbage leaves bitter?

9. What difference is there in the process of bleaching cabbage leaves and celery?

10. Why are spinach leaves used as food? Are they bleached?

11. Is all chlorophyll equally bitter?

12. Are very thin leaves, such as lettuce and spinach, as bitter as the heavy thick leaves of unbleached celery? Why?

13. In which of the above-named leaves is the petiole the principal food? In which the leaf blade?

14. Boil some of the spinach leaves in alcohol. Is chlorophyll soluble in alcohol?

NOTE: In boiling alcohol use a deep dish and a low flame and do not boil too fast. Why?

Modified Leaves

1. We have seen that the normal functions of leaves is in photosynthesis, transpiration, respiration, and digestion. Leaves also serve as a food storage region, and we are to consider other uses to which leaves are put.

2. Examine the new growth of ivy, pea, grape, woodbine, and other plants that have tendrils.

3. Which of these have their tendrils arranged opposite leaves or in the place of leaves?

4. Examine the leaves of pitcher plant, drosera. These leaves are modified to capture insects.

5. The pitcher plant leaf is, as its name indicates, in the form of a pitcher. Notice the colored streak on the inside of the leaf. Mosquitoes are frequently caught in the pitcher plant. Notice the bristles inside the leaf. Which way do they point? How could these bristles aid in the imprisonment of insects?

6. Most of the leaves of the pitcher plant are erect. They thus hold rain water. Do you find any insects floating in the water? Would the decayed insects furnish food for the plant?

7. If possible, observe the pitcher plant blossom. Does this blossom appeal to insects for pollination? Give reasons for your answer.

Are the insects that are attracted to the pitcher plant blossom entrapped in any way? Do the leaves and blossoms use different kinds of insects?

8. Examine barberry leaves from different shrubs. Some of these leaves show a variation from a large leaf with a few thorns down to a very small leaf with large thorns to a condition of only thorns.

9. Leaves as hold-fasts. We have already seen that some leaves are replaced by tendrils. Other leaves keep their leaf-like shape while their petioles serve as hold-fasts. Examine petioles of nasturtium and clematis. Can you find other leaves in which the petioles are holding the plant erect?

10. Examine the new growth of common locust and compare it with the year-old stems. Select the common locusts that show common appearance. What relation do these thorns have to the leaf in the new growth? What relation do they have to the leaf scar in the old growth? These thorns are the modified stipules of the leaf.

11. We have thus seen that the leaf blade may be modified for various purposes as in food storage, tendrils, insect traps. The petioles may be modified into hold-fasts as in nasturtiums and clematis, and the stipules into thorns as in the case of common locust.

12. Examine in the field, if possible, the drosera leaves during favorable weather. Some of these leaves will be found open and others will have their toothed edges closed holding an insect. These leaves are special adaptations for catching insects. In case it is impracticable to make a field trip, a very good idea of the action of these leaves may be gained from pictures and drawings in addition to the descriptive matter.

Digestion

1. Select a strong growing plant and fasten two pieces of black paper on opposite sides of a part of the leaf. Place the plant in the sunlight. After five or six hours cut off the leaf and remove the black paper.

2. Place the leaf in boiling water to remove the chlorophyll.

3. Test the leaf for starch by boiling in a solution of iodine.

4. Which part shows a blue color?

5. Account for the fact that not all the leaf develops a blue color. What has become of the starch that must have been under the black paper earlier?

6. Account for the fact that potatoes grown in the shade of a building will not do so well as out in full sunlight.

7. Where is the starch made that forms the large part of the potato tuber?

8. What color is always associated with chlorophyll? What is the relation of this color to chlorophyll?

9. Name some plants that are not green and that cannot make starch.

10. Name four functions of leaves.

11. Why do plants that lose their foliage fail to bear fruit?

12. Suppose the leaves of a potato plant were picked off early in the season. How could this affect the tubers?

13. What is the effect if potato beetles eat a large part of the foliage of potato vines?

14. If tent caterpillars eat the foliage of apple trees, how will this affect the apple crop?

15. What is the effect on the peach crop when the leaves turn yellow or have leaf curl?

16. Why should the state and national governments maintain experimental stations to study diseases of plants and animals?

17. What is the effect on the price when there is a big crop of foodstuffs?

18. How does this affect all the people?

FIELD TRIP

Adaptations of Plants That Serve as Protection

1. Take a field trip to a pasture lot and study the plants that the cattle have not cropped.

2. Make a list of them and try to explain why they are uneaten. Some plants have thorns or prickers, some are bitter, sour, pungent, or otherwise distasteful. Some are poisonous, some are very hairy, and some are too dry and leathery. Many of the plants have objectionable odors.

3. What other objectionable features can you find from your standpoint?

4. This list may be inaccurate because we assume that cattle like and dislike in the same way we do. Cattle have preferences in their food taste and if they can get all the good grass they want, they may not eat certain plants. If the grass dries up, or if the cattle are too crowded on pasture, they may eat some of the plants that seem objectionable to us.

5. Several field trips will show that at different times cattle will have different tastes for plants.

6. Another point we should be careful about is this: avoid saying a plant is poisonous and therefore it will not be eaten. A better way to say it is, that a plant is poisonous and cattle have come to recognize it as such and have learned not to eat it. We should be careful about giving reasons for plants being thorny, bitter, sour, sweet, fuzzy, or poisonous.

7. Thus we should not say that all of these are bitter and hence animals will not eat them, because some animals eat plants for the bitter taste, and we also know now that a bitter taste is always associated with chlorophyll. We also know that plants must have chlorophyll in order to make starch. So that the real reason that plants are bitter is because chlorophyll is bitter.

ALGAE, FOR EXAMPLE, SPIROGYRA

1. Gather the green pond scum from watering troughs or standing water and place a portion of it under a low-power microscope.

NOTE: Not all such pond scum is spirogyra, for there are many species of algae which are green.

2. Examine your specimen for spiral bands of green running through the tubes. Are these spirals marked off into cells?

3. What color are these spyra bands? What is suggested by this color? Are these threads attached to roots or branches? Are they independent?

4. How are these plants able to live without a root system or without leaves? Are these threads more like leaves or stem? Give a reason for your answer.

5. From a prepared slide or chart, study conjugation. Can you find outgrowths from adjoining stems? Can you find a tube connecting adjoining stems?

6. Can you find zygospores? Compare the formation of a zygospore of the spirogyra and the bread mold or any other mold as to position, shape, color.

7. The formation of zygospores in spirogyra serves the same purpose as in mold. What is it? How is this process an adaptation?

8. Some algae have archegonia and antheridia and reproduce sexually. Is spirogyra sexual or asexual? Is the zygospore produced by sperms and eggs? How is it produced?

BACTERIA

NOTE: Bacteria are small fungus plants that are either parasites or saprophytes. They are widely distributed, and air and dust contain large numbers. Certain substances, known as media, are prepared from meat juices, gelatin, and sugars, which afford favorable growing places for bacteria. One of these media is prepared from agar, which is a gelatin-like substance obtained from plants. Agar media may be made from a formula or purchased in test tubes from supply houses. When this agar is melted in boiling water and poured in plates, we have a growing-place for bacteria.

1. Place four test tubes of agar in a vessel containing water and bring to a boil.

2. Take a few drops of tap water or a drop of milk and place in a petri dish.

3. Cool the boiling water that contains the test tubes of agar to a temperature that is comfortable to the hand. Shake the water around the test tubes until the agar has been cooled to the same degree.

4. Pour the partly cooled agar into the petri dish and replace the cover. Give the petri dish a slightly whirling motion to mix the agar with the drops of water in the dish. Allow this to stand for three or four days at room temperatures.

5. Hold the petri dish up to the light and count the spots that have formed on the agar. These are colonies of bacteria. Each colony has grown from a single bacterium. The number of colonies will indicate

the number of bacteria that you placed in the petri dish that are nourished by this agar medium.

6. This method of counting bacteria is used in determining the bacteria in milk or water. If the colonies are too numerous to count, then the experiment should be repeated by diluting. For example, if 1 cc. of milk is placed in 100 cc. of sterile water, and then 1 cc. of the dilution is taken, the total number of bacteria in 1 cc. of milk can be determined by multiplying the number of colonies on the petri dish by 100.

7. Notice that the shape and color of the colonies vary. Some are elliptical, some are round, and some are uneven. Some are gray, some are white, some are yellow. What other shapes and colors can you find?

A FUNGUS, FOR EXAMPLE, BREAD MOLD

1. Take pieces of moist bread and keep them in a loosely covered tin box for a few days or until the familiar bread mold appears.

2. Describe the general color.

3. Is there any evidence of chlorophyll? What do you conclude?

4. Plants that lack chlorophyll are unable to lead an independent life. Such plants are either parasites or saprophytes. Parasites are found on living forms and saprophytes on lifeless forms. Is the bread mold a parasite or saprophyte?

5. Examine with a hand lens the mass of bread mold. Can you find dark spots on the ends of white stalks? Sporangia are born on the ends of white stalks and contain spores. When these sporangia break, the spores are scattered and are widely distributed. They develop into bread mold when the conditions of growth become favorable.

6. Study from prepared slides or charts the structure of the mold mass (mycelium) and the sporangia. Do you find any evidence of cell structure in the mycelium?

7. From a prepared slide or chart study the conjugation of bread mold. The joining threads of the mycelium under certain adverse conditions send out projections which meet and form a zygospore. This spore is resistant to a high degree. It is a means of reproduction and is an adaptation to carry the mold through unfavorable conditions.

8. Some spores are not killed by prolonged boiling in water.

THE MOSS

1. Gather specimens of moss that have the long, reddish stems growing from the top surmounted with capsules.

2. Separate several plants from the cluster and notice the short, leafy stems at the lower part, poorly developed root system, and the slender stem with the capsule growing out of the top of the leafy stem.

3. This plant represents both generations (sexual and asexual). The lower leafy part is the gametophyte, and the upper slender part, the sporophyte.

4. Make a sketch to show both generations of moss. Label.

5. Compare the moss and the fern as to the relation of the gametophyte and the sporophyte.

6. Which is the conspicuous generation in the fern, sporophyte or gametophyte?

7. Which is the conspicuous generation in the moss, sporophyte or gametophyte?

8. Examine the capsule at the top of the sporophyte with a low-power microscope. Can you find the opening at the top through which the spores emerge? Can you find the tooth-like projections (peristome) at the upper part of the capsule?

9. From a prepared slide or from a chart study sections through the top of the gametophyte and compare archegonia of moss and fern. Compare antheridia of moss and fern. Compare spores of moss and fern.

10. On the prothallus of the fern we find both archegonia and antheridia. How is it in the moss?

11. Study the development of the moss spore from a prepared slide or chart and compare it with the thread-like algae (spirogyra).

THE LOWER PLANTS

The Fern

1. Gather some fronds (leaves) of ferns. Examine the plant for roots and stems. Is there a good root system? Are the stems woody? Are the fronds green? Can they make starch?

2. Examine the underside of some of the fronds for little brown spots. These are clusters of spore cases (sori).

3. Examine some of the sori under a low-power microscope. Notice the spore cases (sporangia) that hold the spores.

4. Examine the spores under a low-power microscope. Are the surfaces smooth or rough?

5. Under favorable conditions of temperature and moisture, the spores will grow into small flat plants called prothallia (the gametophyte).

6. If possible examine a prepared slide showing the underside of the prothalium. Look for spherical bodies (antheridia) and bottle-shaped bodies (archegonia). These antheridia produce sperm cells and the archegonia produce the eggs.

7. When a sperm cell, which is motile, reaches the egg in the archegonium, fertilization takes place, and a new plant (sporophyte) grows which lives for a time on the prothalia (the gametophyte).

8. The little plant (sporophyte) is later to grow into the same kind of plant we started with having fronds, stems, and roots.

9. Examine the place where ferns grow in abundance, either out of doors or in a greenhouse, for the prothallia and also look for the little off shoots (sporophytes) that are growing from the prothallium.

10. Notice that we have in the life history of a fern a sexual generation (prothallium) and an asexual generation (sporophyte).

11. Alternation of generation, is illustrated in the life history of the fern. We have first a sexual generation that is inconspicuous. It is followed by an asexual generation, and these continue to alternate during the life of the species.

12. From a prepared slide sketch the prothallium showing cell structure, antheridia, archegonia, and the rhizoids (root-like structures).

13. Sketch a portion of a frond showing sori and spore cases.

14. Sketch a spore case (sporangium) with spores.

HUMAN BIOLOGY

ADAPTATION OF THE HUMAN HAND

1. Examine your hand. Notice the joints of the fingers. How many are there?

2. Grasp your wrist with one hand. What advantage is there in having the thumb larger than any of the fingers?

3. Hold firmly on to your wrist with one hand and try to pull your hand from your clenched thumb and fingers. Push hard against your fingers. Push hard against your thumb. Is your thumb as strong as the four fingers?

4. What advantage is derived from having the fingers with so many joints? Turn the pages of this book and watch the motion of your fingers as you do so. How do you turn over the pages? How do you hold the book with the other hand as you turn over the pages? Do the joints in the fingers play a large part in this?

5. Place on the table small bits of paper, pins, and other tiny articles. Pick them up and put them in your hand. What device of the fingers enables you to do this?

6. Clench your fists. How is the clenched fist an organ of defense? What other adaptation has the hand? How many uses can you name for the hand?

THE HEAD

1. What advantage is there in the shape of the head?

2. What advantage in having the eyes in the front of the head? Close one eye and look at an object. Close the other eye and look at the same object. Is there an image formed of the object in each eye? When both eyes are focused on an object at the same time how many objects can you see? Can you judge distance better by looking at an object with both eyes than with one eye at a time? What advantage is there in judging a distance in case of danger?

3. The nose is above the mouth. If odors rise, is this an advantage? What danger comes from eating decayed foods?

4. The ears are so arranged that we catch the sound most readily from the front. Is this an advantage? Would it be more advantageous if the ears were movable, as in the case of dogs and horses?

5. What advantages are there in the different forms of teeth? For what are the incisors or front teeth adapted? What is the use of the molars or back teeth? Could the incisors or molars be advantageously interchanged? Some flesh-eating animals have long canine teeth. The dog and the cat are examples. Would we be better off with long canine teeth like a dog? Give reasons for your answer.

6. What advantage is there in the hair of the head? Does the head need special protection? The skull is thicker in front and in the back than at the side. Is there any advantage in this?

THE BACKBONE

1. The backbone is made up of many individual vertebrae separated by pads of cartilage. What advantages do these many small bones give to the backbone? What advantage is there in having pads between the vertebrae?

2. The backbone is not straight but curves forward. What advantage is there in this shape as compared with one that is straight?

NOTE: In considering the adaptation we should bear in mind the position of the head with its contents and also the jar that necessarily comes from our methods of locomotion.

THE FEET

1. In most animals there is considerable resemblance between the front feet and the hind feet. A man has a marked difference between the hands and the feet. Would use account for this? Show how.

2. In what way are the feet adapted for walking? For supporting weight? For defense? For offense?

3. Stand up and raise yourself on your toes. Where is the muscle that enables you to do this? Where is the fulcrum (pivot)? How does the distance from the ankle to the heel compare with the distance from the ankle to the toes? Suppose the distance from the ankle to the toes is four times the distance from the ankle to the heel, how many times your weight must the muscle pull to lift you up on your heels?

NOTE: There are three classes of levers. In the first class the fulcrum is in the middle between the weight and the power; in the second class the weight is between the power and the fulcrum; and in the third class the power is between the fulcrum and the weight.

Which class of lever is the foot when lifting the body?

DIGESTION

Mouth Digestion

1. Collect from the mouth ten cc. of saliva in each of three test tubes.

2. Into each of these test tubes put a little corn-starch paste. Thoroughly shake all three test tubes. Test one at once with Fehling's solution. Set the other two aside in warm water for two or three hours or longer. Test one of these for grape sugar. After 24 hours test the third for grape sugar.

3. Account for the results that you have obtained in each of the three cases.

4. From your results what is the value of thorough mastication of the food and the mixing of it with saliva?

Stomach Digestion

1. Make artificial gastric juice by taking one half gram, or 7 grains pepsin, 2 cc. strong hydrochloric acid, and 50 cc. of water.

Note: Normal gastric juice has rennin in addition, but the only action of the rennin is to curdle the milk. We may omit the rennin.

2. Put 10 cc. of artificial gastric juice into each of three test tubes. Label them from 1 to 3. In No. 1 place minced white of egg. Place No. 1 where it is as near body temperature as possible. Place No. 2 where it is as cold as possible without freezing. Place No. 3 in water and boil for 15 or 20 minutes.

3. Test No. 3 for peptone. The test for peptone is to add concentrated solution of caustic soda and a few drops of copper sulphate. A rose pink color indicates peptone. A violet color means that the white of egg has not been digested. What result do you get?

4. Test No. 2 for peptone in the same way. Test No. 1 for peptone.

5. The normal action of gastric juice is to digest protein, that is, change it to peptone. Protein cannot be absorbed through the walls of the intestines, while peptone is easily absorbed.

6. What temperature is best for the digestion of protein, high, low, or medium?

Intestinal Digestion

1. Make artificial pancreatic juice by mixing 10 grains (1 gram) of pancreatin and 20 grains (2 grams) of baking soda with 200 cc. of water.

2. Take 10 cc. of artificial pancreatic juice in a test tube and to it add corn-starch paste. Set for two hours in a place where body temperatures can be maintained. Test for grape sugar. What is the effect of pancreatic juice on starch? What other juice has had a similar effect on starch?

3. Take 10 cc. of artificial pancreatic juice to which you have added 8 or 10 drops of olive oil or any other oil. Shake for a few minutes. What is the appearance of the mixture? When oil is so finely divided that the whole mixture looks milky it is called an emulsion. Is milk an emulsion? What fat or oil is suspended in the milk? Is milk a perfect emulsion in that it keeps the fat suspended indefinitely? What is cream? Does pancreatic juice make an emulsion? Does this aid digestion?

4. What is the effect of pancreatic juice on fats and oils?

5. It can also be shown that pancreatic juice breaks up fat into glycerine and fatty acids, and thus enables them to be absorbed into the system.

6. Put in a test tube some minced white of egg with 10 cc. of pancreatic juice. Keep the test tube at body temperature for two or three hours. Shake the solution from time to time to mix the solution. Test for peptone. What result? What other digestive juice digests minced white of egg?

7. Note that the pancreatic juice has some starch, fat, and protein.

8. How important would you judge the pancreatic juice to be?

Action of Bile

1. To a test tube containing minced white of egg add bile or gall. Put in a warm place for 3 or 4 hours.

Note: Bile or gall may be obtained from the meat market by notifying the butcher a few days in advance of the time you need it.

2. To a test tube containing corn-starch add bile and put in a warm place.

3. To a test tube containing minced white of egg add bile and pancreatic juice and put in a warm place.

4. To a test tube containing minced white of egg add pancreatic juice only.

5. After a few hours compare the results when both bile and pancreatic juice are added and where the pancreatic juice alone is added.

6. Does bile alone digest the minced white of egg? Does bile alone digest corn-starch? What is the effect of bile on intestinal digestion?

OSMOSIS

1. Take an egg and break off the shell from the larger end without breaking the inside membrane. Have this area about an inch across.

2. With a large needle make a hole in the small end of the egg opposite.

3. With sealing wax fasten a small glass tube about 8 inches long over the hole on the small end of the egg.

4. Place the egg with large end down in a tumbler one quarter full of strong solution of grape sugar.

5. Observe after a few hours and after a few days.

6. Do you observe anything rising in the glass tube?

7. Break the egg and test the contents for grape sugar. With what result?

8. How could grape sugar get into the egg?

9. Test the contents of the tumbler for protein. How could the protein get into the tumbler?

10. Is it clear that grape sugar has passed into the egg and that protein has passed out of the egg? Is the membrane broken?

11. This passing of solutions through animal or plant membrane is osmosis, and foods that have been digested or modified are taken up by the membranes of the digestive tract in the same way.

THE TEETH

1. Obtain from a dentist the different types of teeth, such as incisors, cuspids, bicuspids, and molars.

2. Examine an incisor. What is its shape? What is its adaptation?

3. The crown is the part that shows in the mouth. The root is beneath the gum. The end of the nerve cavity shows at the lower part of the tooth.

4. Sketch an incisor and label the above-mentioned features.

5. Make similar studies of a cuspid, bicuspid, and molar.

6. Note the special adaptation of each.

7. From a microscopic slide or chart study a longitudinal section of a tooth. Note pulp cavity, dentine, enamel, and cement, and make a sketch to show these features.

8. Compare human teeth with those of the horse or cow or other lower animal and note the differences.

BONES

1. From a butcher get long bones, irrregular bones, and, if possible, flat bones.

2. Examine a long bone. Make out the shaft, the long part of the bone, the openings where the blood vessels enter, the rough places where muscles were attached. Sketch and label.

3. Compare a flat bone with a long bone as to openings and rough places.

4. Compare an irregular bone with that above. Do you find corresponding features?

5. Take a small bone and place in a weak solution of hydrochloric (muriatic) acid for a day or two. What has happened to the bone? What has been removed from the bone? Is animal or mineral matter left?

6. Burn a small bone over an iron plate until it crumbles. What has been removed? Is animal or mineral matter left?

7. Examine a microscopic slide or chart showing cross-section of a bone. Make out the following: *a*. large openings for blood vessels; *b*. layers that encircle the opening; *c*. small cavities separating the layers.

8. Make a sketch to show these features.

SKIN

1. Examine the skin of your hand with a low-power lens. Make out the creases and ridges and small openings.

2. Make a sketch to show the creases and ridges as you see them.

3. Take your finger print on paper over which you have spread printer's ink. Examine the loops and lines. Compare your finger prints with those of other pupils. How do they differ? What are finger prints?

4. Make a study from a microscopic slide or chart of a cross-section of the skin, and make out the following: *a.* epidermis; *b.* dermis; *c.* hair follicle; *d.* papilla; *e.* sebaceous glands; *f.* perspiration glands.

5. Make a sketch and label as many of these as you can make out.

6. Put a few drops of ether or alcohol on your hand. What is the feeling due to the ether or alcohol? What causes this feeling?

7. What is the effect of moderate evaporation on the skin?

8. What is the effect of rapid evaporation on the skin?

NERVE TISSUE

1. From a chart or microscopic slide study a nerve cell.

2. Make out:
   a. Connective tissue
   b. Nerve sheath
   c. Axis cylinder
   d. Nucleus, etc.

3. Sketch a nerve cell, and label as many as you can make out.

4. Study a cross-section of the spinal cord from a chart or microscopic slide.

5. Make out the following:
   a. Ventral fissure
   b. Dorsal fissure
   c. The coverings. How many layers?
   d. White portion (under coverings)
   e. Gray portion (inside)
   f. Canal (in the center)

NOTE: During life this canal carries the spinal fluid.

   g. Nerve roots
   h. Blood vessels

6. Sketch a cross-section and label as many of the features above as you can make out.

7. Study spinal cells under a high-power lens or from a chart. Notice shape of the nuclei, axis-cylinder, etc.

8. Sketch a spinal cell under high power and label as far as possible.

THE EYE

1. Examine your eye with a mirror.

2. Make a sketch to show eyebrow, eyelid, cornea, iris, pupil, sclerotic coat. The cornea is in front near iris and the outer part of the ball of the eye is part of the sclerotic coat.

3. Examine your iris. What is the shape and color? Compare your eyes with the other pupils' as to shape and color.

4. Examine the pupil of your eye. How is it formed? Does its shape change? Does its size change?

5. Compare the pupil of your eye with the pupil of a cat's eye. How do they differ in size, shape, and varying form?

6. From a model or chart make out the following:
   a. Sclerotic coat
   b. Choroid
   c. Retina
   d. Crystalline lens
   e. Iris
   f. Pupil
   g. Aqueous humor
   h. Vitreous humor
   i. Optic nerve

7. Make a sketch to show features above and label.

THE EAR

1. From a model or chart study the human ear.

2. The external ear made up of the shell or passageway leading to the middle ear.

3. The drum is at the middle of the passage. What is the function of the drum?

4. The middle ear is made up of three small bones, malleus, stapes, and incus. It also contains the Eustachian tube leading to the throat. How could this Eustachian tube protect the drum from a jar or a big explosion?

5. The internal ear is made up of the vestibule, semicircular canals and the cochlea.

6. Make a sketch to show the regions above and label.

THE CELL

1. Examine a cell from some plant, from a prepared slide or chart.

2. What is the shape? Make out the following:

a. The protoplasm region

b. The nucleus

c. The nucleolus

d. The chromatin may be found in some specimens as deeply colored strands

e. The cell wall is present in most specimens

3. Make a sketch to show features above and label.

4. Compare with plant cell above some animal cell as amoeba or paramecium or other simple cell.

5. Make a sketch and label as many regions as you can make out.

6. Compare a prepared slide showing a human cell with a plant or lower animal cell.

7. What differences can you make out?

8. What would you say in general of the plant cell, lower animal cell, and the cell from a human body, as to resemblances and differences?

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